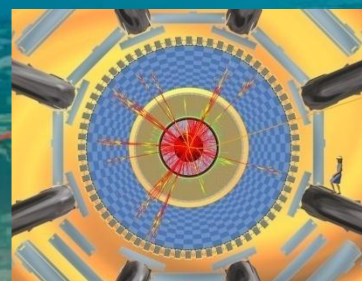
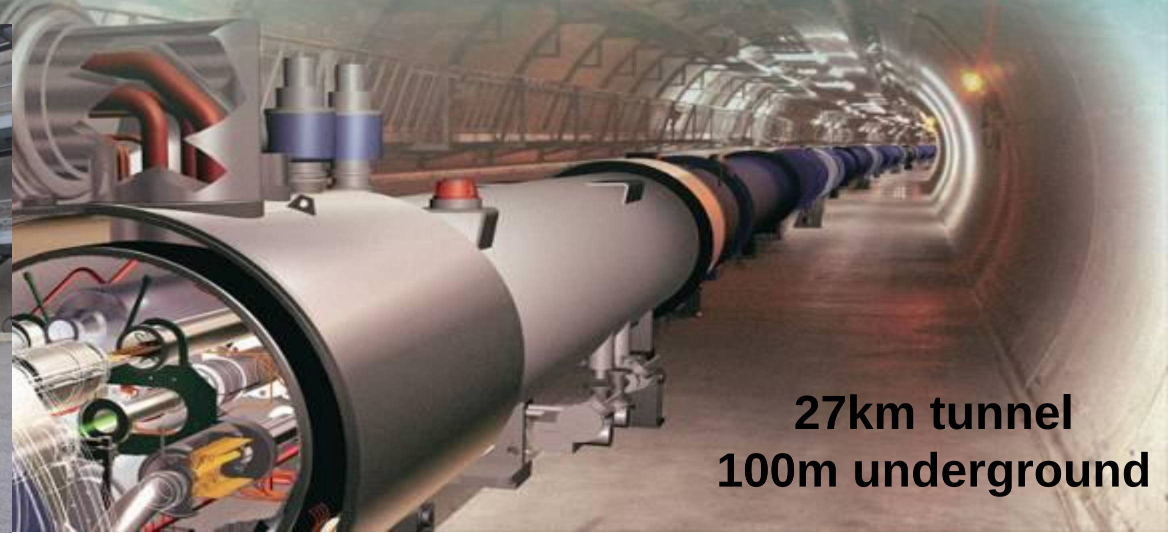
Higgs Search at ATLAS

CERN

CMS



ATLAS



27km tunnel
100m underground

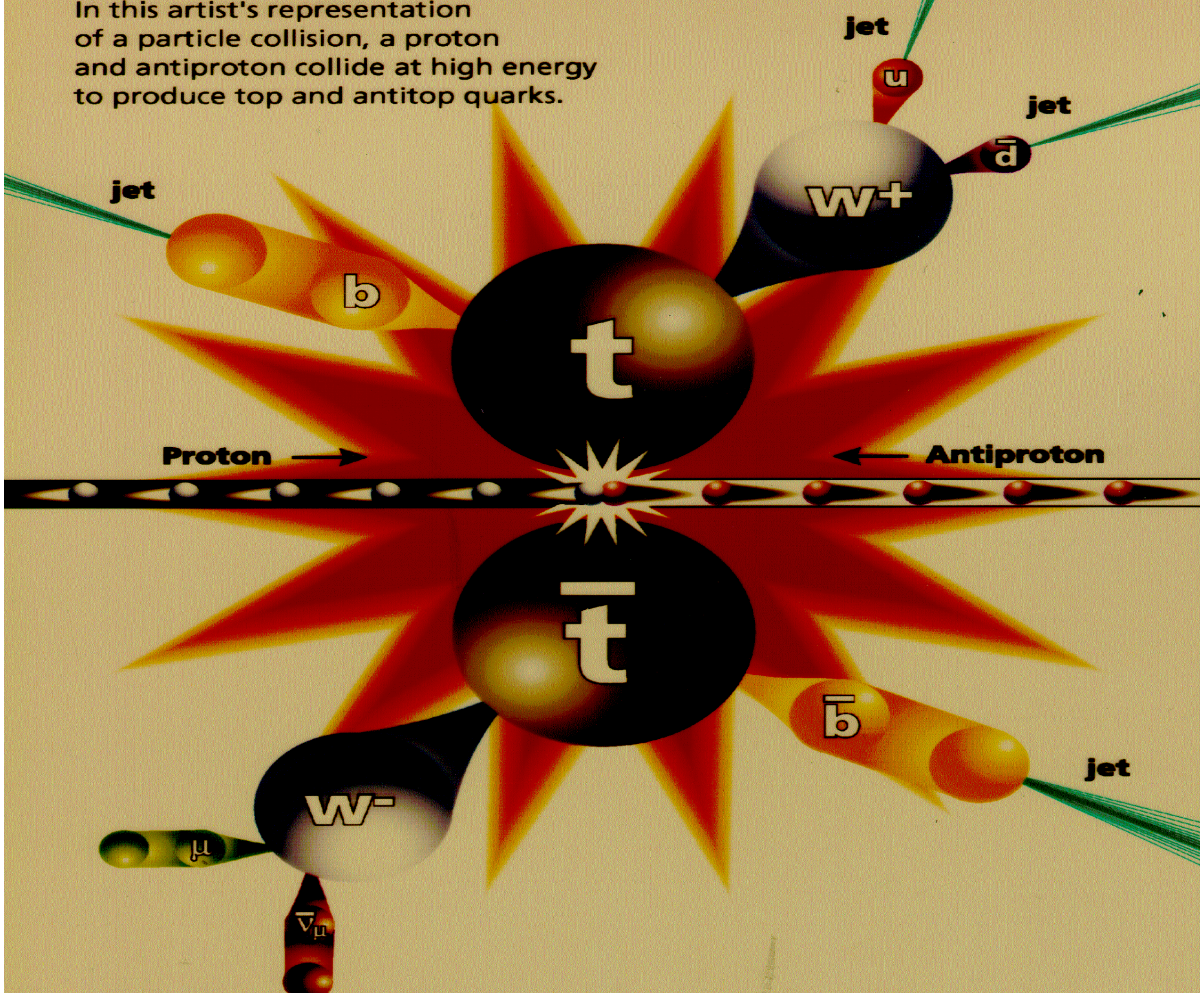
What Did ATLAS Find?

What is God Particle (Higgs)?

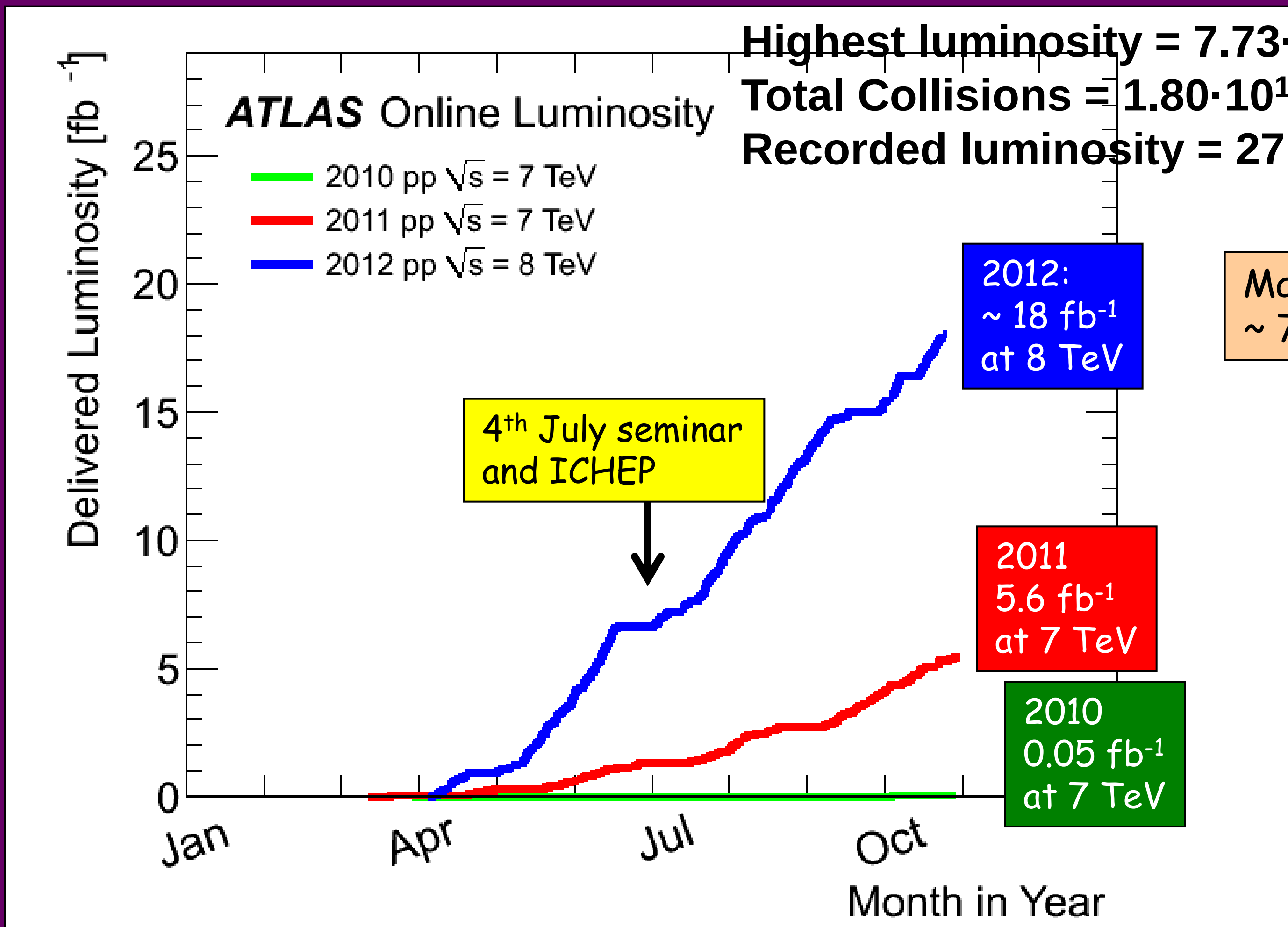
Computing Tomorrow

Collision!

In this artist's representation of a particle collision, a proton and antiproton collide at high energy to produce top and antitop quarks.



Luminosity delivered to ATLAS since the beginning

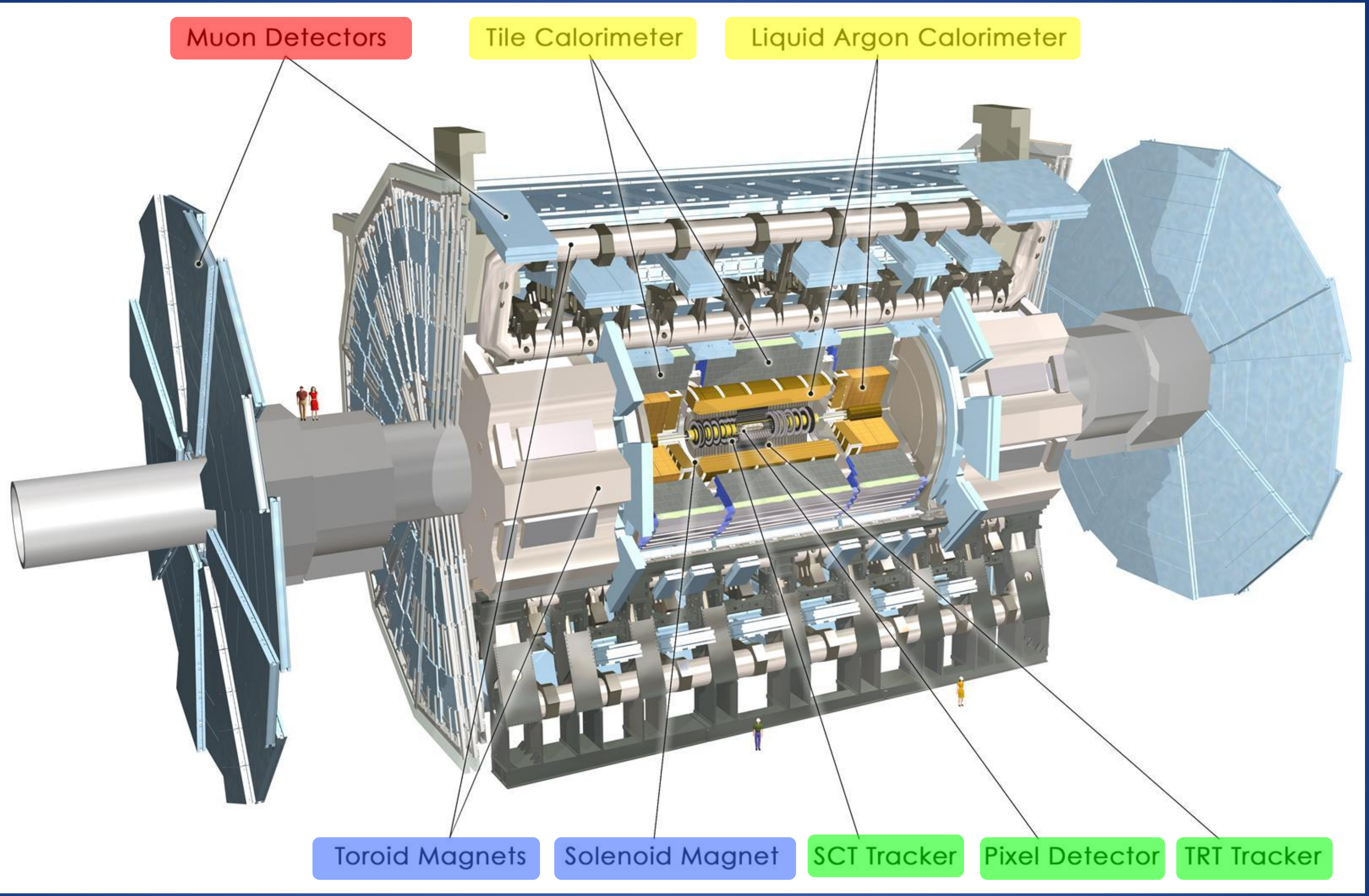


Highest luminosity = $7.73 \cdot 10^{33}$ cm^{-2}s^{-1}
Total Collisions = $1.80 \cdot 10^{15}$
Recorded luminosity = 27.03 fb^{-1}

Max luminosity: ~ 7.7 $\times 10^{33}$ cm^{-2} s^{-1}

ATLAS is very grateful to the LHC team for this superb performance

The ATLAS detector



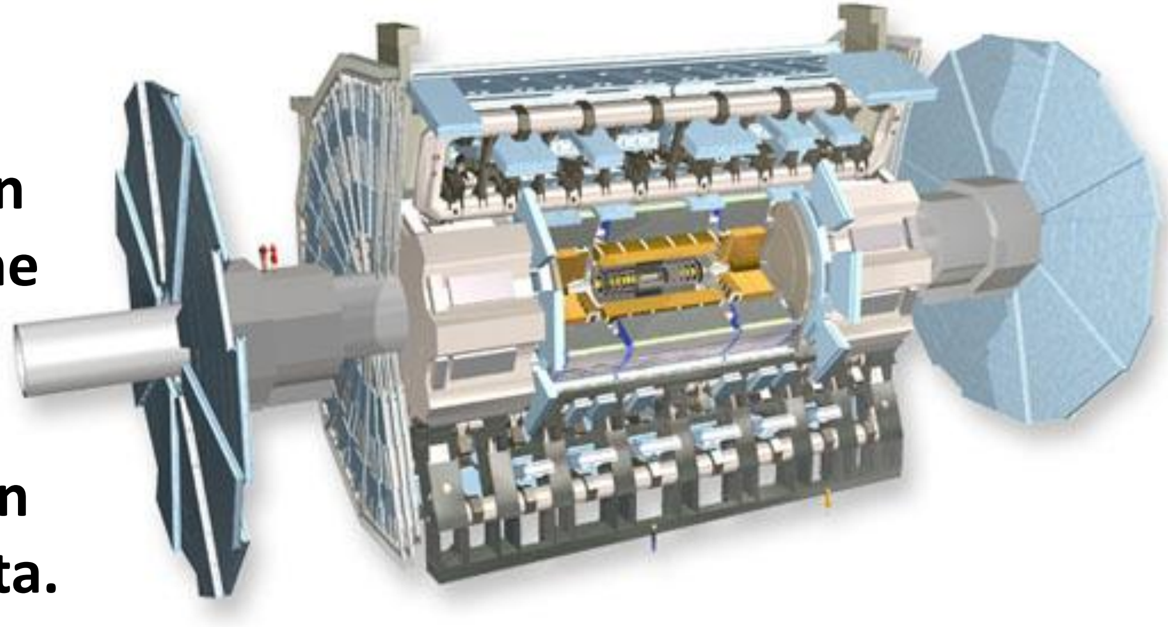
4 Superconducting magnets: Central Solenoid
3 Air core Toroids

Inner detector

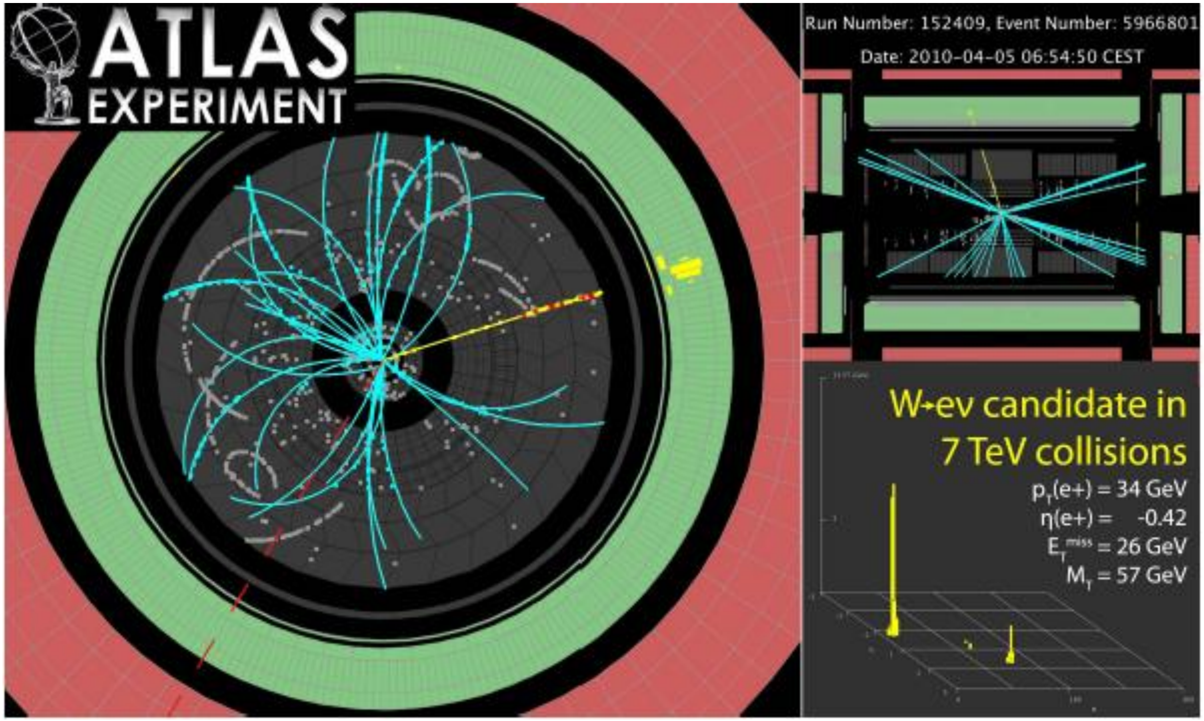
Calorimetry

Muon Spectrometer

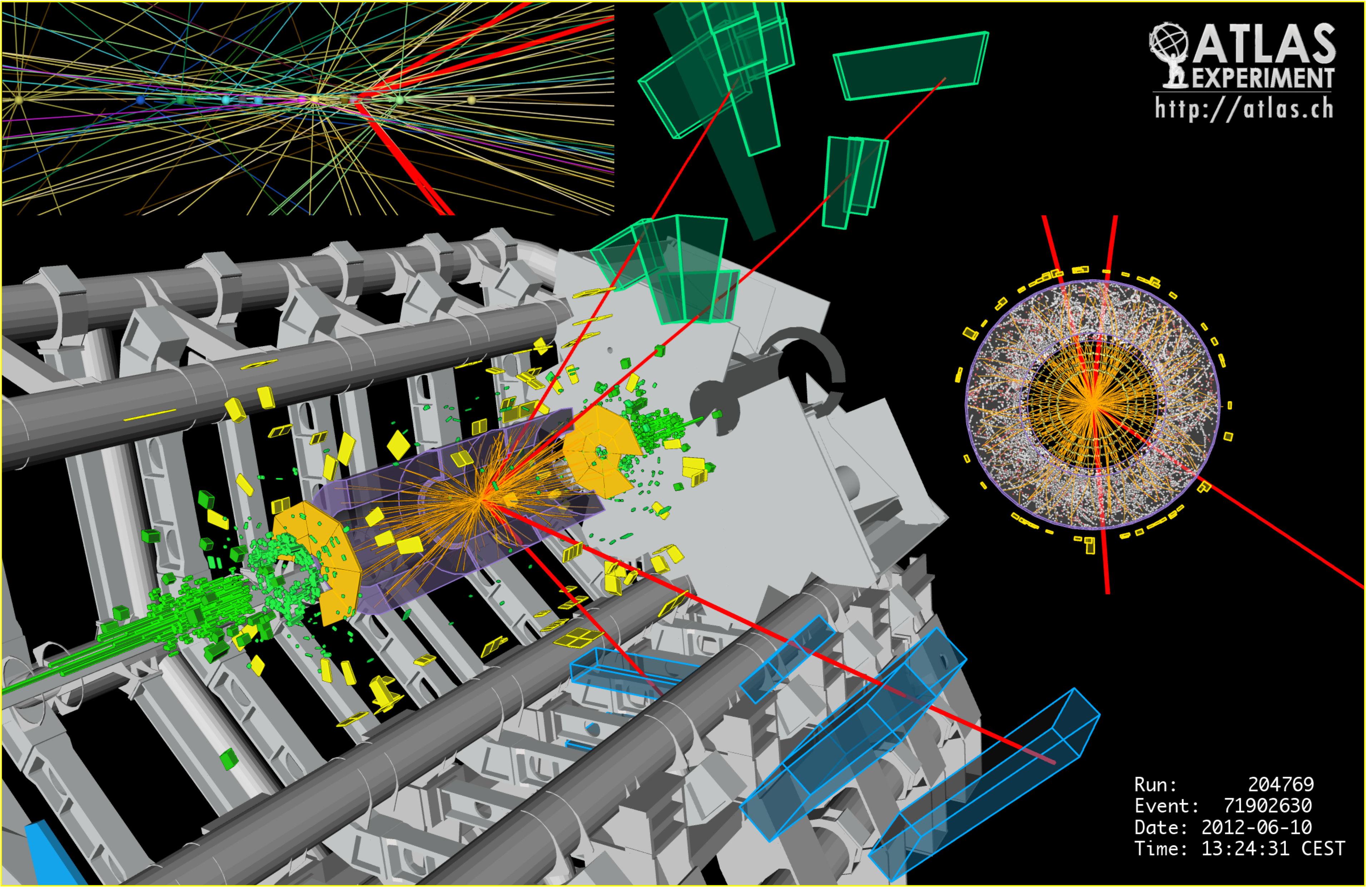
Our detector is 46m long, 25m high. It has 100 million channels of digital data. The proton-proton collisions happen 20 million times every second. Each collision produces megabytes of data.



We need fast processing using WLCG to turn the digital data from 100M channels into the particle tracks as well as energy signals for neutral particles, as you see in the right plot.



Nearly 1 Billion channels of 0 and 1 need to be processed into particles every 50ns.



Tue, 3 Jul 2012 18:32:19 +0200

CERN experiments observe particle consistent with long-sought Higgs boson

Geneva, 4 July 2012. At a seminar held at CERN today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. Both experiments observe a new particle in the mass region around 125-126 GeV.

"We observe in our data clear signs of a new particle, at the level of 5 sigma, in the mass region around 126 GeV. The outstanding performance of the LHC and ATLAS and the huge efforts of many people have brought us to this exciting stage," **said ATLAS experiment spokesperson Fabiola Gianotti,** ***"but a little more time is needed to prepare these results for publication."***

"The results are preliminary but the 5 sigma signal at around 125 GeV we're seeing is dramatic. This is indeed a new particle. We know it must be a boson and it's the heaviest boson ever found," **said CMS experiment spokesperson Joe Incandela.** ***"The implications are very significant and it is precisely for this reason that we must be extremely diligent in all of our studies and cross-checks."***

"It's hard not to get excited by these results," **said CERN Research Director Sergio Bertolucci.** ***" We stated last year that in 2012 we would either find a new Higgs-like particle or exclude the existence of the Standard Model Higgs. With all the necessary caution, it looks to me that we are at a branching point: the observation of this new particle indicates the path for the future towards a more detailed understanding of what we're seeing in the data."***

Tue, 3 Jul 2012 09:24:02 +0200

CERN experiments home in on new particle

Geneva, 4 July 2012. At a seminar held at CERN today as a curtain raiser to the year's major particle physics conference, ICHEP2012 in Melbourne, the ATLAS and CMS experiments presented their latest preliminary results in the search for the long sought Higgs particle. Both experiments see strong indications for the presence of a new particle in the mass region around 126 GeV.

"We observe a significant excess of events, at the level of 5 sigma, in the mass region around 126 GeV. The outstanding performance of the LHC and ATLAS and the huge efforts of many people have brought us to this exciting stage,"* said ATLAS experiment spokesperson Fabiola Gianotti, *"but a little more time is needed to prepare these results for publication."

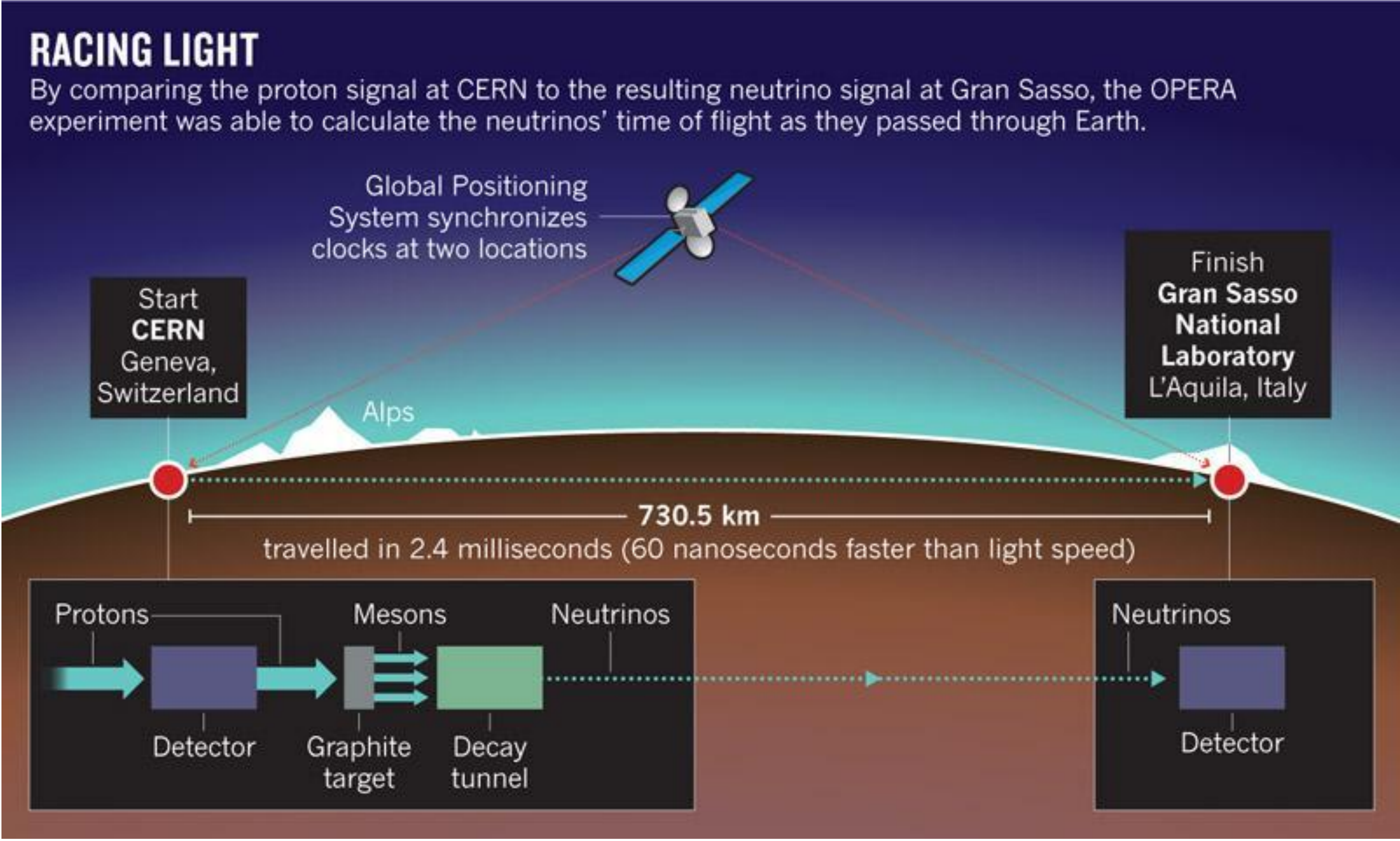
"The results are preliminary but the 5 sigma signal we're seeing is dramatic. If this is indeed a new particle, then we know it must be a boson and it would be the heaviest such particle ever found,"* said CMS experiment spokesperson Joe Incandela. *"The implications are very significant and it is precisely for this reason that we must be extremely diligent in all of our studies and cross-checks."

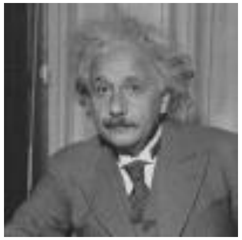
"It's hard not to get excited by these results,"* said CERN Research Director Sergio Bertolucci. *" We stated last year that in 2012 we would either find a new Higgs-like particle or exclude the existence of the Standard Model Higgs. With all the necessary caution, it looks to me that we are at a branching point: the observation of this new particle indicates the path for the future towards a more detailed understanding of what we're seeing in the data."

The next step will be to determine the precise nature of the particle and its significance for our understanding of the universe. Are its properties as expected for the Higgs boson predicted in 1964, the final missing ingredient in the Standard Model of particle physics? Or is it something more exotic? The Standard Model describes the fundamental particles from which we, and every visible thing in the universe, are made, and the forces acting between them. All the matter that we can see, however, appears to be no more than about 4% of the total. A more exotic version of the Higgs particle could be a bridge to understanding the 96% of the universe that remains obscure.

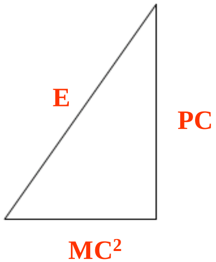
Many thanks for sending a preview of the press announcement.
Such a pre-announcement is very much needed and expected by the media to prepare proper actions!
Let me quickly comment on the general content of this release:
It avoids to quote a "Discovery" but rather repeats "indication" as already used in the December 2011 presentations and declarations. Most media are therefor likely to report this, if at all, in short notes only. This intention was communicated to me by some of the leading German media, and I can understand their reasoning well.
If a low public attendance at this time is indeed anticipated, this press release serves its purpose. In this case, however, we will owe a later "discovery" statement to the public in due time. Especially since Fermilab announced its findings yesterday already, saying that their findings (discoveries in the press?) will (just) have to be confirmed by LHC.
If more is anticipated now, and public attendance not to be lost, a somewhat sharper and clearer statement would be needed now. Something like a clear "Discovery" of a new massive particle, thereby keeping the careful interpretation as it is phrased now.
Last December it was said that 5 sigma will be a discovery (or exclusion). We must be careful to stick to our own measures and not to contradict ourselves.

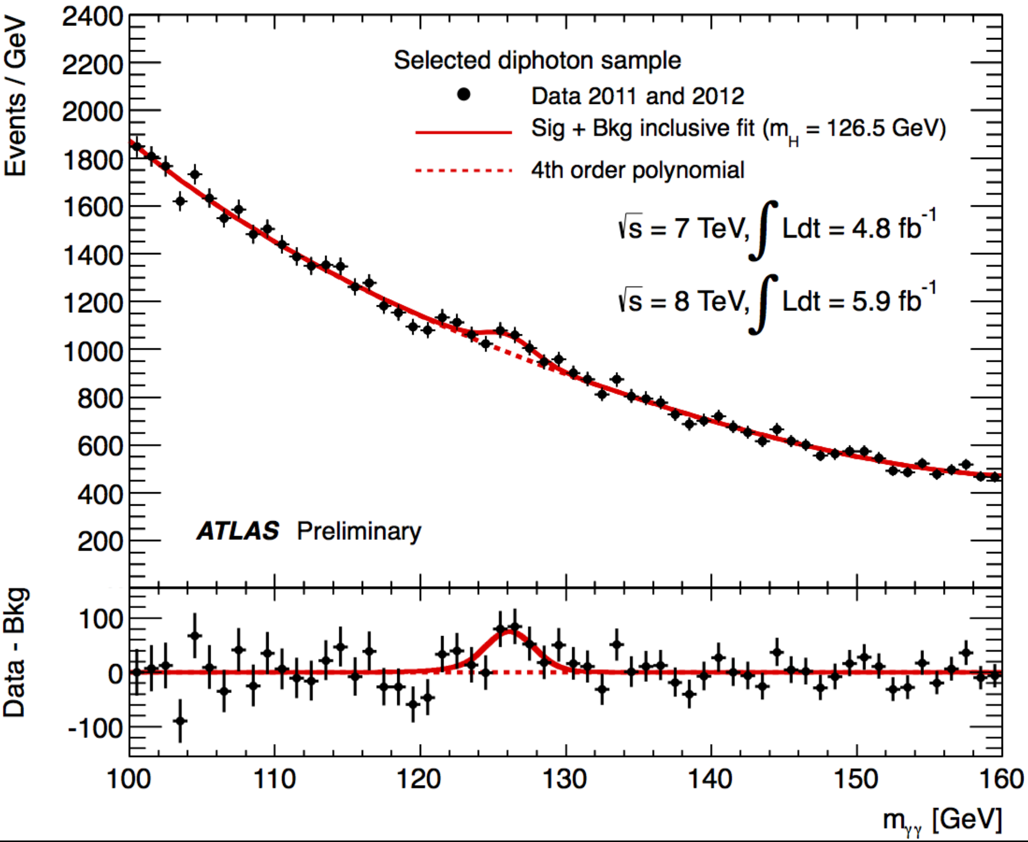
I am sorry to contradict you (I guess this is the first time that this occurs). I think that the draft is very carefully written and correct.
The so called 5-sigma is very much dominated by the 2-photons, where some people (including partly myself) have still some doubts on the assumed systematics of the background, and therefore on its statistical significance. Other channels are coming up (like WW*) for the final publication that will allow everybody to feel confident about announcing a clear discovery. I am not afraid of political implications regarding the FERMILAB announcement (there were similar announcements from SLC about number of neutrinos, but at the end it is the real understanding from the LEP results that stands in the books).


RACING LIGHT
By comparing the proton signal at CERN to the resulting neutrino signal at Gran Sasso, the OPERA experiment was able to calculate the neutrinos' time of flight as they passed through Earth.
Global Positioning System synchronizes clocks at two locations
Start
CERN
Geneva, Switzerland
Finish
Gran Sasso National Laboratory
L'Aquila, Italy
Alps
730.5 km
travelled in 2.4 milliseconds (60 nanoseconds faster than light speed)
Protons
Detector
Mesons
Graphite target
Decay tunnel
Neutrinos
Neutrinos
Detector



$$E^2 = (MC^2)^2 + P^2C^2$$


E
PC
MC²



Total after selections: 59059 events

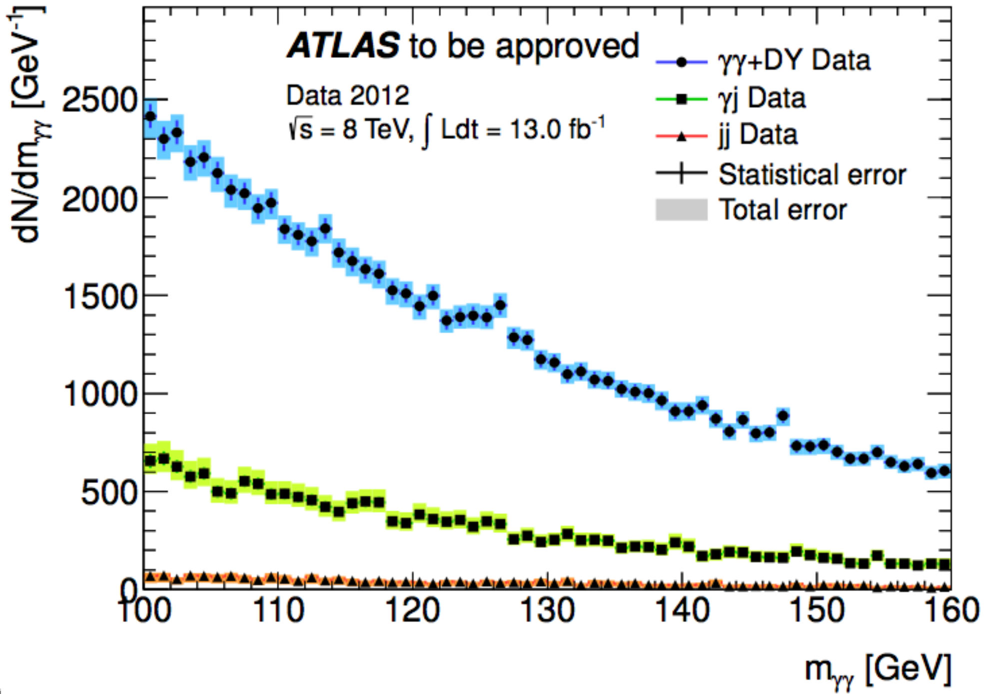
$m_{\gamma\gamma}$ spectrum fit, for each category, with Crystal Ball + Gaussian for signal plus background model optimised (with MC) to minimize biases
Max deviation of background model from expected background distribution taken as systematic uncertainty

Main systematic uncertainties

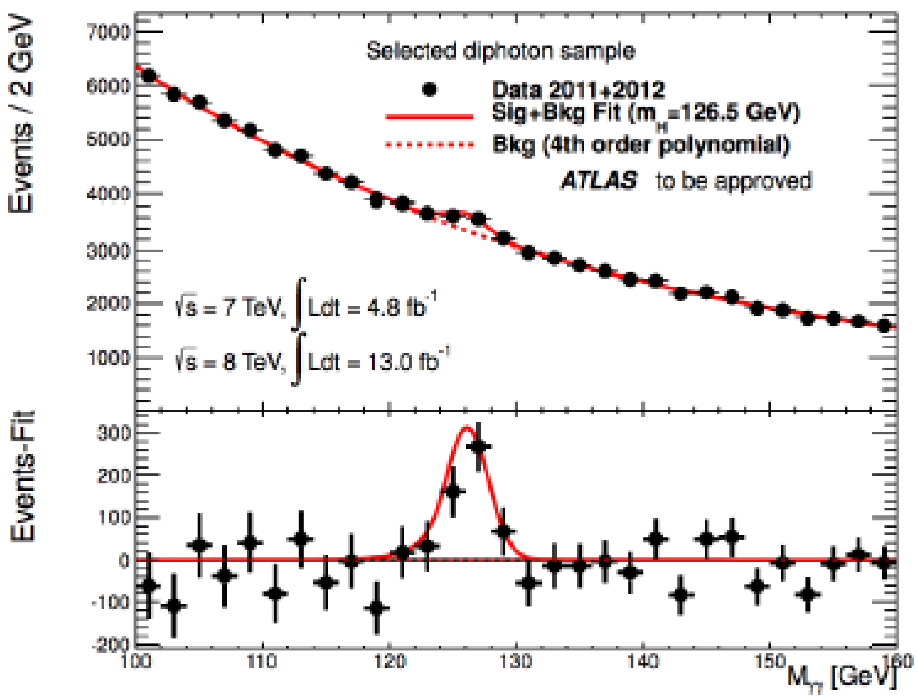
Signal yield	
Theory	~ 20%
Photon efficiency	~ 10%
Background model	~ 10%
Categories migration	
Higgs p_T modeling	up to ~ 10%
Conv/unconv γ	up to ~ 6%
Jet E-scale	up to 20% (2j/VBF)
Underlying event	up to 30% (2j/VBF)
$H \to \gamma\gamma$ mass resolution	~ 14%
Photon E-scale	~ 0.6%

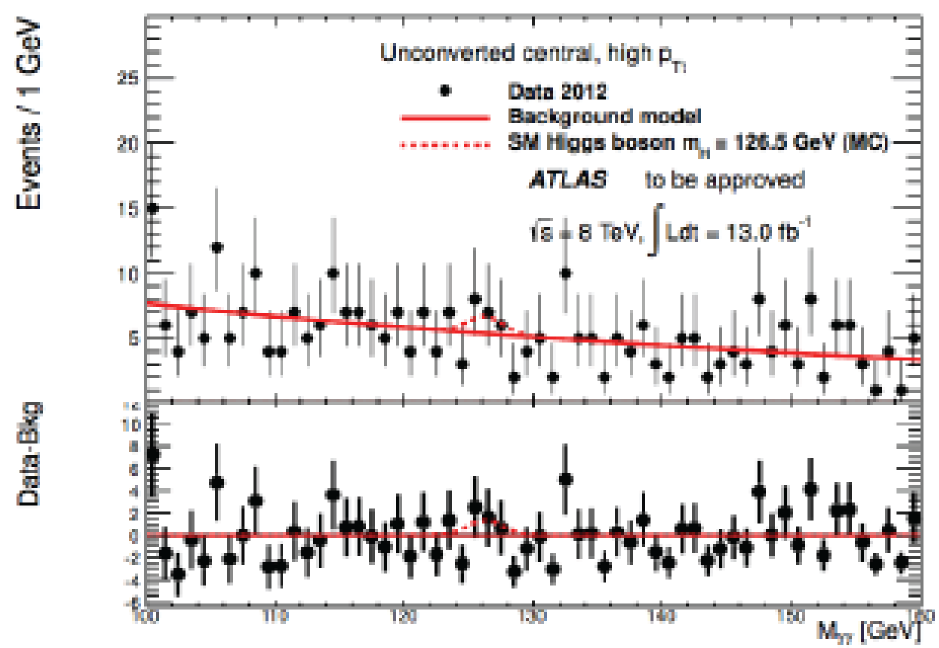
Di-Photon Mass Spectrum

Where is Higgs?

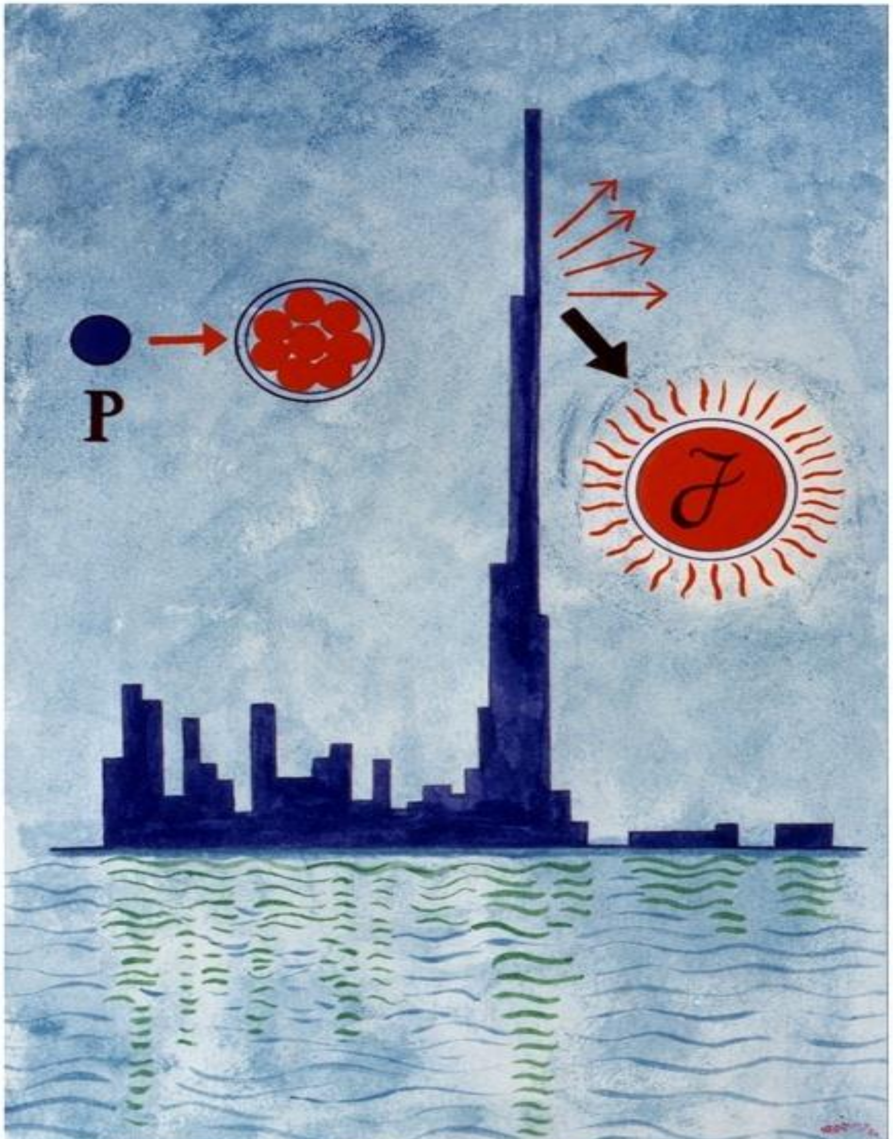


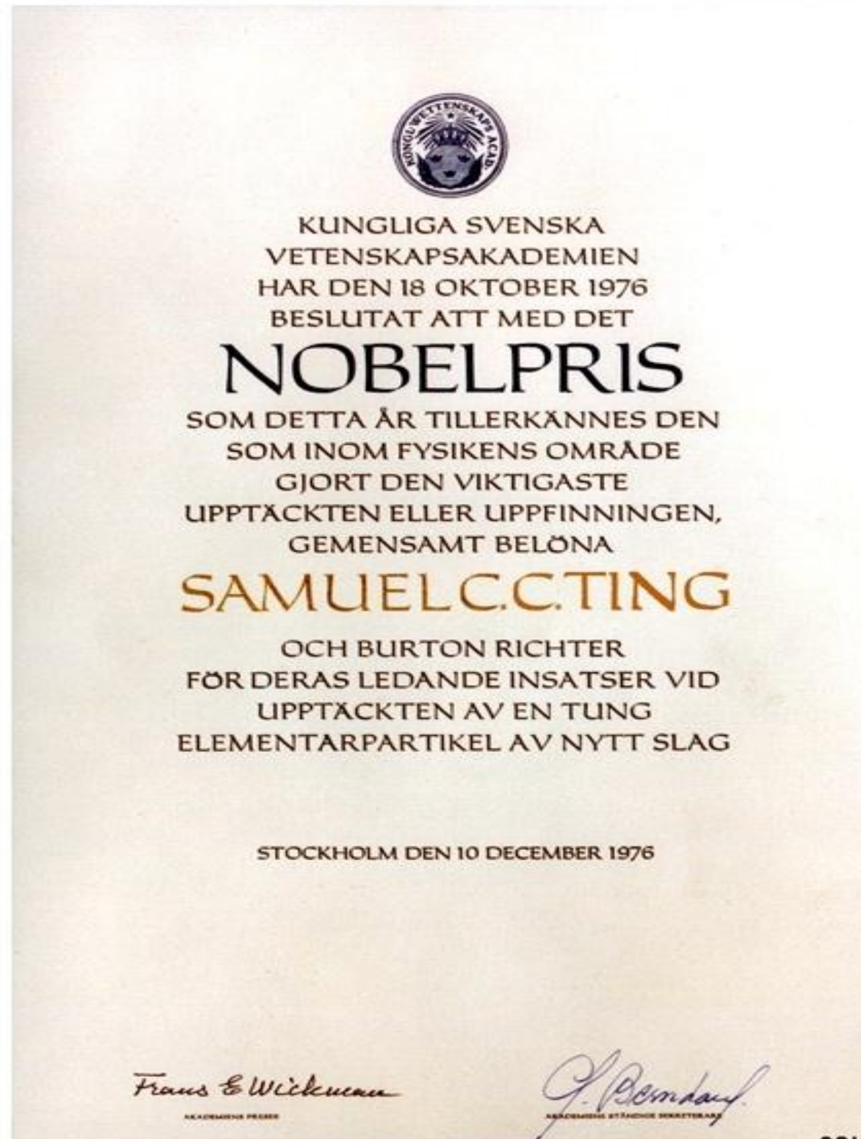
Observed mass spectrum





Seeking new physics by looking for peaks





KUNGLIGA SVENSKA
VETENSKAPSAKADEMIEN
HAR DEN 18 OKTOBER 1976
BESLUTAT ATT MED DET

NOBELPRIS

SOM DETTA ÅR TILLERKÄNNES DEN
SOM INOM FYSIKENS OMRÅDE
GJORT DEN VIKTIGASTE
UPPTÄCKTEN ELLER UPPFINNINGEN,
GEMENSAMT BELÖNA

SAMUEL C.C. TING

OCH BURTON RICHTER
FÖR DERAS LEDANDE INSATSER VID
UPPTÄCKTEN AV EN TUNG
ELEMENTARPARTIKEL AV NYTT SLAG

STOCKHOLM DEN 10 DECEMBER 1976

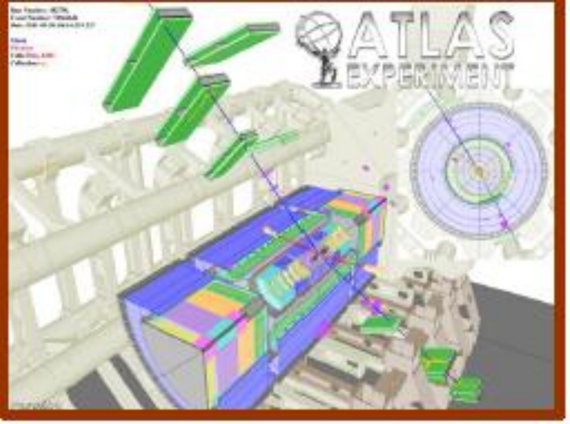
Frans E Wickman

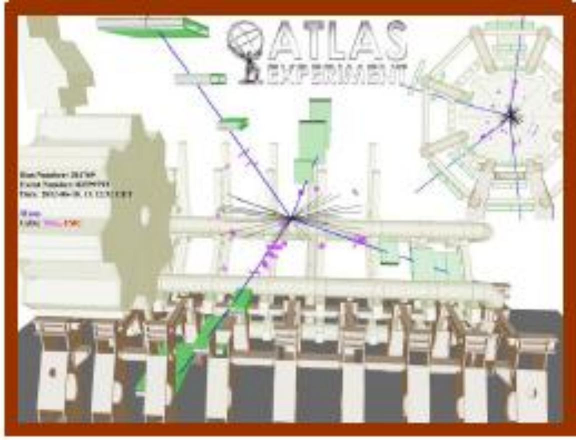
y03K297a

I just wanted to say that I strongly endorse the decision to not publish in Nature. While I fully appreciate issues like impact factors of journals and cross disciplinary audiences, given the scope of coverage of the Higgs in the popular press already, plus the difficulties attributing papers to individuals in our field (as seen by our academic colleagues), I don't really see how either area would affect our journal choice.

And, quite frankly, in the end from the standpoint of posterity I would much prefer having our seminal results discussed in the scientific equivalent of the New York Times rather than the National Enquirer, regardless of the number of readers and wider audience of the latter. Given that publishing the Higgs paper in a European journal seems sensible, Phys.Lett.B seems like a reasonable choice.

Best regards,
Rob



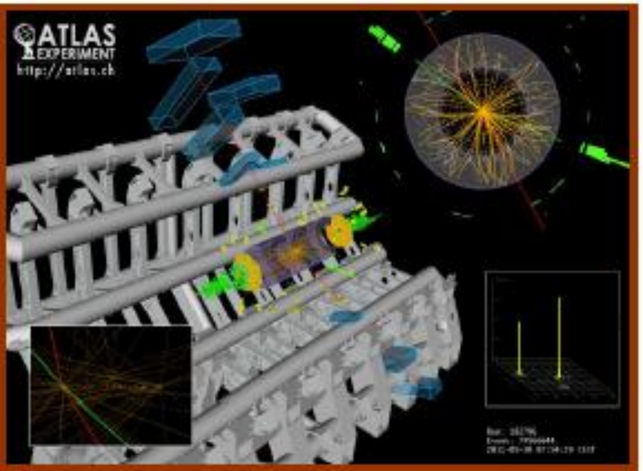


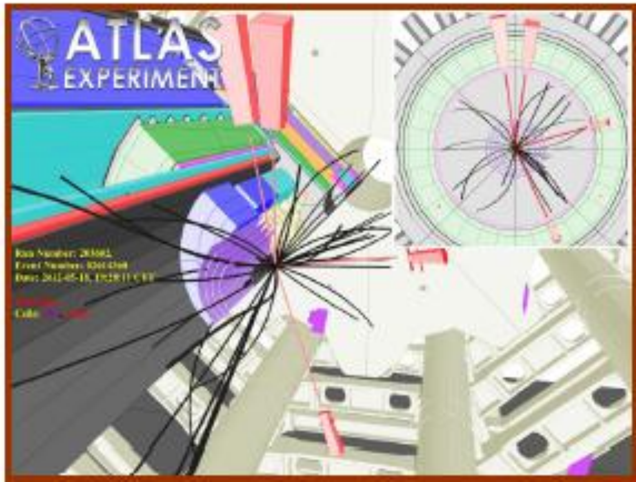
SM Higgs searches with the ATLAS Experiment at the LHC

Rachid Mazini
Academia Sinica Taiwan
On behalf of the ATLAS Collaboration

Kruger 2012

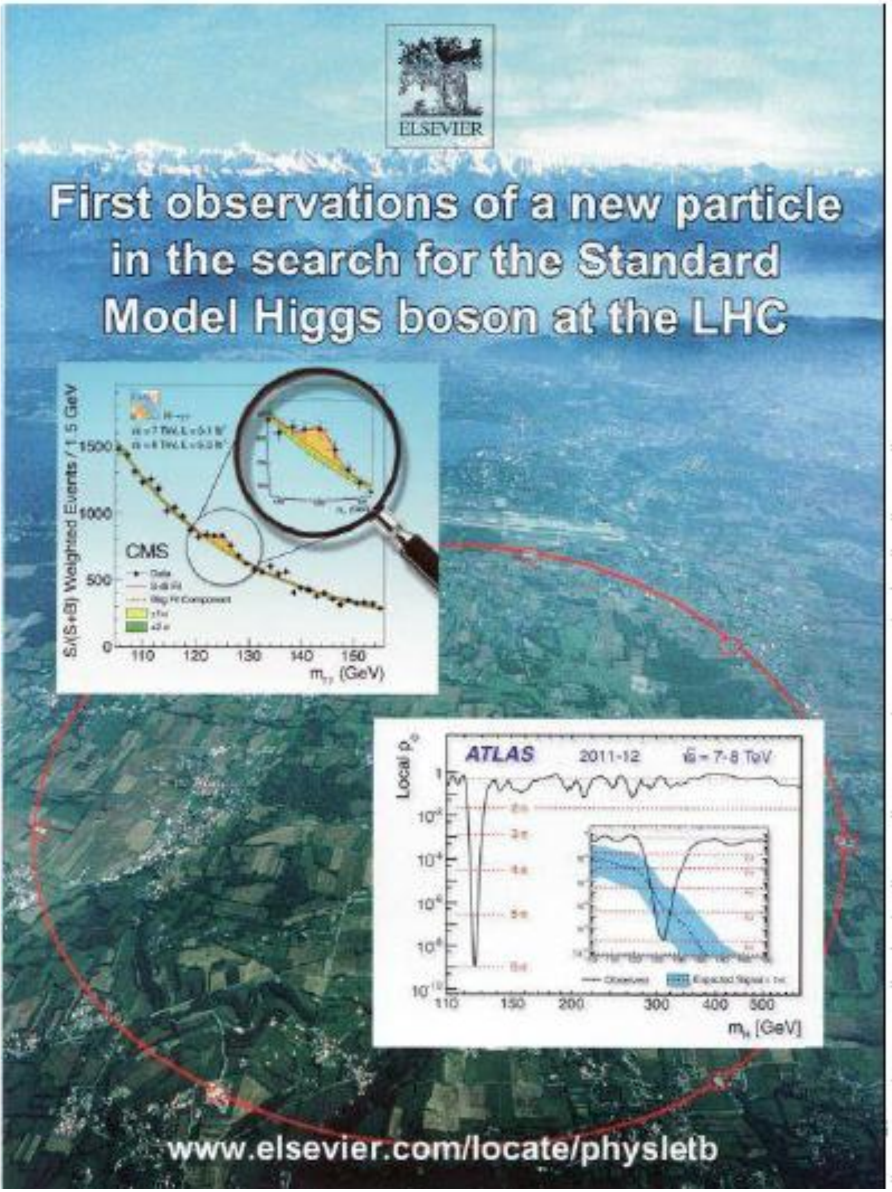
December 3-7, 2012





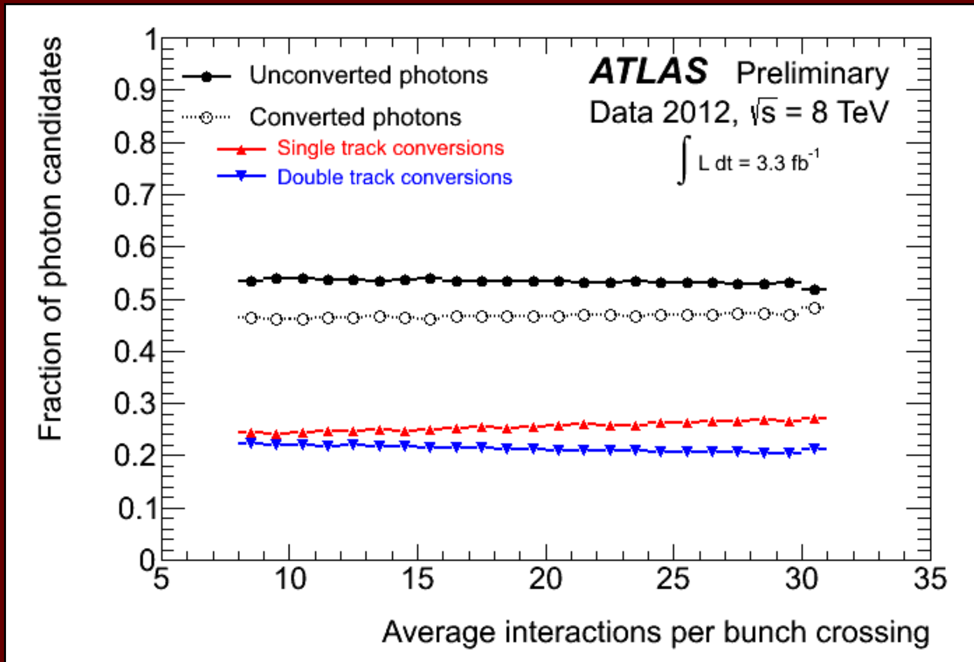
Higgs Search at ATLAS

Phys.Lett. B716 (2012) 1-29



- After the discovery of a Higgs-like particle, efforts are deployed to consolidate the measurements:
  - –Strengthening the results with more data
  - –Exploring additional channels
  - –Precision mass measurement
  - –Extracting Coupling parameters
- Analyses based on channels/data below.

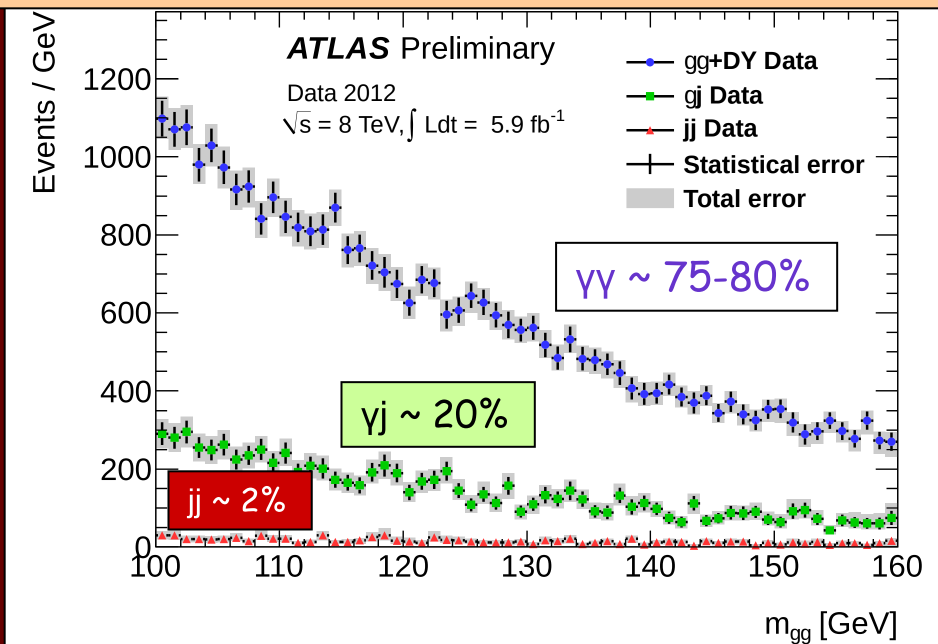
Higgs Boson Decay	Subsequent Decay	Sub-Channels	$\int L\,dt$ [fb^{-1}]
		2011 $\sqrt{s}$ =7 TeV	
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu\}$	4.8
$H \to \gamma\gamma$	–	10 categories $\{p_{Tt} \otimes \eta_\gamma \otimes \text{conversion}\} \oplus \{2\text{-jet}\}$	4.8
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	$\{e\mu\} \otimes \{0\text{-jet}\} \oplus \{\ell\ell\} \otimes \{1\text{-jet}, 2\text{-jet}, \text{boosted}, VH\}$	4.7
	$\tau_{lep}\tau_{had}$	$\{e, \mu\} \otimes \{0\text{-jet}, 1\text{-jet}, \text{boosted}, 2\text{-jet}\}$	4.7
	$\tau_{had}\tau_{had}$	$\{\text{boosted}, 2\text{-jet}\}$	4.7
$VH \to Vbb$	$Z \to \nu\nu$	$E_T^{miss} \in \{120-160, 160-200, \geq 200 \text{ GeV}\} \otimes \{2\text{-jet}, 3\text{-jet}\}$	4.6
	$W \to \ell\nu$	$p_T^W \in \{< 50, 50-100, 100-150, 150-200, \geq 200 \text{ GeV}\}$	4.7
	$Z \to \ell\ell$	$p_T^Z \in \{< 50, 50-100, 100-150, 150-200, \geq 200 \text{ GeV}\}$	4.7
		2012 $\sqrt{s}$ =8 TeV	
$H \to ZZ^{(*)}$	4ℓ	$\{4e, 2e2\mu, 2\mu2e, 4\mu\}$	5.8
$H \to \gamma\gamma$	–	10 categories $\{p_{Tt} \otimes \eta_\gamma \otimes \text{conversion}\} \oplus \{2\text{-jet}\}$	5.9
$H \to WW^{(*)}$	$e\nu\mu\nu$	$\{e\mu, \mu e\} \otimes \{0\text{-jet}, 1\text{-jet}\}$	13
$H \to \tau\tau$	$\tau_{lep}\tau_{lep}$	$\{\ell\ell\} \otimes \{1\text{-jet}, 2\text{-jet}, \text{boosted}, VH\}$	13
	$\tau_{lep}\tau_{had}$	$\{e, \mu\} \otimes \{0\text{-jet}, 1\text{-jet}, \text{boosted}, 2\text{-jet}\}$	13
	$\tau_{had}\tau_{had}$	$\{\text{boosted}, 2\text{-jet}\}$	13
$VH \to Vbb$	$Z \to \nu\nu$	$E_T^{miss} \in \{120-160, 160-200, \geq 200 \text{ GeV}\} \otimes \{2\text{-jet}, 3\text{-jet}\}$	13
	$W \to \ell\nu$	$p_T^W \in \{< 50, 50-100, 100-150, 150-200, \geq 200 \text{ GeV}\}$	13
	$Z \to \ell\ell$	$p_T^Z \in \{< 50, 50-100, 100-150, 150-200, \geq 200 \text{ GeV}\}$	13



γ reconstruction, γ/jet separation

Fraction of converted and unconverted γ vs pile-up is now stable (within 1%) →small migration between categories, accurate specific calibration

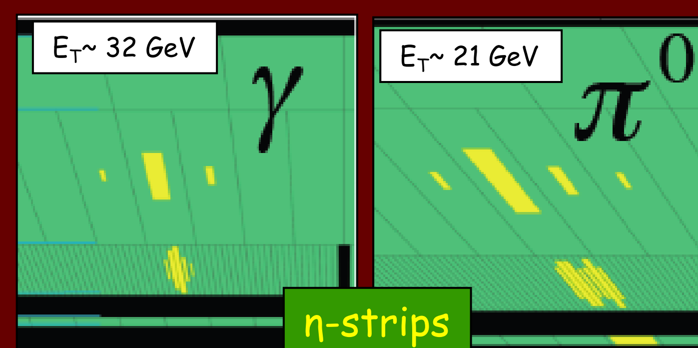
Data-driven decomposition of selected γγ sample

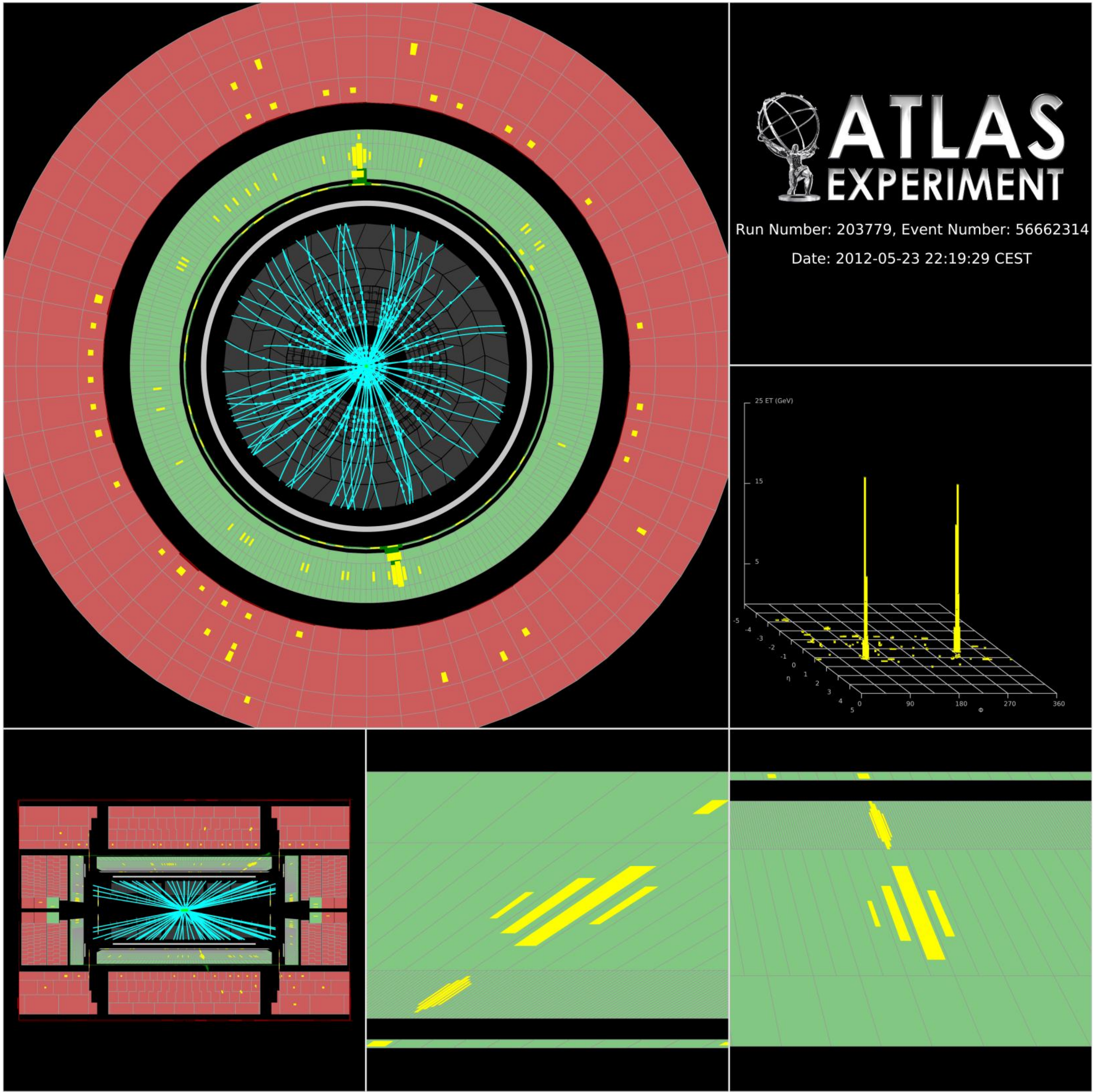


High γγ purity thanks to:

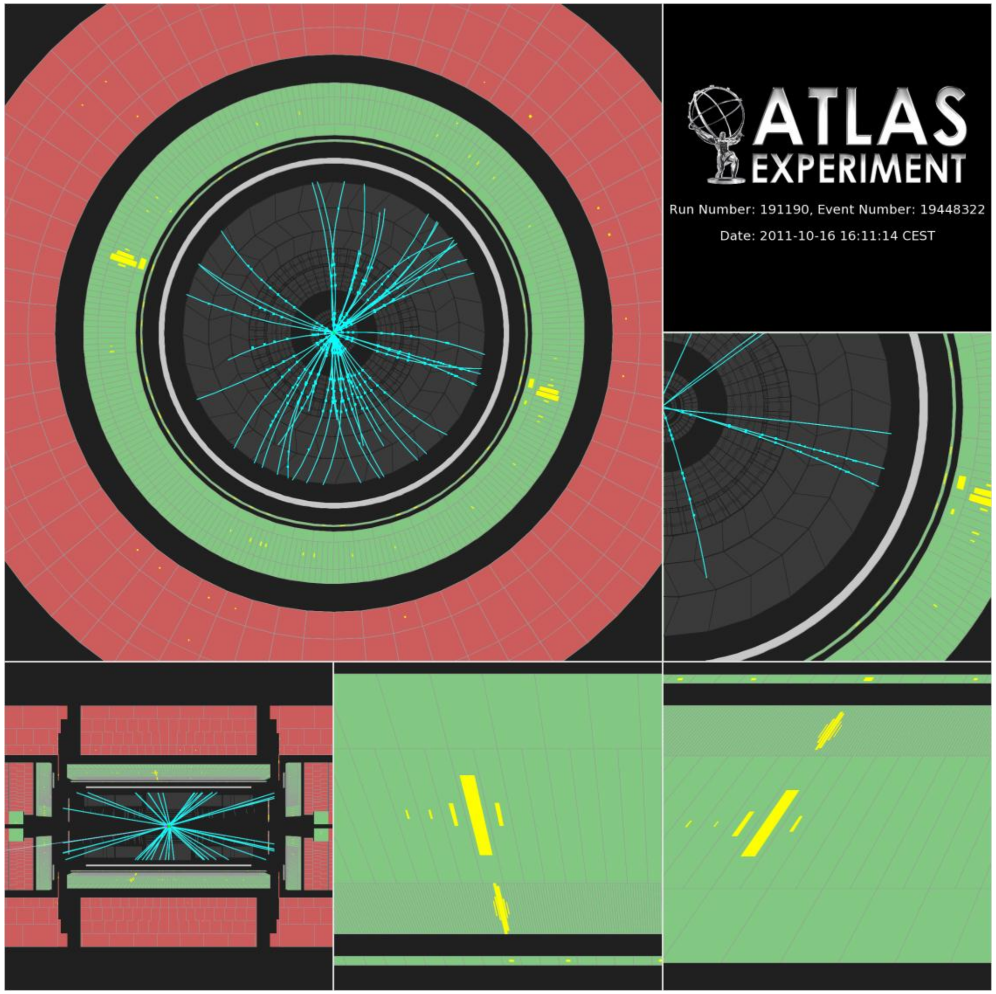
$R_j \sim 10^4$

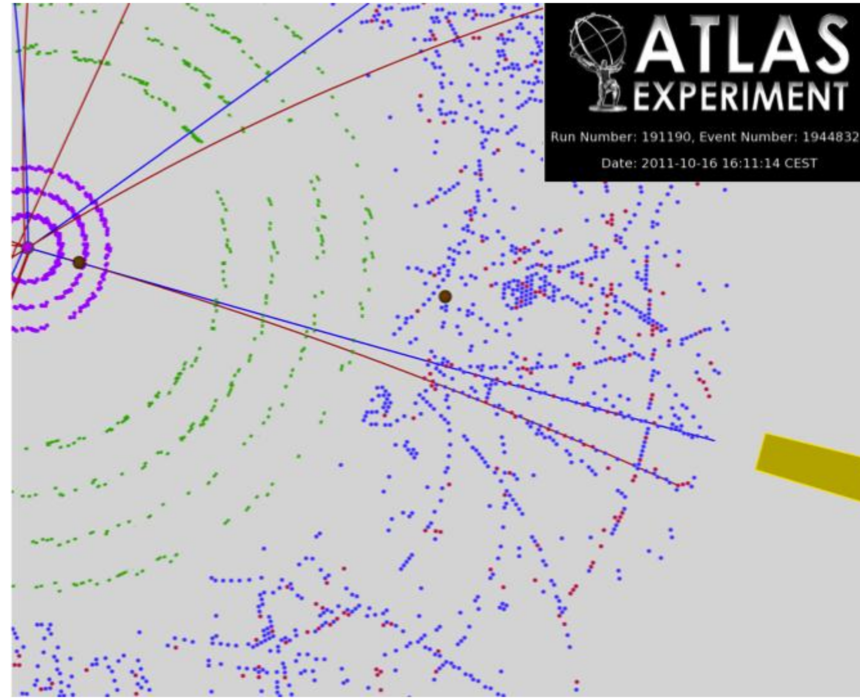
$\varepsilon(\gamma) \sim 90\%$

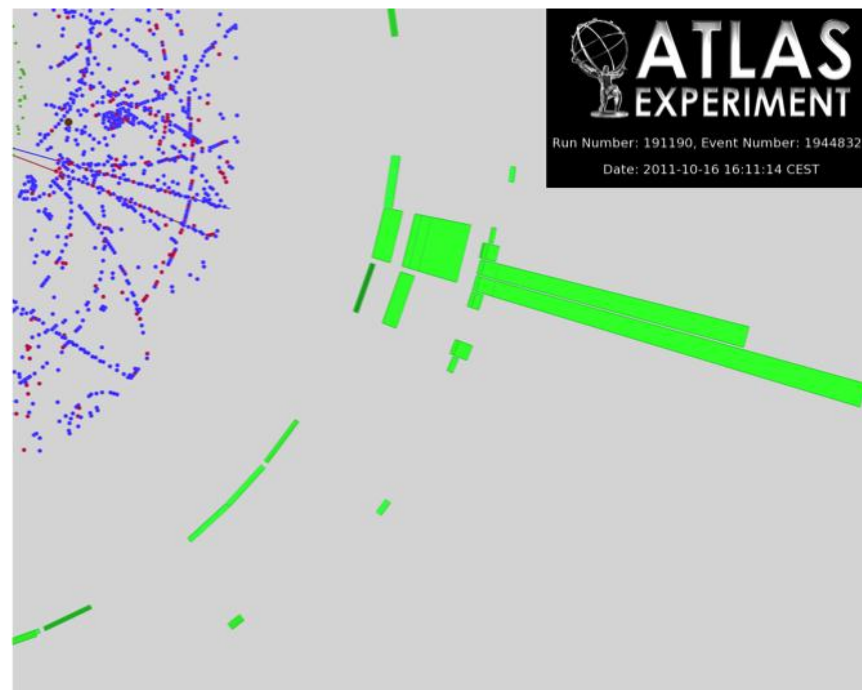




A Higgs candidate decays to two photons. The invariant mass of the two photons is 126.9 GeV.





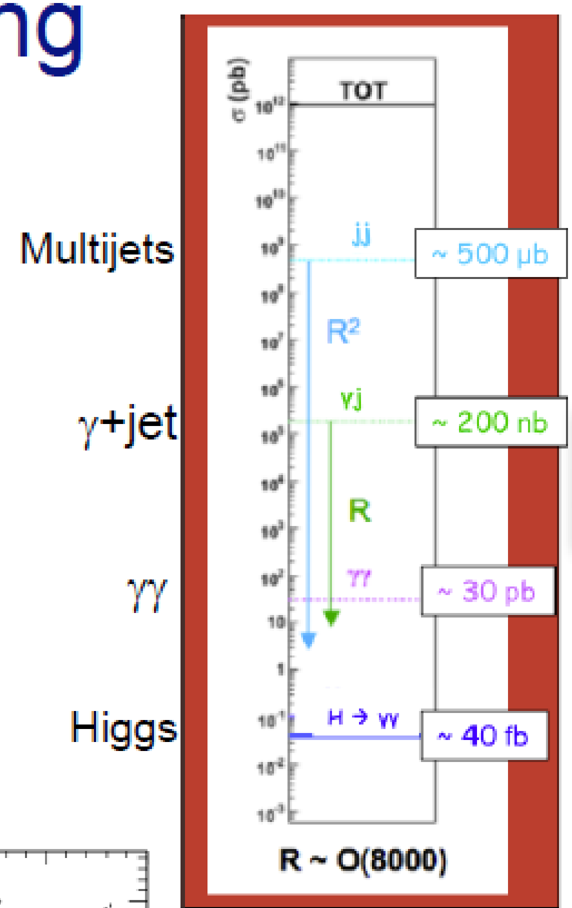


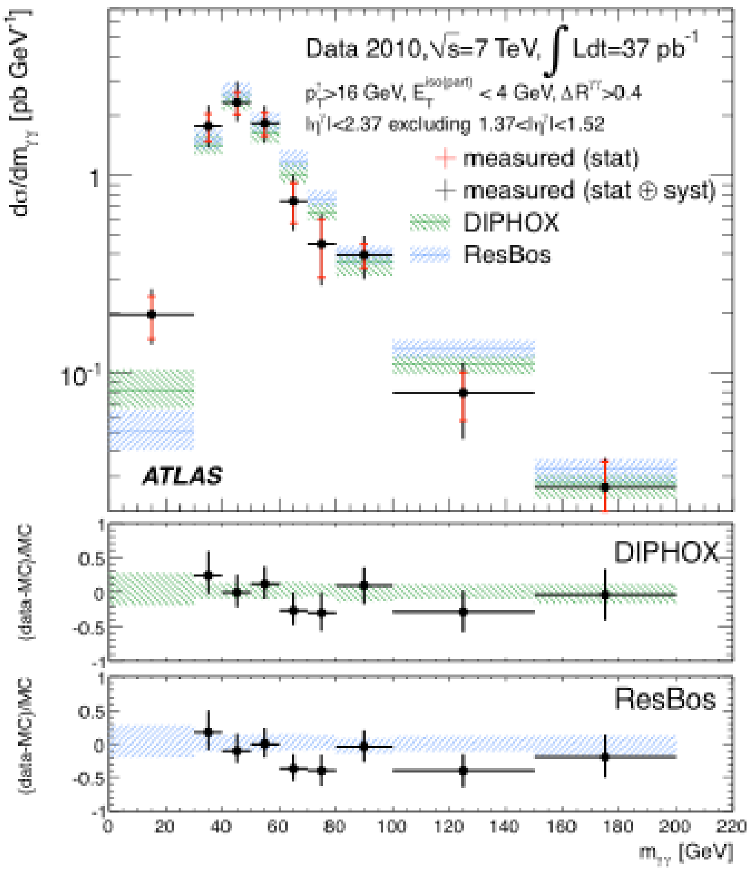
A Higgs candidate decays to two photons. One of the photons converted to a pair of electron and positron. Invariant mass of the two photons is 125.8 GeV.

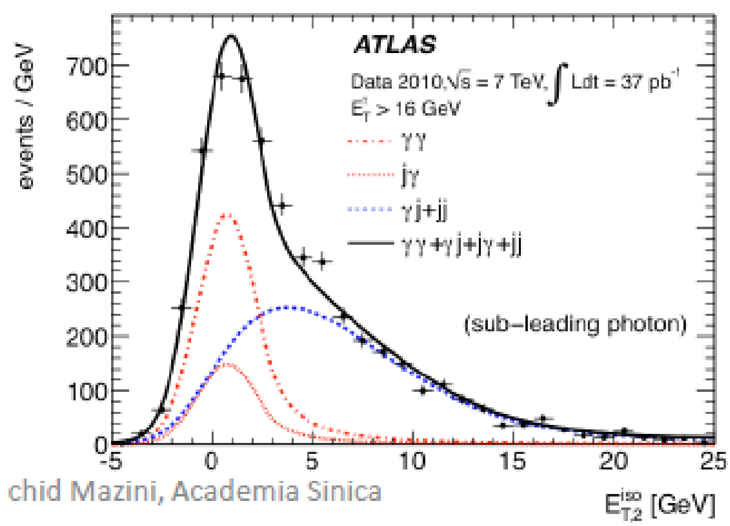
Background modelling

<u>Estimate backgrounds from data</u>

• Mass spectrum is smooth and non-resonant. Signal modeled with a crystal ball + broad gaussian (for poorly reconstructed energy)
• Simulation-based estimates subject to relatively large theory uncertainties, mis-modeling of large background rejection factors
• Background models are tested for possible bias and chosen to give the best p0 value at 125GeV





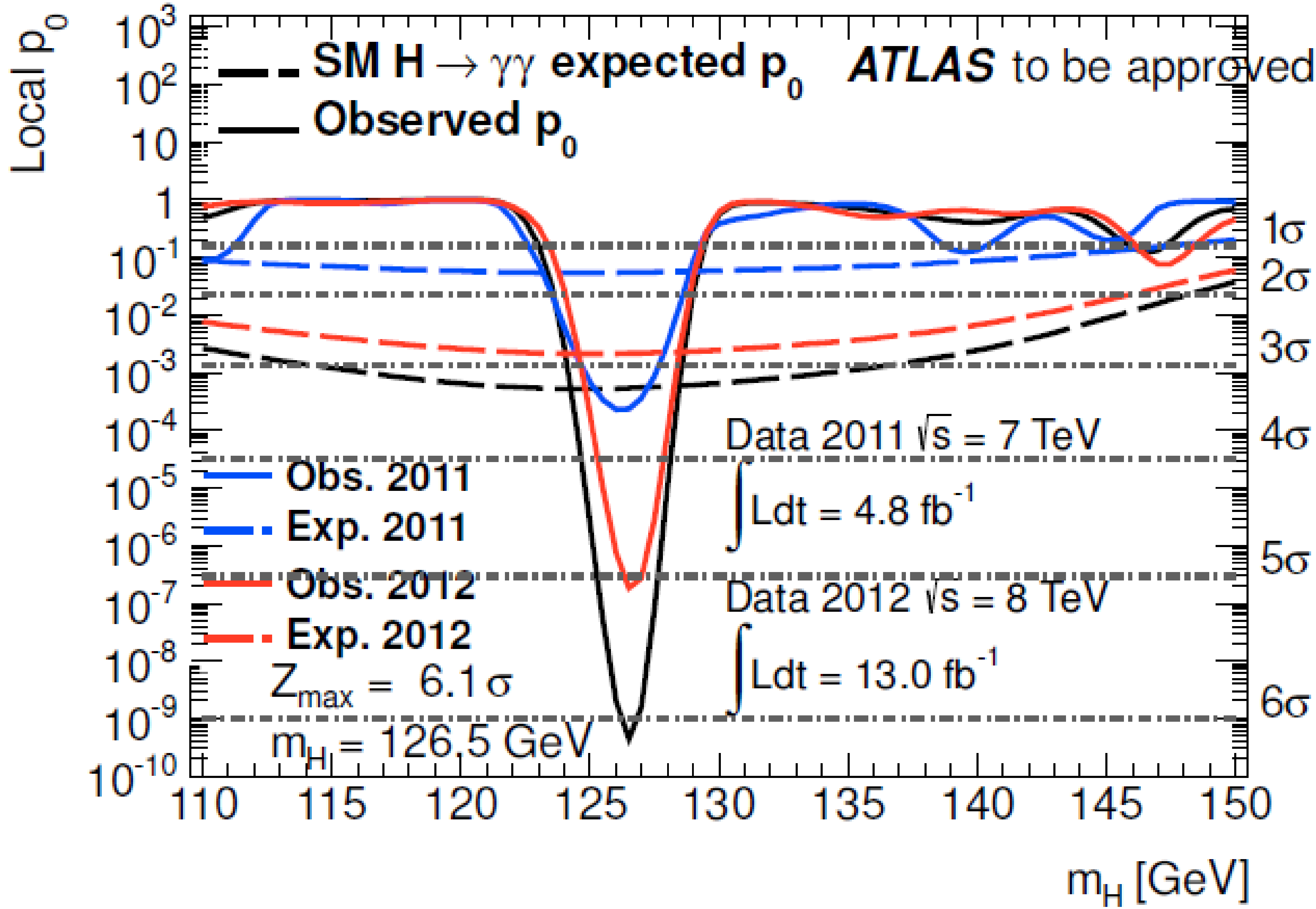


Observation and study of the newly discovered boson in the two photon decay channel with the ATLAS detector at the LHC

The ATLAS Collaboration

Abstract

A search for the Standard Model Higgs boson in the two photon decay channel with the ATLAS detector at the LHC is presented. The datasets used correspond to integrated luminosities of 4.8 fb^{-1} collected with $\sqrt{s}$ = 7 TeV collisions and 13.0 fb^{-1} collected with $\sqrt{s}$ = 8 TeV collisions. This result confirms the observation of a new boson which was previously reported by the ATLAS and CMS collaborations with the combination of several decay channels. With the additionnal data, the observation has a local significance of 6.1 standard deviations in the diphoton decay channel alone, with a measured mass of 126.6 ± 0.3 (stat) ± 0.7 (sys) GeV. The fitted number of signal events is found to be 1.80 ± 0.30 (stat) $^{+0.21}_{-0.15}$ (syst) $^{+0.20}_{-0.14}$ (theory) times its Standard Model predicted value.



Local p_0
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
SM $H \rightarrow \gamma\gamma$ expected p_0
Observed p_0
ATLAS to be approved
Obs. 2011
Exp. 2011
Obs. 2012
Exp. 2012
$Z_{max} = 6.1\sigma$
$m_H = 126.5$ GeV
Data 2011 $\sqrt{s} = 7$ TeV
$\int Ldt = 4.8\ fb^{-1}$
Data 2012 $\sqrt{s} = 8$ TeV
$\int Ldt = 13.0\ fb^{-1}$
1σ
2σ
3σ
4σ
5σ
6σ
110
115
120
125
130
135
140
145
150
m_H [GeV]

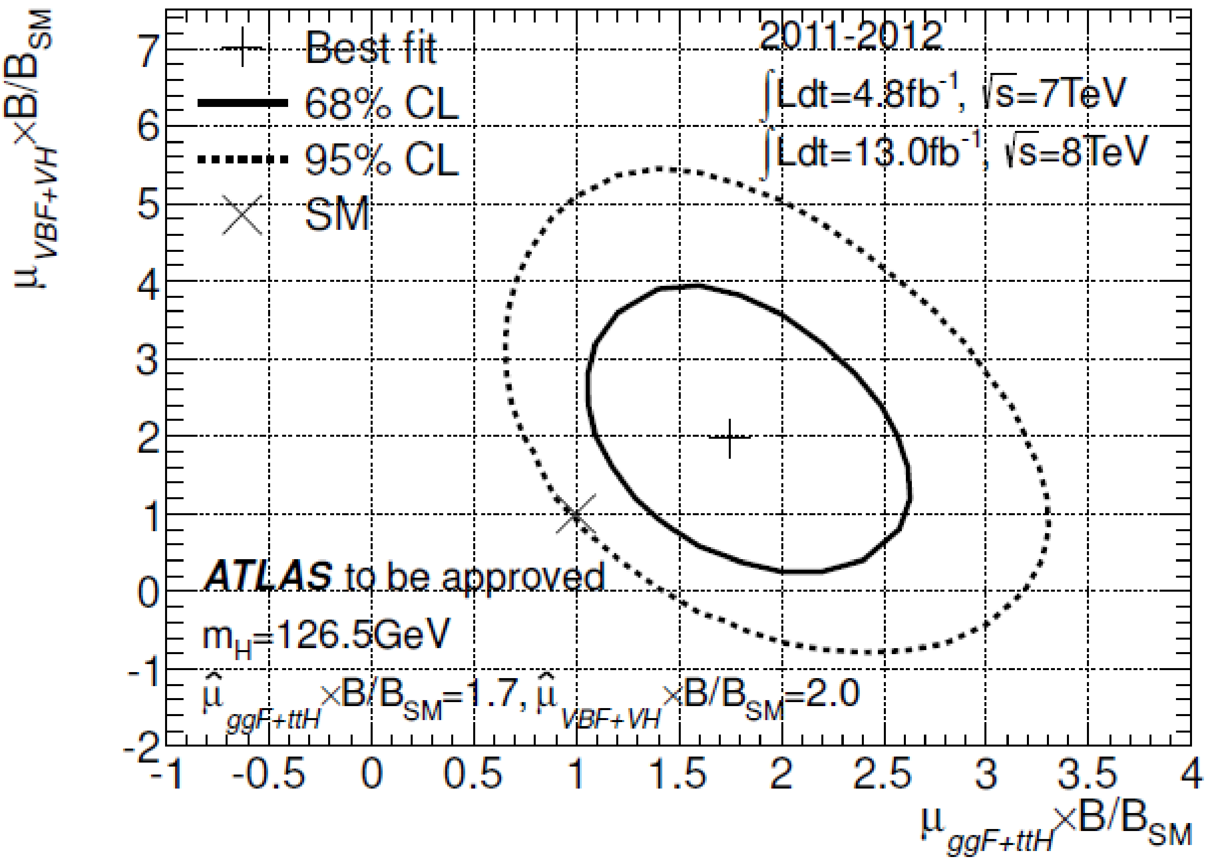
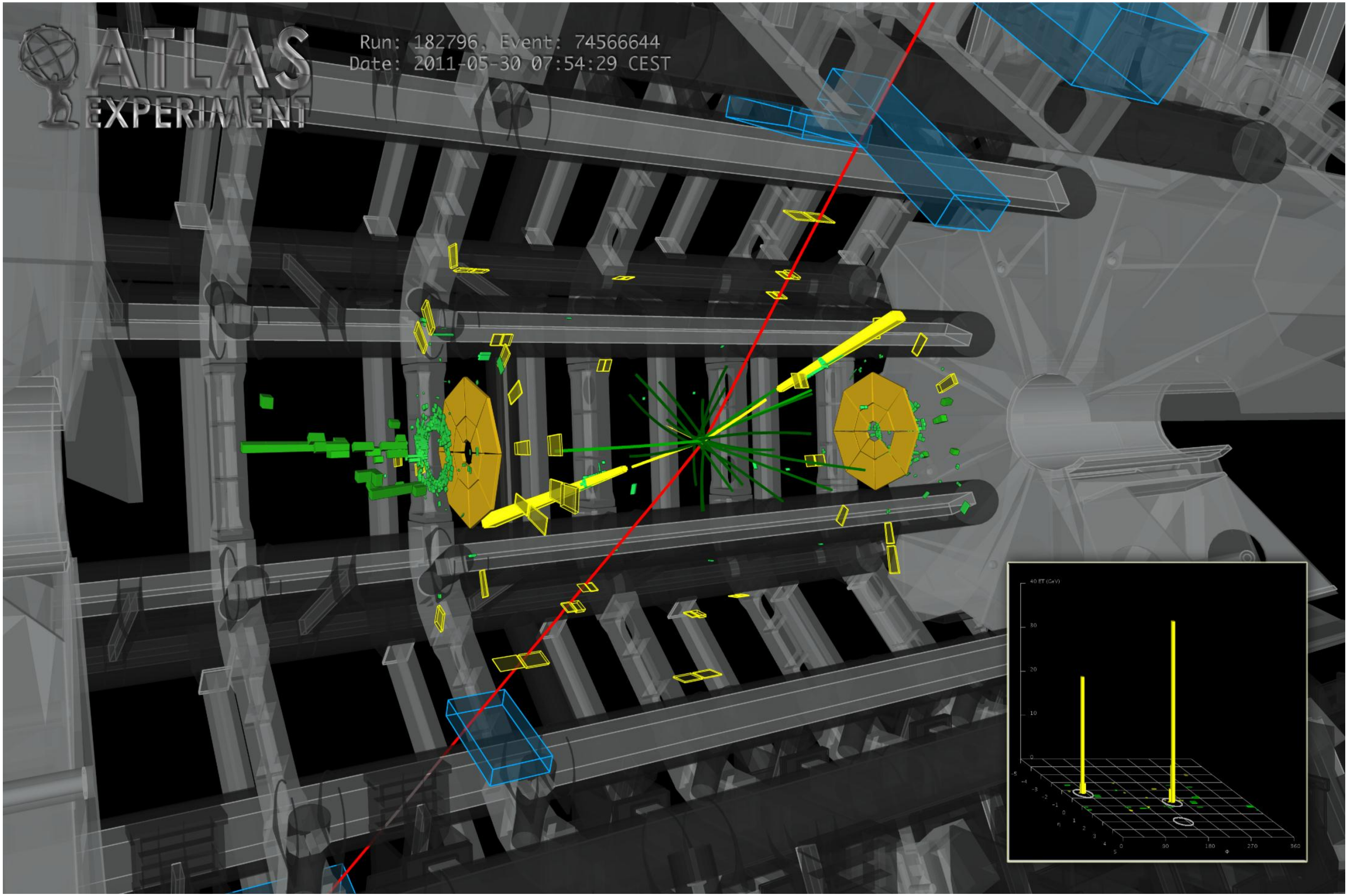
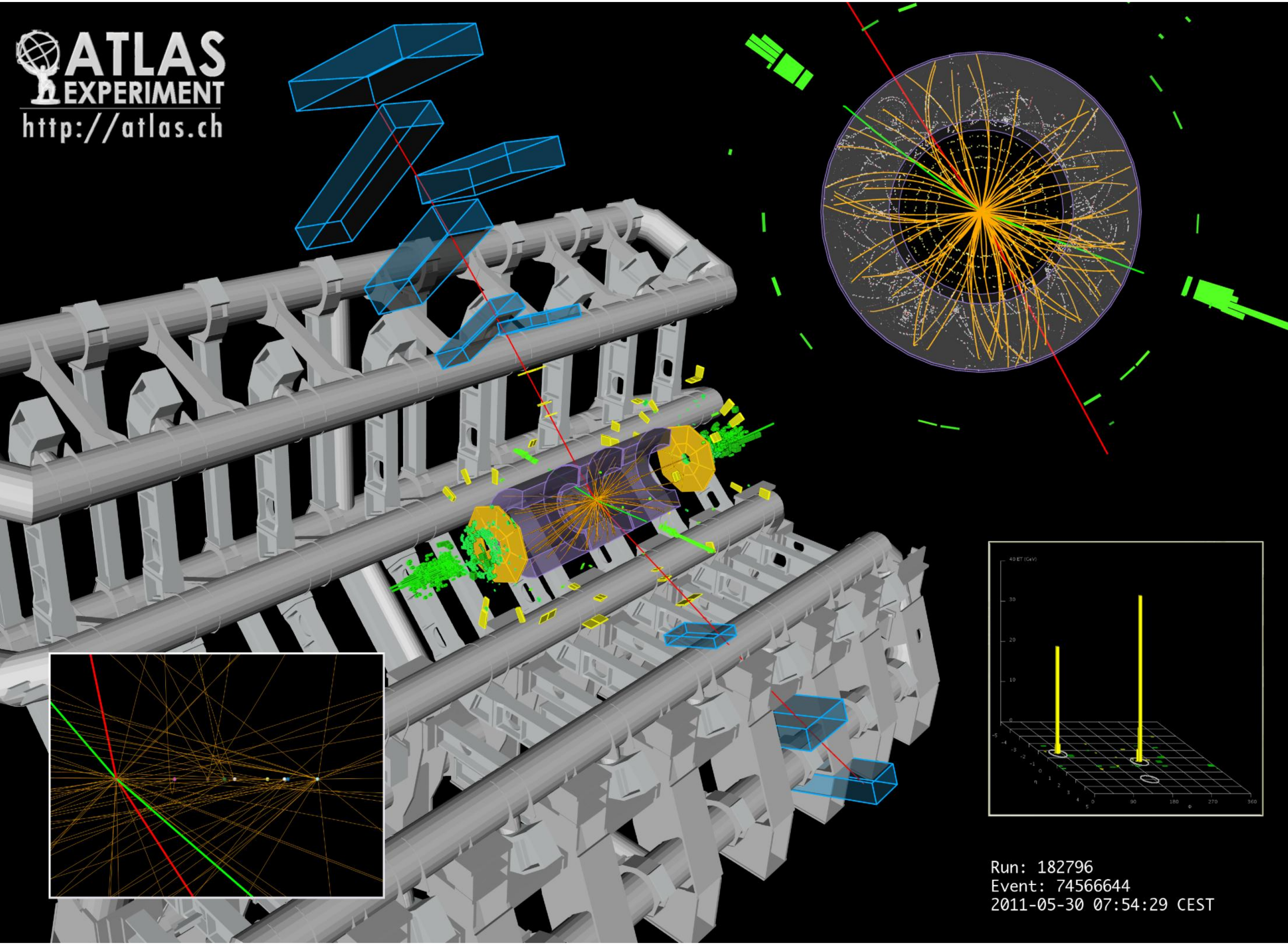
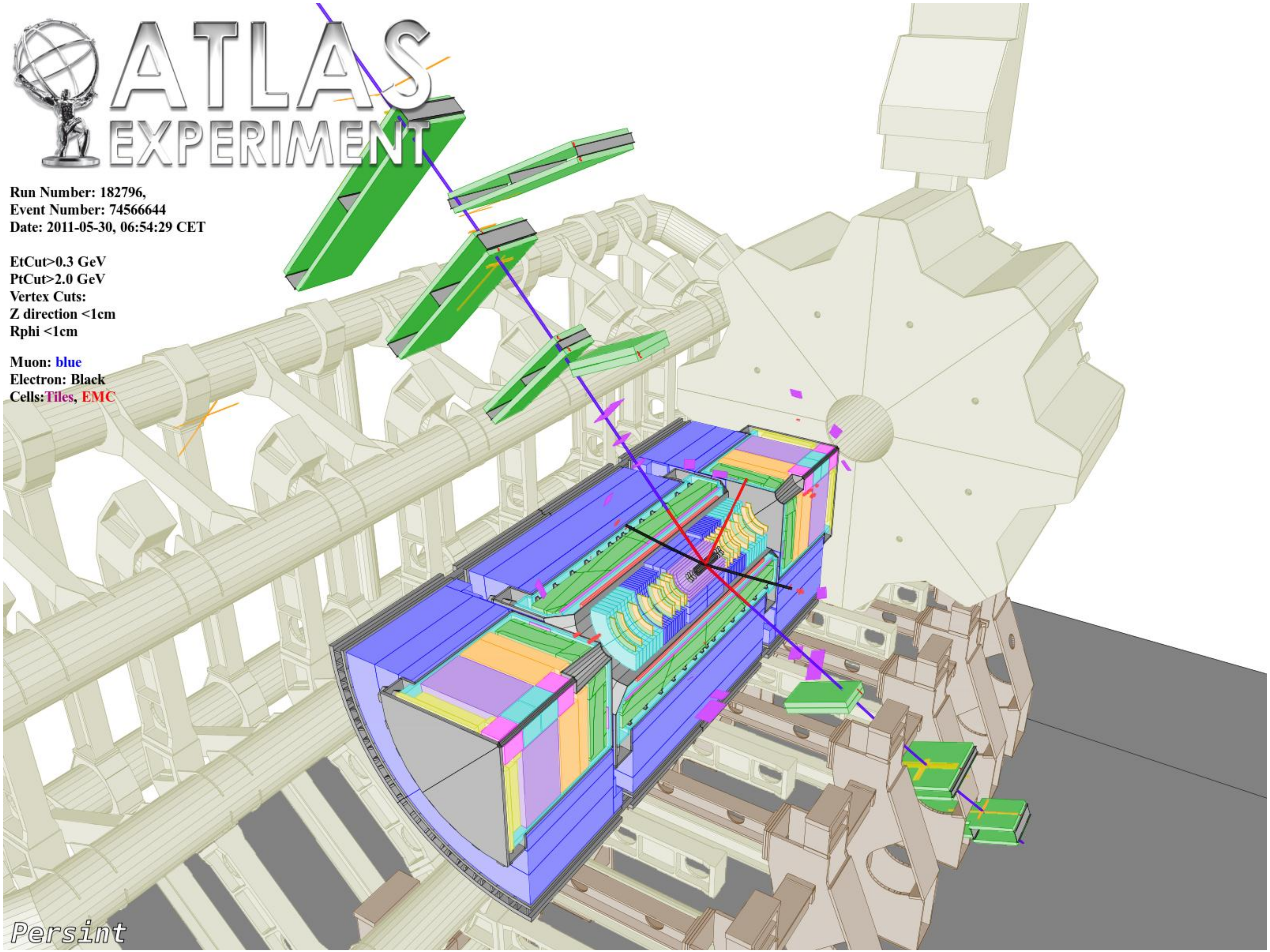


Figure 5: The best-fit values (+) of $\mu_{ggF+ttH} \times B/B_{SM}$ and $\mu_{VBF+VH} \times B/B_{SM}$ and their 68 % (solid) and 95 % (dashed) CL contours.

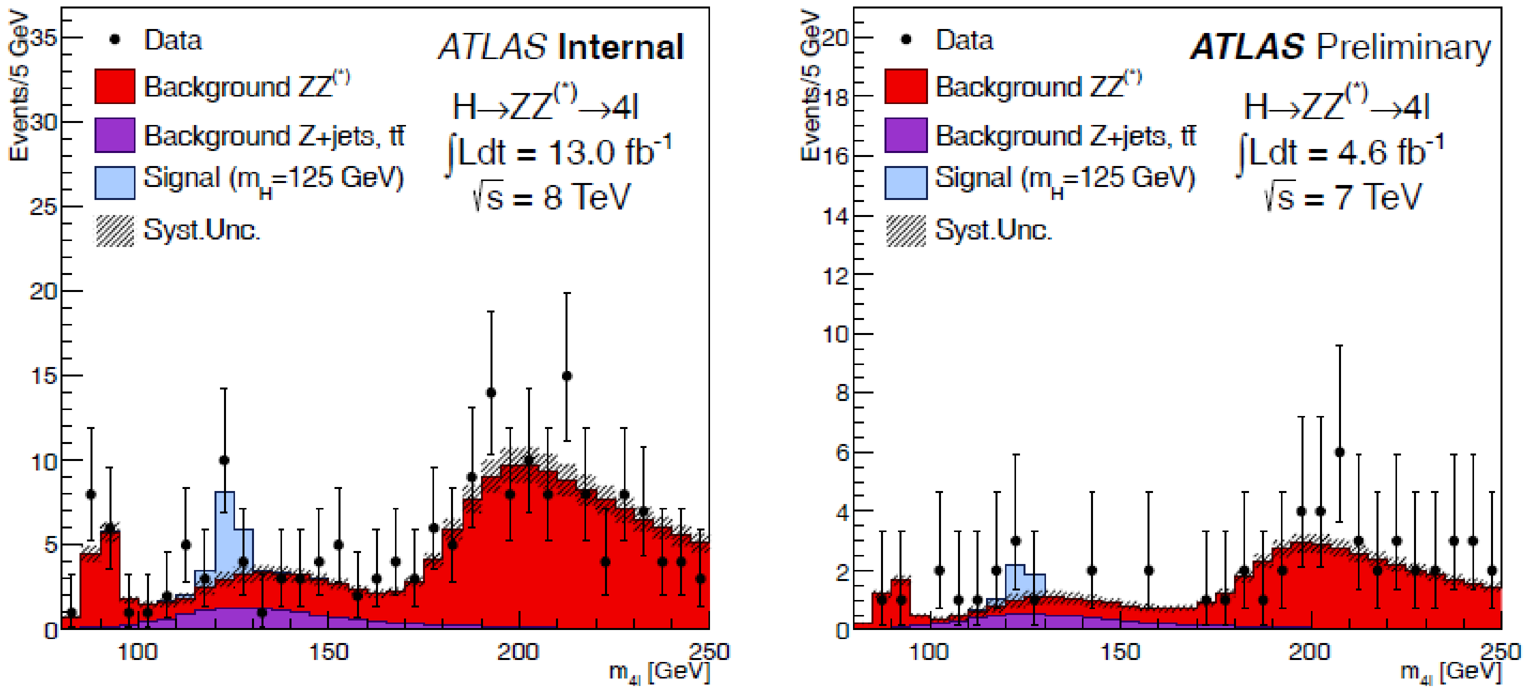
新粒子衰變到一對電子及一對緲子




ATLAS
EXPERIMENT
http://atlas.ch
Run: 182796
Event: 74566644
2011-05-30 07:54:29 CEST


ATLAS EXPERIMENT
Run Number: 182796,
Event Number: 74566644
Date: 2011-05-30, 06:54:29 CET
EtCut>0.3 GeV
PtCut>2.0 GeV
Vertex Cuts:
Z direction <1cm
Rphi <1cm
Muon: blue
Electron: Black
Cells:Tiles, EMC
Persint

	Signal	$ZZ^{(*)}$	Z + jets, $t\bar{t}$	Observed
	$\sqrt{s} = 8$ TeV and $\sqrt{s} = 7$ TeV			
4μ	3.99 ± 0.51	2.03 ± 0.09	0.36 ± 0.09	8
$2\mu 2e$	1.71 ± 0.25	0.70 ± 0.05	1.21 ± 0.18	2
$2e2\mu$	2.36 ± 0.31	1.02 ± 0.05	0.30 ± 0.07	4
$4e$	1.75 ± 0.26	0.94 ± 0.09	1.72 ± 0.23	4
total	9.93 ± 1.33	4.69 ± 0.28	3.59 ± 0.32	18



(a) (b)

Figure 8: The distribution of the four-lepton invariant mass, $m_{4\ell}$, for the selected candidates compared to the background expectation in the 80–250 GeV mass range for the (a) $\sqrt{s} = 8$ TeV and (b) $\sqrt{s} = 7$ TeV data sets. The signal expectation for several m_H hypotheses is also shown.

Updated search and measurement of properties of the new Higgs-like particle in the four lepton decay channel with the ATLAS detector

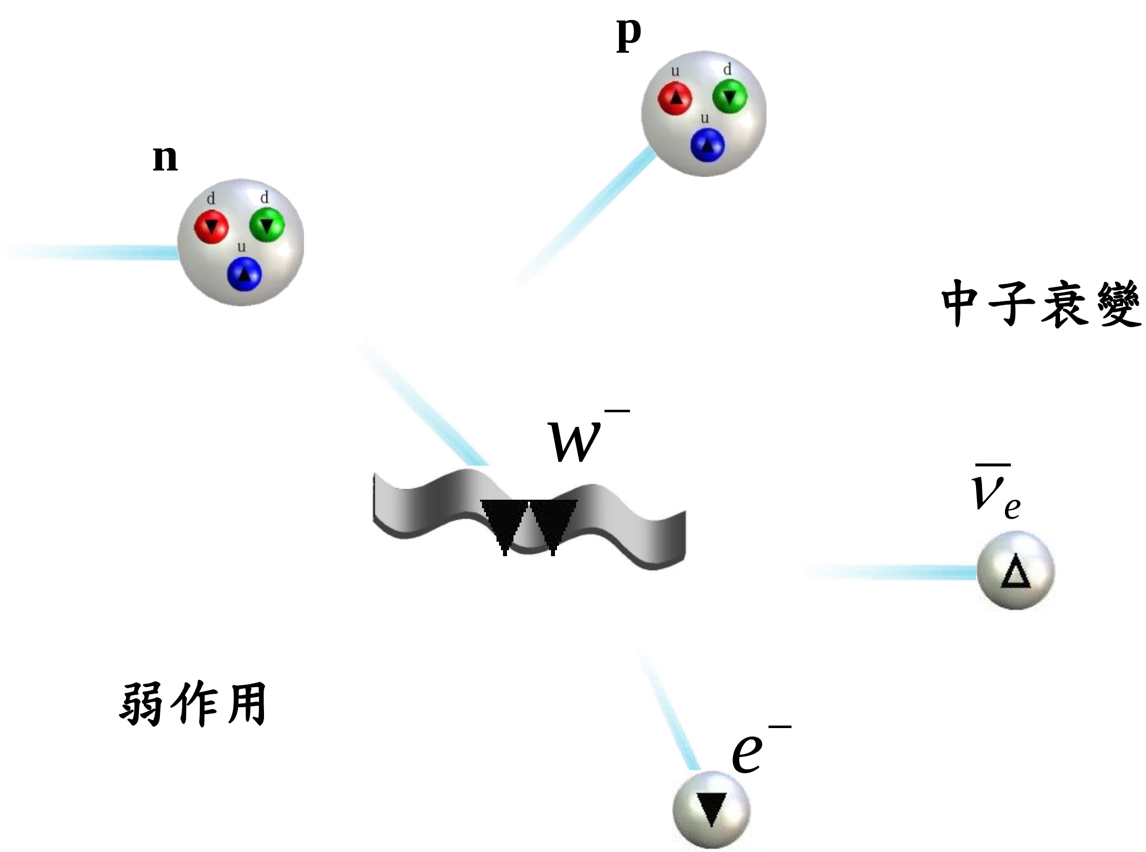
The ATLAS Collaboration

Abstract

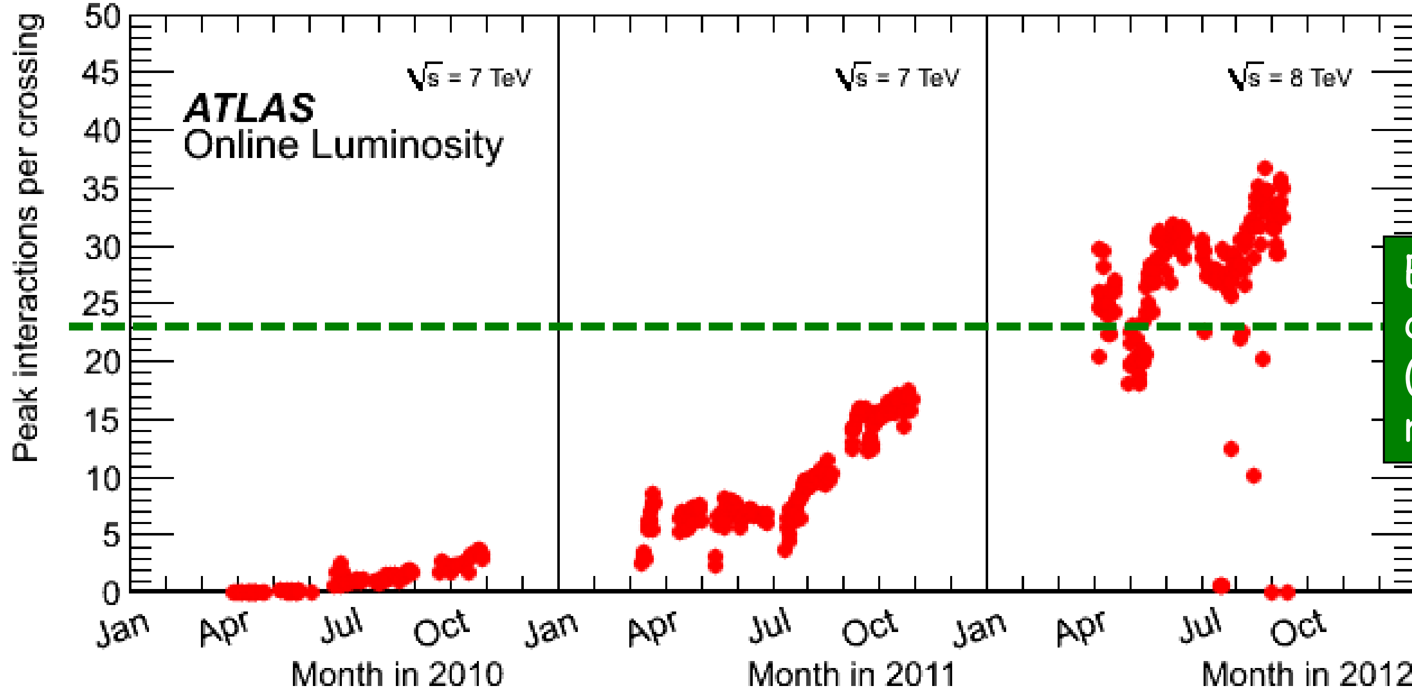
This note presents an update of the search results and a first measurement of the properties of the newly observed Higgs-like particle in the decay channel $H \to ZZ^{(*)} \to \ell^+\ell^-\ell'^+\ell'^-$, where $\ell, \ell' = e$ or μ, using 4.6 fb^{-1} and 13.0 fb^{-1} of proton-proton collisions at $\sqrt{s} = 7$ TeV and 8 TeV, respectively, recorded with the ATLAS detector. The p_0 value of the excess of events at $m_H = 123.5$ GeV is 0.0021% (4.1 standard deviations) in the combined analysis of the two datasets. The fitted mass is measured to be $\boxed{123.5 \pm 0.9(\mathrm{stat})^{+0.4}_{-0.2}(\mathrm{syst})\ \mathrm{GeV}}$, and the signal strength at this mass is found to be $\boxed{1.3^{+0.6}_{-0.4}.}$ An analysis is performed on the spin and parity of the events with 115 GeV $< m_H <$ 130 GeV. The 0^+ state is found to be favoured over 0^-, 2^+_m and 2^-.

Missing Transverse Momentum is key to new physics！

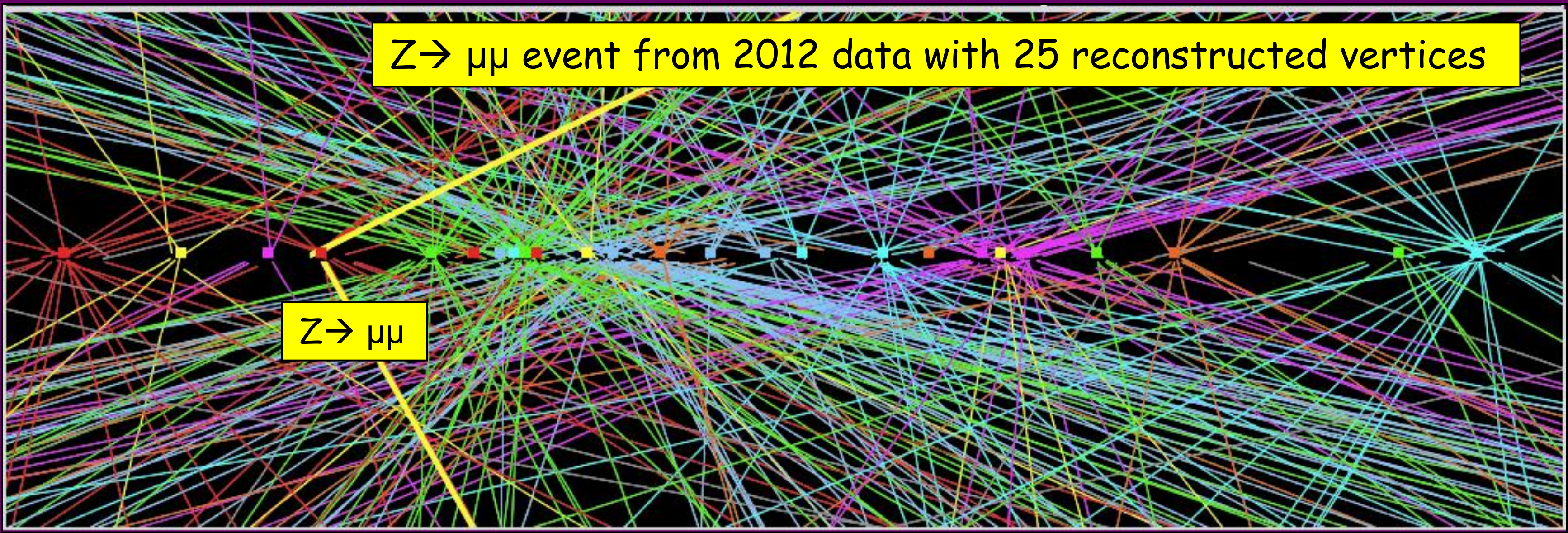
E_T^{miss}



The BIG challenge in 2012: PILE-UP

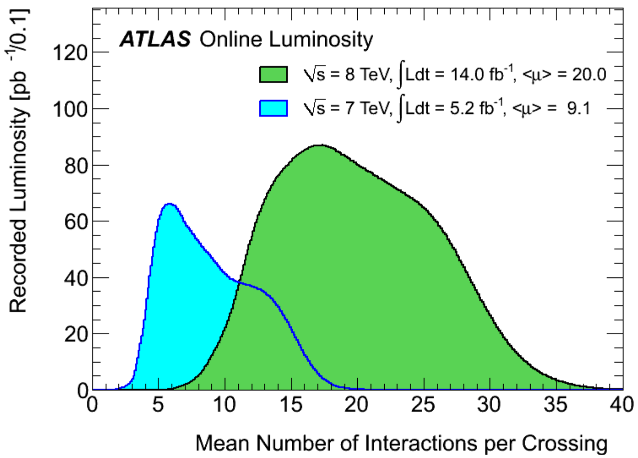


Experiment's design value (expected to be reached at $L=10^{34}$!)

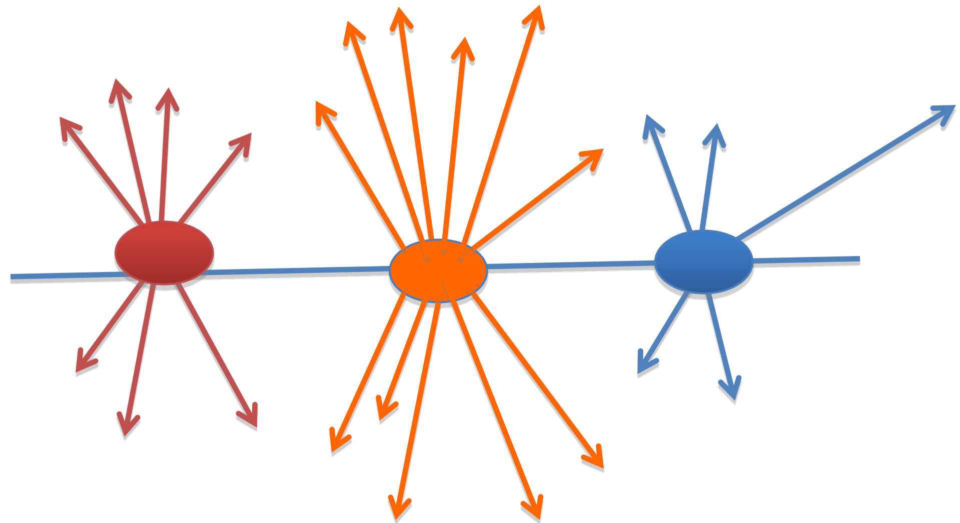


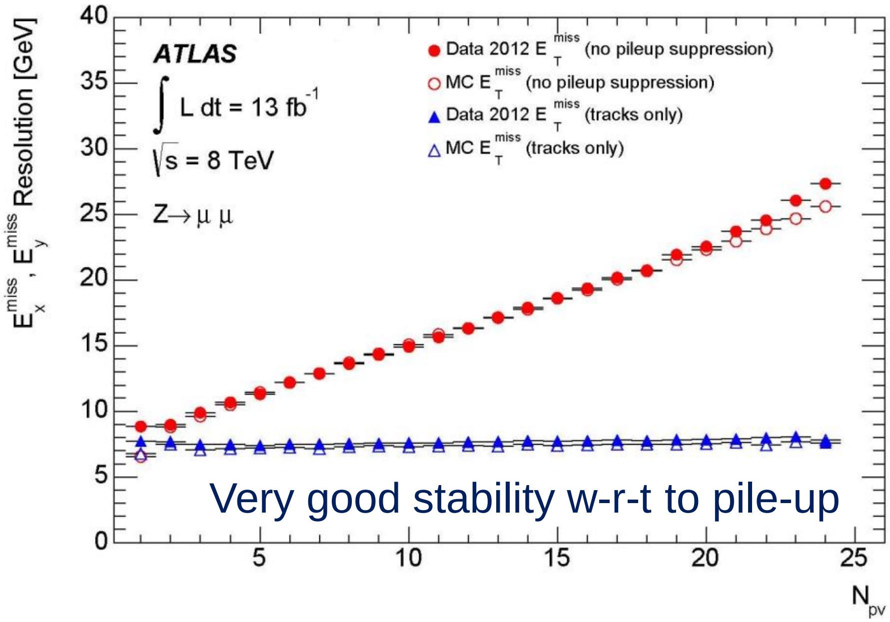
We proposed to use track based p_T^{miss}

High luminosity from the LHC comes wit the cost of multiple interactions per bench crossing: High pile-up



Vertex based p_T^{miss}





Choose the correct Primary Vertex v and calculate p_T^{miss} from high quality tracks associated to v:

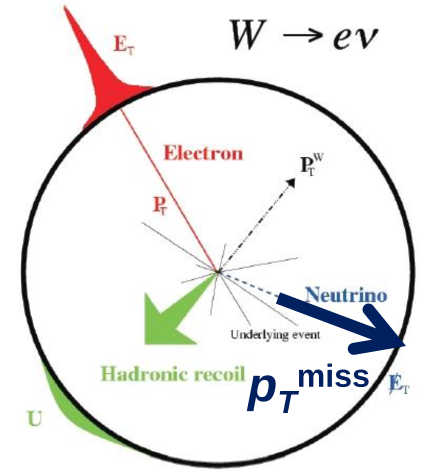
$$P_x^{miss}(v) = \Sigma_{i=0}^{(v)i=NTrack}(p_{x_i}^{v})$$

$$P_y^{miss}(v) = \Sigma_{i=0}^{(v)ii=NTrack}(p_{y_i}^{v})$$

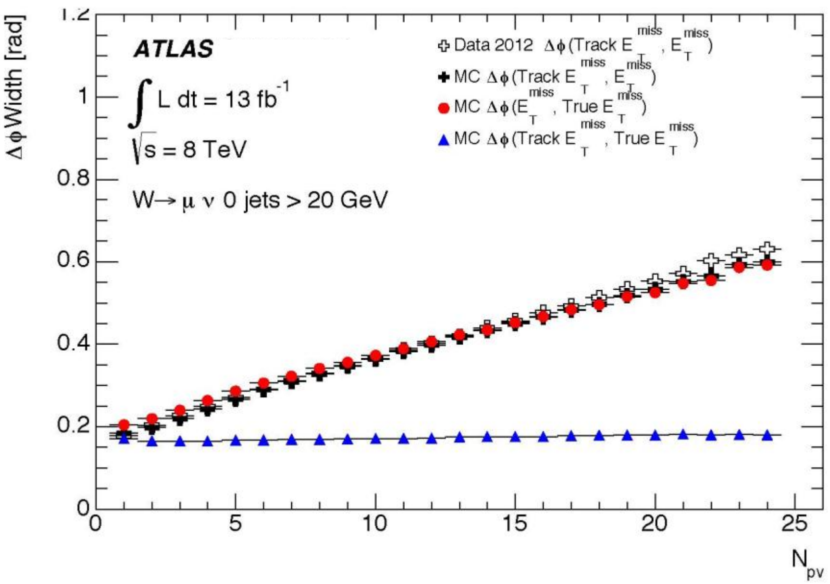
$$P_T^{miss}(v) = \sqrt{P_x^{miss2}(v) + P_y^{miss2}(v)}$$

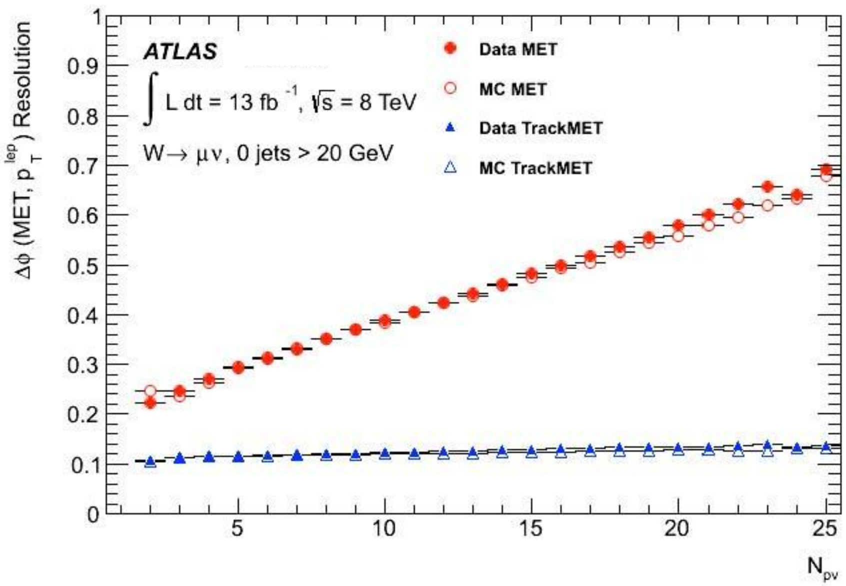
Stability of track-based p_T^{miss} in W events

- $W \to l\nu$ (l=e,μ) offers the possibility to estimate the performances of p_T^{miss} measurement:
  - Low hadrinic activities in events without jets, well known 2-body decay kinematic
  - Undetected neutrino ⇒ Missing energy (conserved in the transverse plan)
  - Direction of missing transverse energy calculated to balance the muon and the hadronic recoil.



- $W \to \mu\nu$ events have been used for p_T^{miss} studies



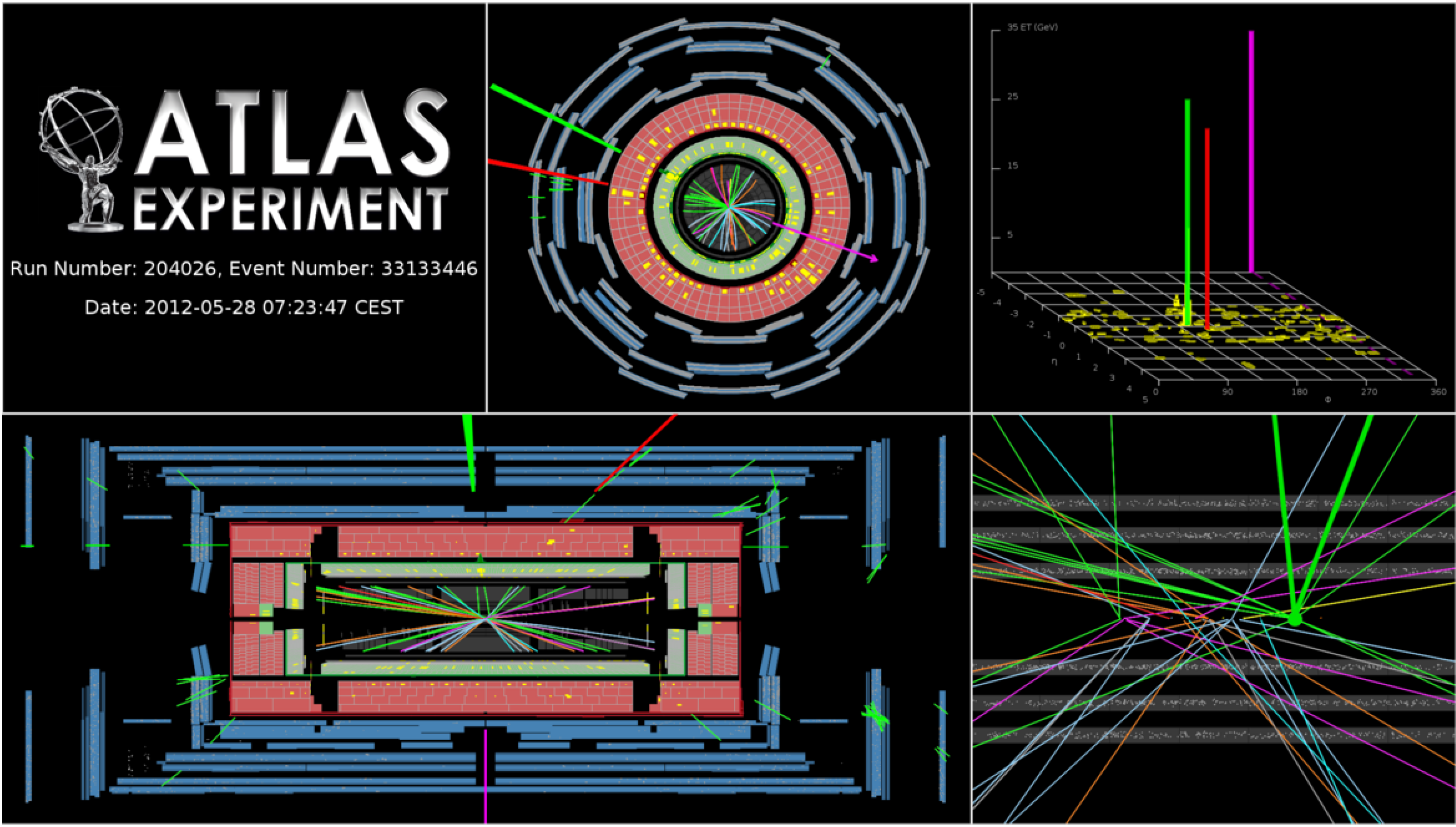


Perfect stability of the resolution on the direction of track-based $\boldsymbol{p_T^{miss}}$ w-r-t pile-up when compared to the “true” missing energy or to the muon directions.

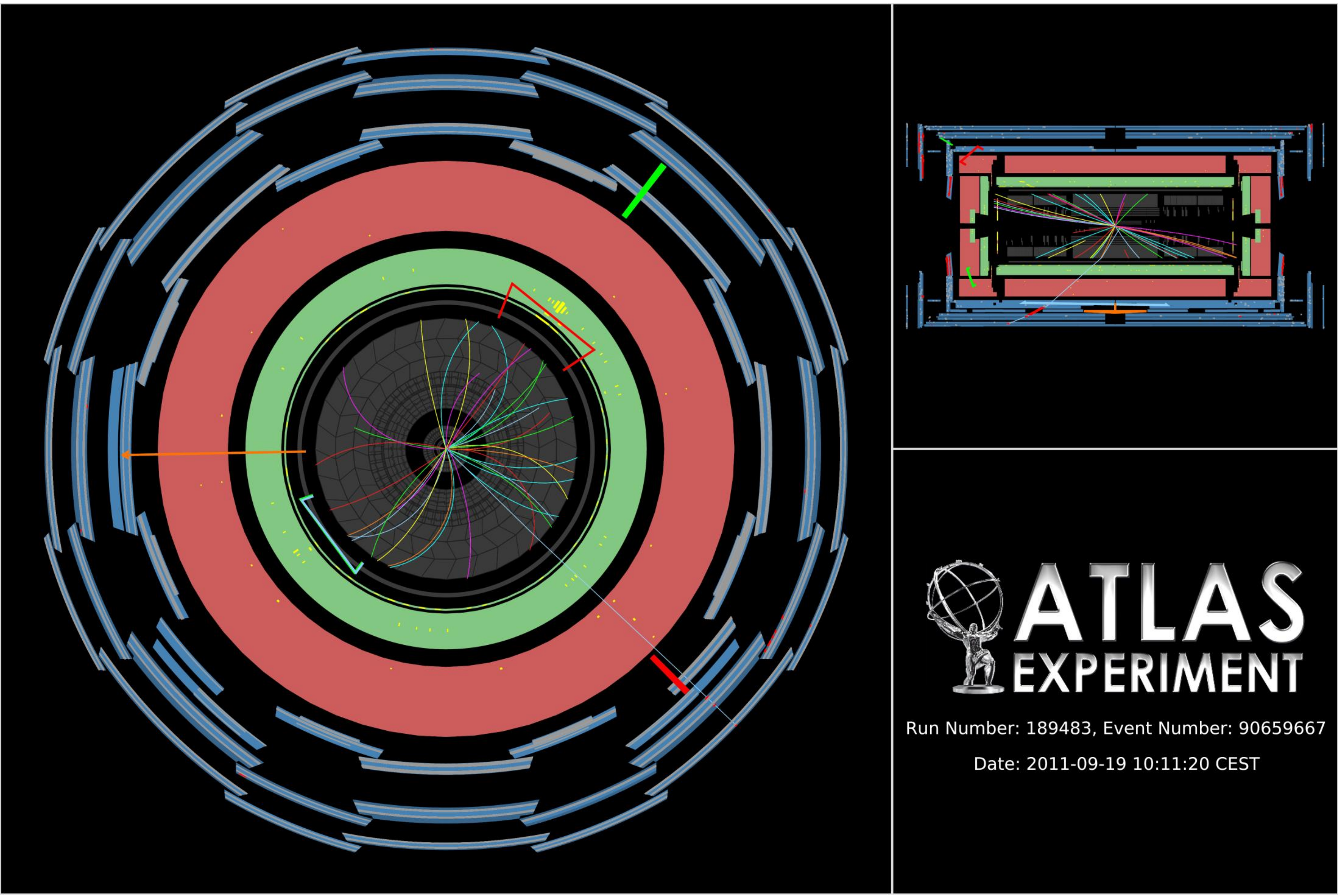
Taiwan group is the leader of the track based missing transverse momentum performance group in ATLAS. The tool is used in Higgs search and SUSY search.

$$H \rightarrow WW^* \rightarrow ll\nu\nu$$

$$H \rightarrow \tau\tau$$



A Higgs candidate decays to two W particles. One of the W decays to a electron and a neutrino while the other decays to a muon and a neutrino. Neutrinos are not detected but inferred from the missing transverse momentum.



A Higgs candidate decays to two W particles which decay to electron, muon and neutrinos.

$H \to WW^* \to ll\nu\nu$: results

signal significance 2.6σ (expected 1.9σ)

signal strength (ratio to SM rate) $\mu = 1.5 \pm 0.6$

} $m_H = 125$ GeV

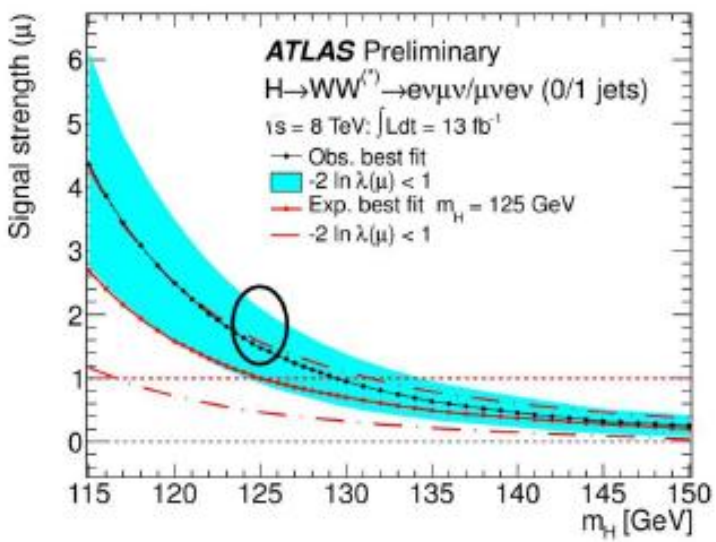
assumes SM ratio of production mechanisms

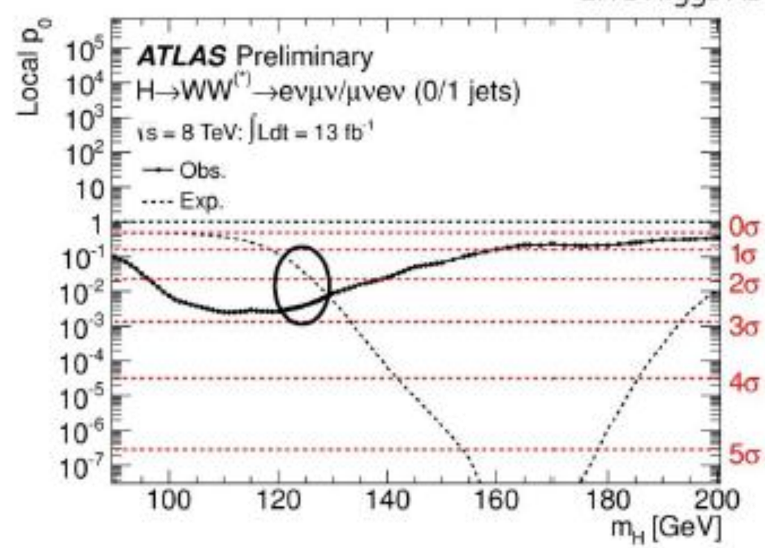
backgrounds & signal acceptance

$$\sigma(pp \to H) \cdot Br(H \to WW) = 7.0^{+1.7}_{-1.6}\ (\mathrm{stat})^{+1.7}_{-1.6}\ (\mathrm{theory})^{+1.3}_{-1.3}\ (\mathrm{exp}) \pm 0.3\ (\mathrm{lum})\ \mathrm{pb}$$

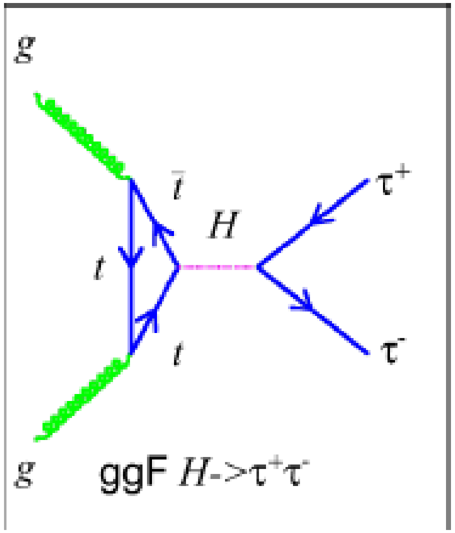
SM expectation: $\sigma(pp \to H) \cdot Br(H \to WW) = 4.77 \pm 0.64\ (\mathrm{xsec}) \pm 0.2\ (\mathrm{BR})\ \mathrm{pb}$

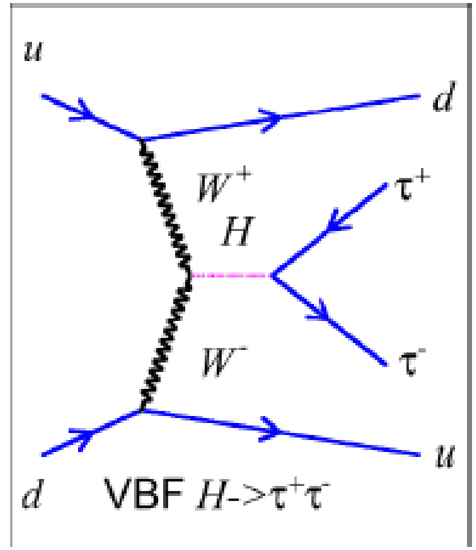
LHC Higgs XS WG

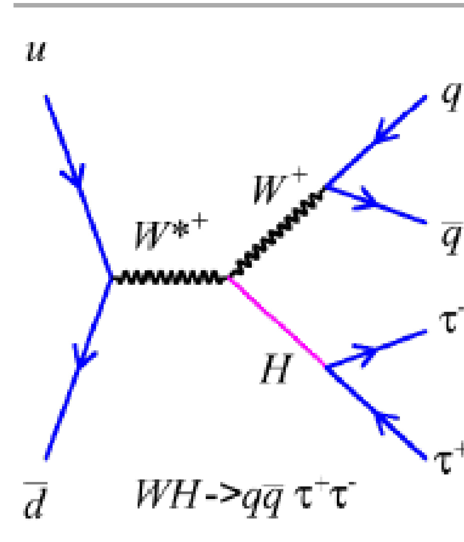




$H \to \tau\tau$ searches in ATLAS







Separate analysis for three different ττ decay mode.

– lep-lep = ll 4ν : (ee)+eμ+μμ

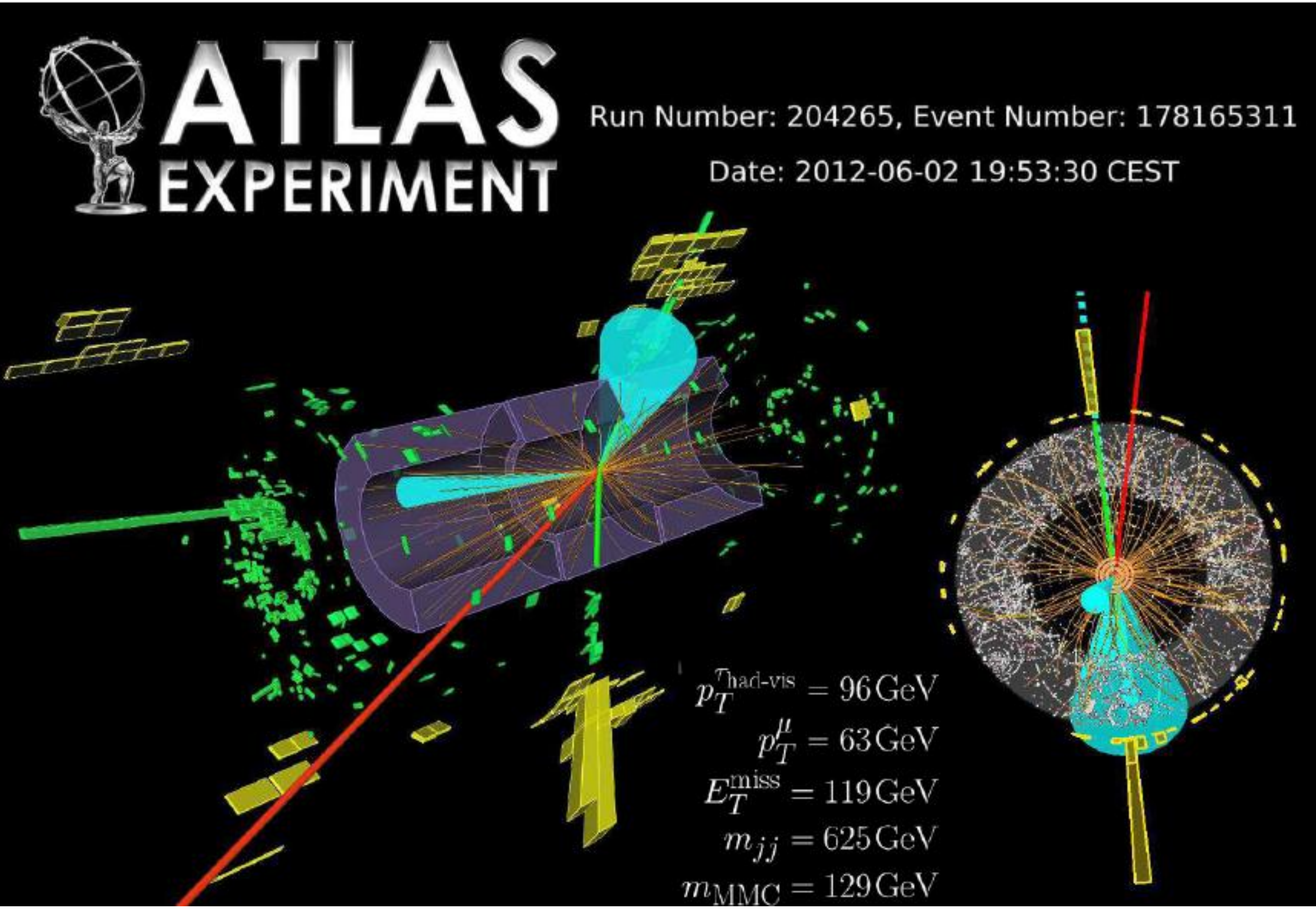
– lep-had = l τ_{had} 3ν : e τ_{had}+ μ τ_{had}

– had-had = τ_{had} τ_{had} $\nu\nu$: (τ_{had} τ_{had})

• Combined all three channels to search for $H \to \tau\tau$ signature.

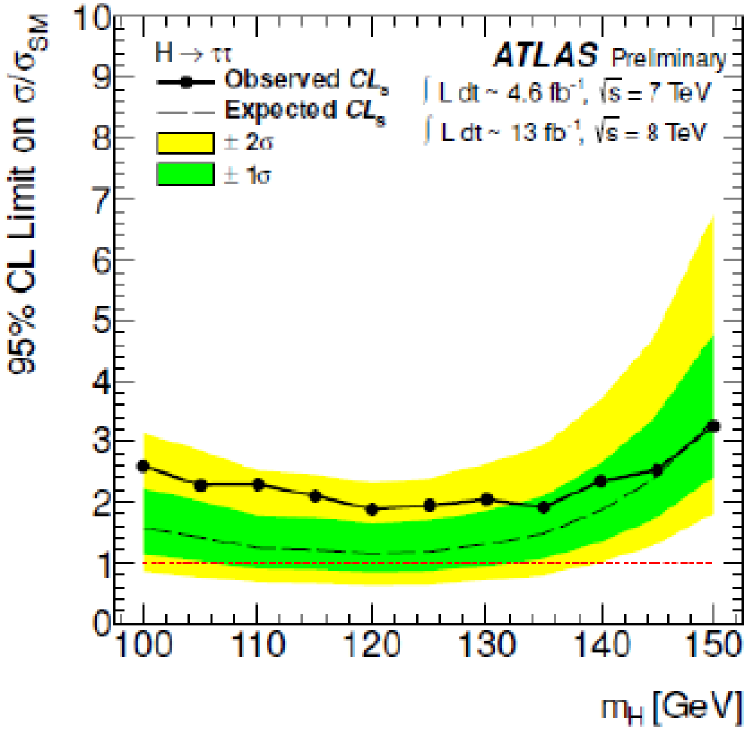
This is the only search channel to probe Higgs coupling to lepton.

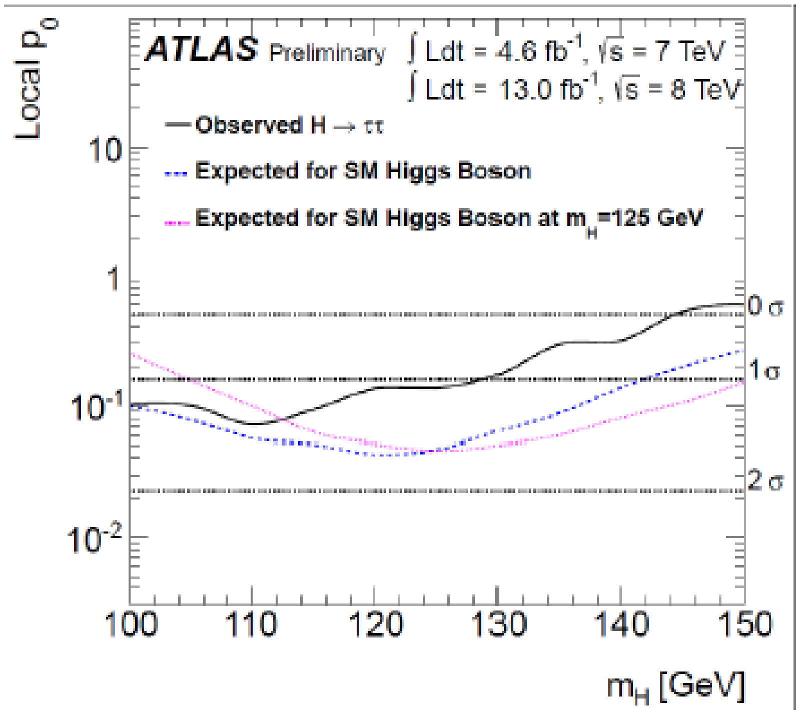
H→ττ seraches in ATLAS



H→ττ results: combined limt and p0

Calculated limits and significance using MMC distribution as the discriminant.
Signal extracted with Profile likelihood.





μ=0

Expected:1.2xSM Observed:1.9xSM

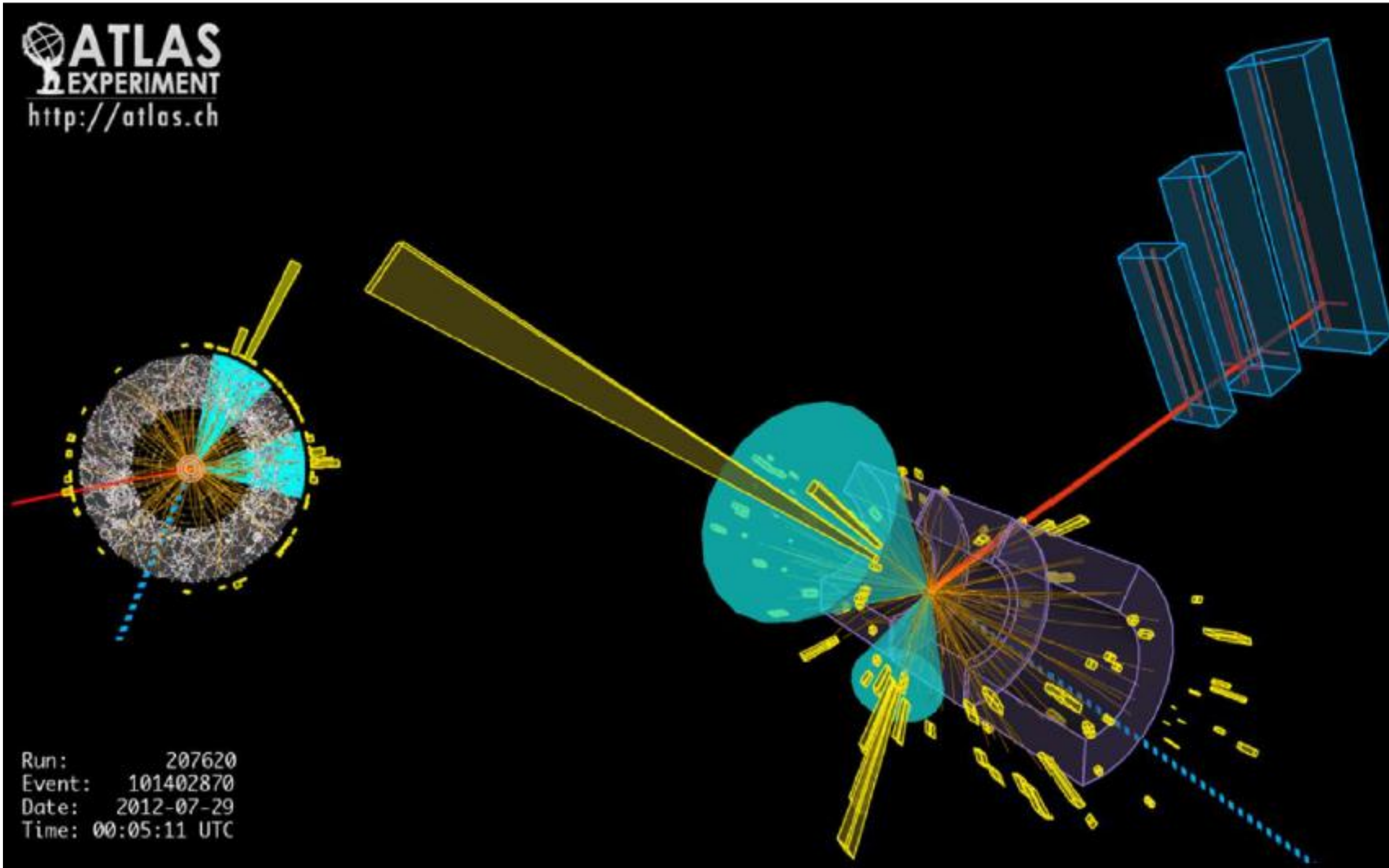
μ=1

Expected:1.2xSM Observed:1.9xSM

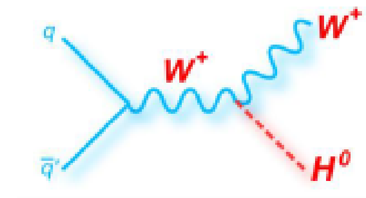
Best fit value of Signal Strength (μ) is 0.7 ±0.7

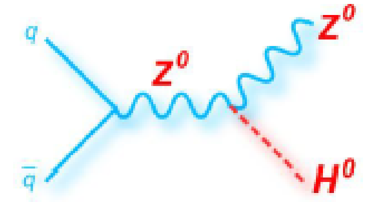
H→bb in ATLAS

WH with $W \to \mu\nu$, $H \to bb$ candidate



VH, with H→bb, analysis strategy





- Analysis is divided into three channels:

Two lepton

ZH → llbb
- No additional leptons
- E_t^{miss} < 60 GeV
- 83 < m_Z < 99 GeV
- Single & di-lepton trigger

One lepton

WH → lνbb
- No additional leptons
- E_t^{miss} > 25 GeV
- 40 < M_T^W < 120 GeV
- Single lepton trigger

Zero lepton

ZH → ννbb
- No leptons
- E_t^{miss} > 120 GeV
- E_t^{miss} trigger

- Total of 16 categories with cuts optimized for each
  - 0-lepton: 3 bins in E_T^{miss} x (2 jor 3 jets)
  - 1 and 2 leptons: 5 bins in $p_T^{W,Z}$

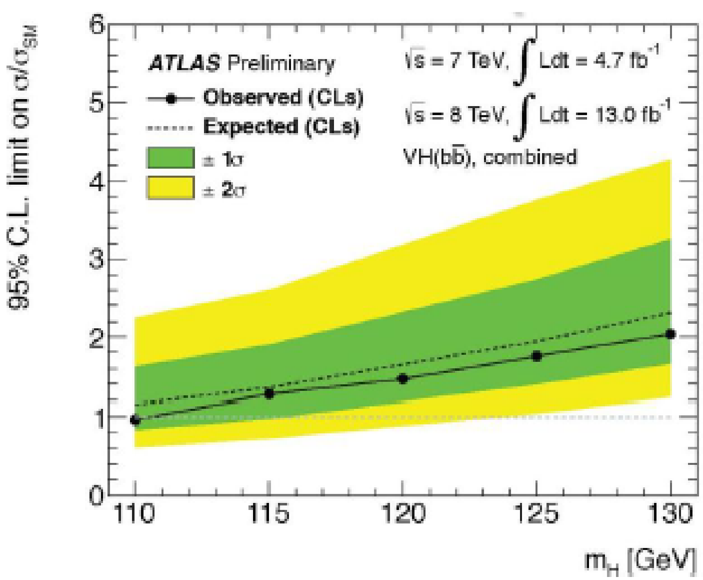
- Leptons with loose ID require p_T > 10 GeV, while medium and tight require 25 GeV.
- Require 2 b-tagged jets using multi-variate tagger (|η|<2.5), extra jets have |η|<4.5
  - Two b-tags: 70% efficiency per tag (mistag ~1%)

- Data used: 4.7fb^{-1} at √s = 7TeV (2011) and 13fb^{-1} at √s=8 TeV (2012)
  - S/B is not large, but increases as p_T^{bb} increases
  - Not yet enough √s and ∫Ldt to use jet substructure techniques

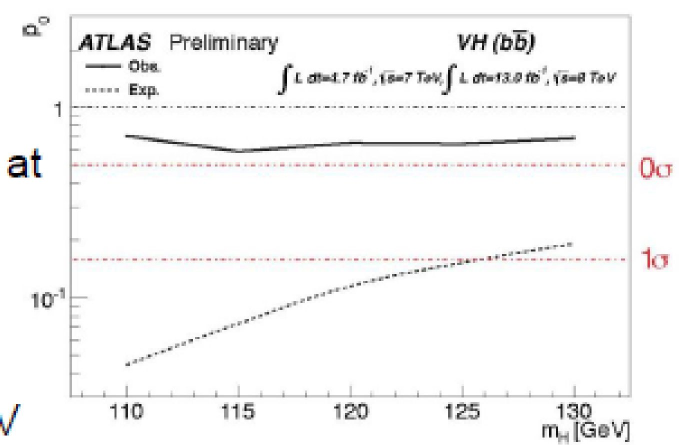
VH, with H→bb results

- Expected and observed events:

Bin	0-lepton, 2 jet			0-lepton, 3 jet			1-lepton					2-lepton				
	E_T^{miss} [GeV]						p_T^W [GeV]					p_T^Z [GeV]				
	120-160	160-200	>200	120-160	160-200	>200	0-50	50-100	100-150	150-200	> 200	0-50	50-100	100-150	150-200	>200
ZH	2.9	2.1	2.6	0.8	0.8	1.1	0.3	0.4	0.1	0.0	0.0	4.7	6.8	4.0	1.5	1.4
WH	0.8	0.4	0.4	0.2	0.2	0.2	10.6	12.9	7.5	3.6	3.6	0.0	0.0	0.0	0.0	0.0
Top	89	25	8	92	25	10	1440	2276	1120	147	43	230	310	84	3	0
$W + c$,light	30	10	5	9	3	2	580	585	209	36	17	0	0	0	0	0
$W + b$	35	13	13	8	3	2	770	778	288	77	64	0	0	0	0	0
$Z + c$,light	35	14	14	8	5	8	17	17	4	1	0	201	230	91	12	15
$Z + b$	144	51	43	41	22	16	50	63	13	5	1	1010	1180	469	75	51
Diboson	23	11	10	4	4	3	53	59	23	13	7	37	39	16	6	4
Multijet	3	1	1	1	1	0	890	522	68	14	3	12	3	0	0	0
Total Bkg.	361	127	98	164	63	42	3810	4310	1730	297	138	1500	1770	665	97	72
	± 29	± 11	± 12	± 13	± 8	± 5	± 150	± 86	± 90	± 27	± 14	± 90	± 110	± 47	± 12	± 12
Data	342	131	90	175	65	32	3821	4301	1697	297	132	1485	1773	657	100	69



- Observed (expected) limit at m_H =125 GeV
  - 1.8 (1.9) x SM
- Observed (expected) p0 value: 0.64 (0.15)
- Exclusion at m_H ~ 110 GeV



$\sigma/\sigma_{SM} = \mu = -0.4 \pm 0.7(\text{stat.}) \pm 0.8(\text{syst.})$

Search for SM Higgs Boson in H→bb at the LHC

Second MCTP Spring Symposium on Higgs Boson Physics

April 16-20, 2012

Song-Ming Wang

Academia Sinica

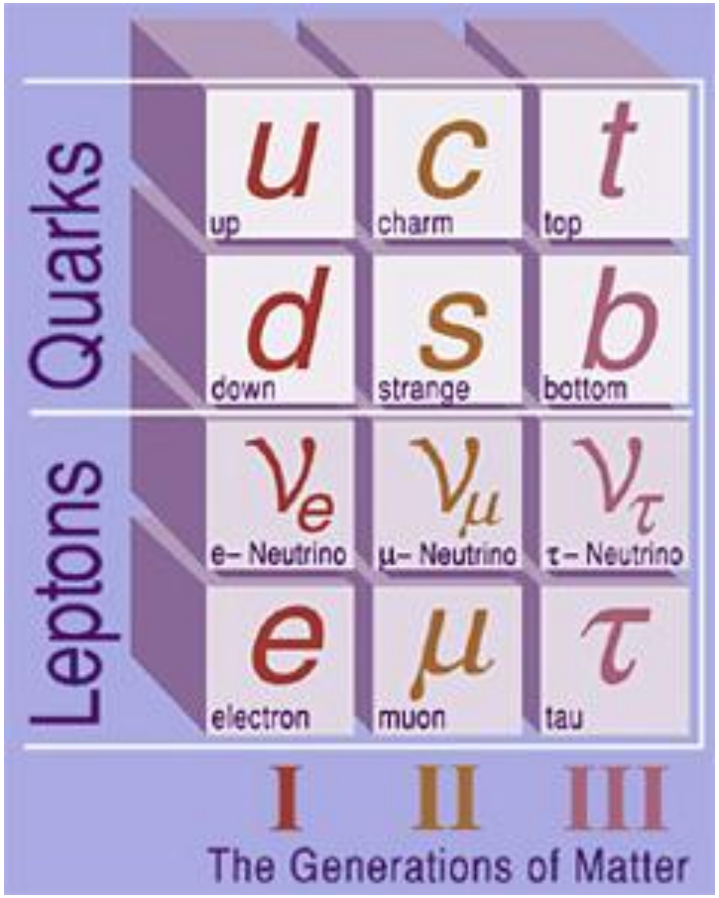
On behalf of the ATLAS and CMS Collaborations

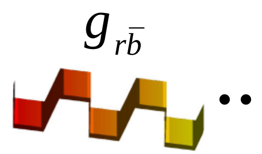
上帝粒子知多少？

任何複雜的變化都是由有限的幾個基本變化組成。

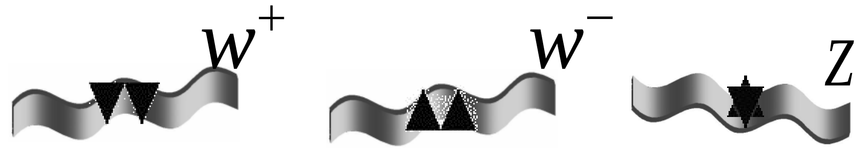
基本變化就是基本粒子狀態的改變。

Reductionism

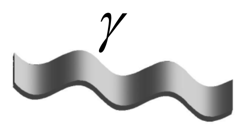




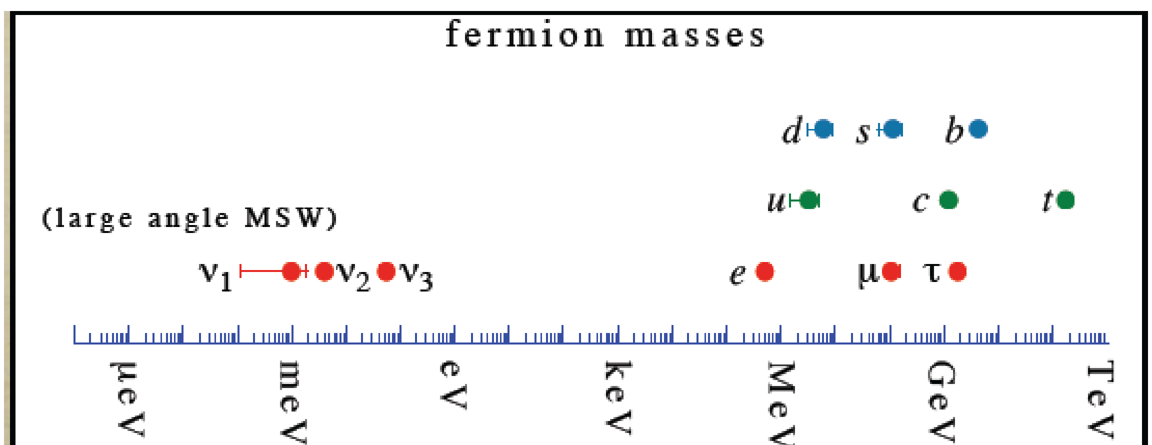
媒介強作用的膠子



媒介弱作用的W及Z粒子



媒介電磁作用的光子

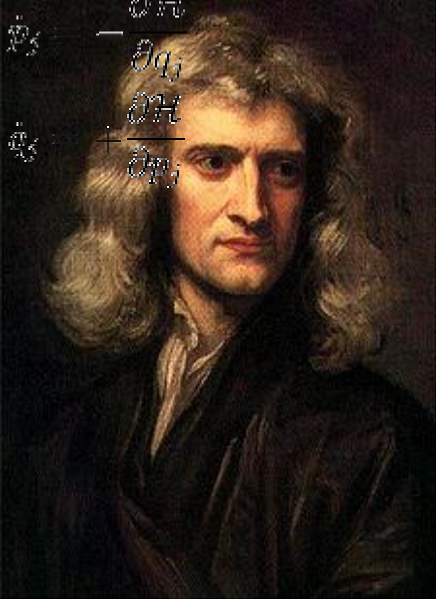


基本變化遵守慣性定律

沒有作用力時，基本粒子的狀態不會改變

＝ 慣性定律

＝ 對稱



牛 頓 1687 年

靜者恆靜，動者恆以等速運動。

靜者恆靜 = 狀態間的對稱

有 “荷” 狀態才能變化。動量就是讓位置變化的 “荷” 。

靜者恆靜因為荷為零。

動者恆以等速運動就是說荷的守恆。

荷與狀態互為表裡，也是物理量之間的對偶。
有狀態間的對稱才有荷的守恆。

$$\dot{p}_j = -\frac{\partial \mathcal{H}}{\partial q_j}$$

$$\dot{q}_j = +\frac{\partial \mathcal{H}}{\partial p_j}$$

有“荷”狀態才能變化。

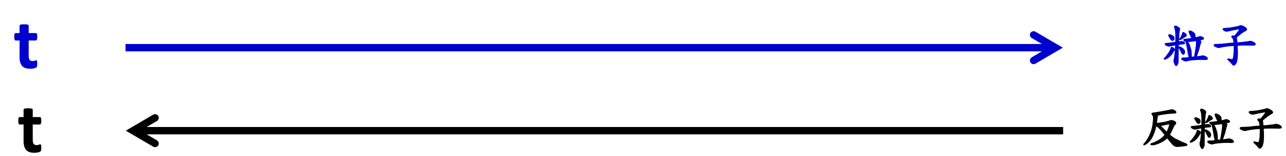
動量就是讓位置變化的“荷”。

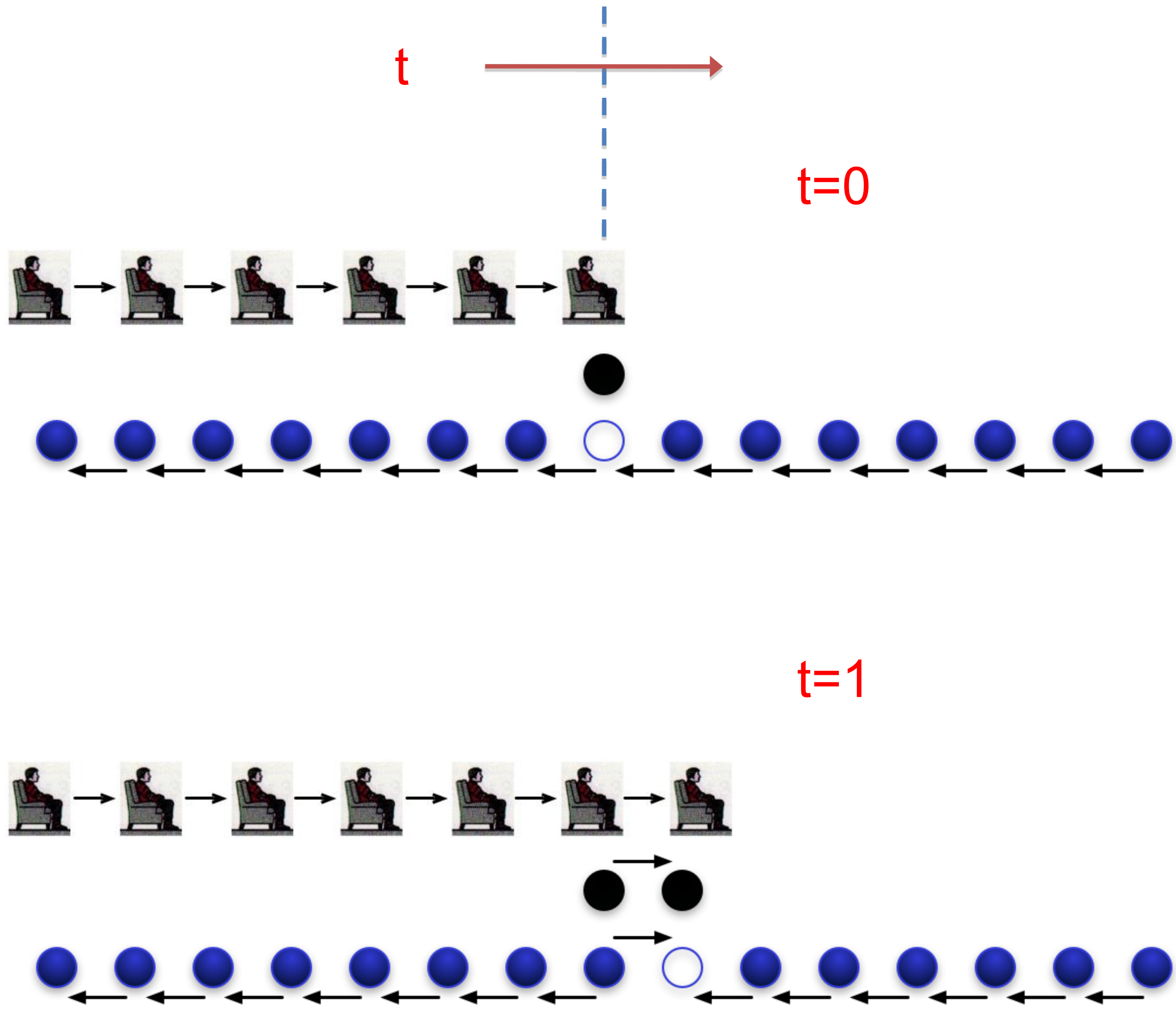
能量就是讓時間變化的“荷”。

因為物質都有質量，也就是帶有讓時間變化的荷，所以時間不停的流動；

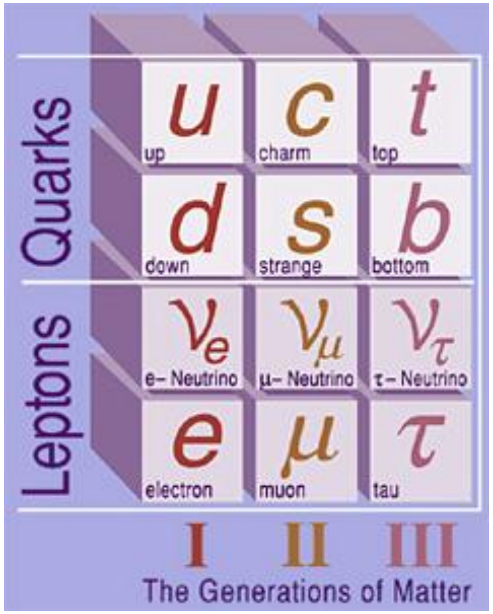
只有氣散而歸於太虛，能量降為零才能讓時間靜止。

只有變為反物質，能量成為負值，才能讓時間倒轉。




t
t=0
t=1

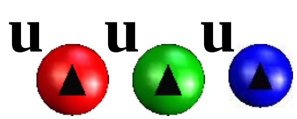
基本粒子狀態的變化

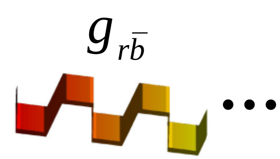


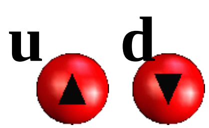
沒有作用力時，基本粒子的狀態不會改變

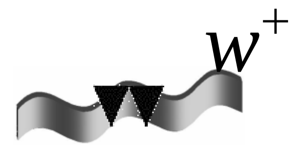
＝ 慣性定律

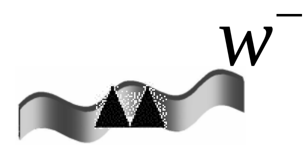
＝ symmetry

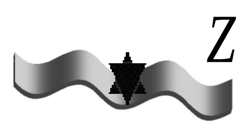
顏色的改變 

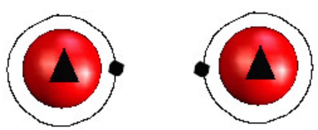
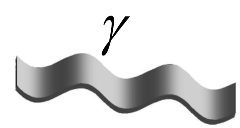
→ 強作用 

上下的改變 

→ 弱作用 

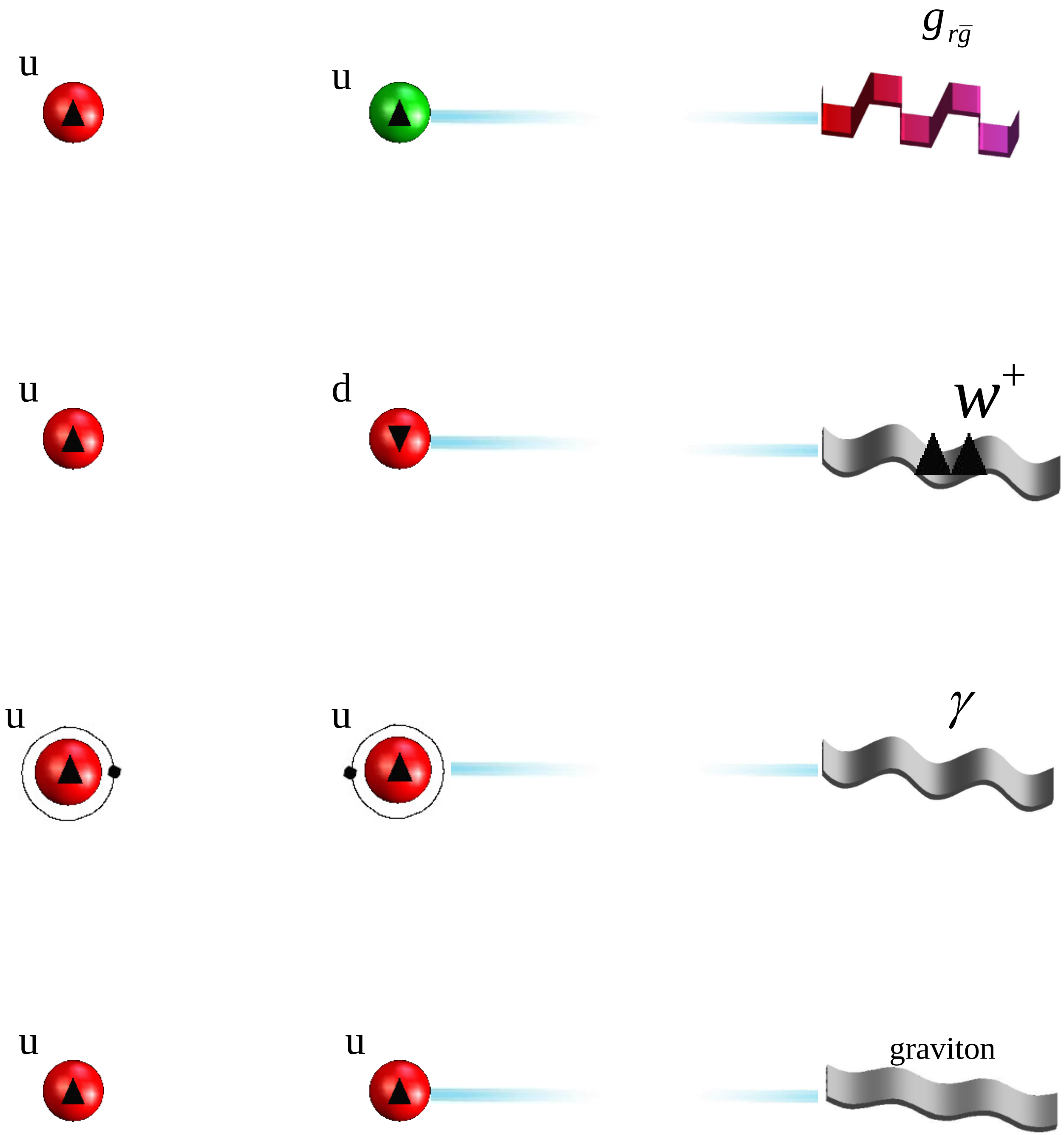




電磁相位的改變 
→ 電磁作用 

動量改變 

→ 重力作用 


u
u
$g_{r\bar{g}}$
u
d
w^{+}
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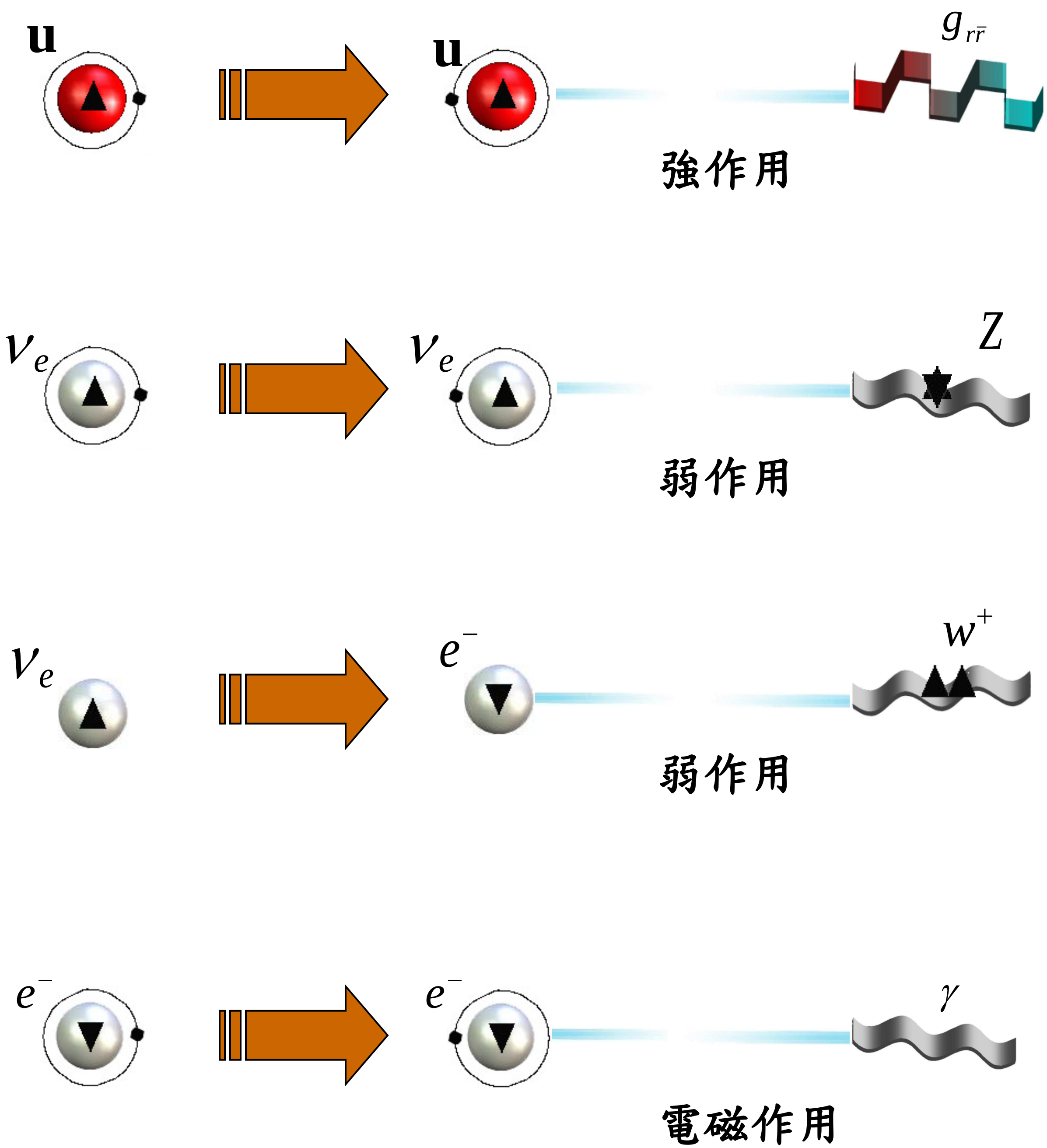
graviton



u
u
$g_{r\bar{r}}$
強作用
ν_e
ν_e
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弱作用
e^-
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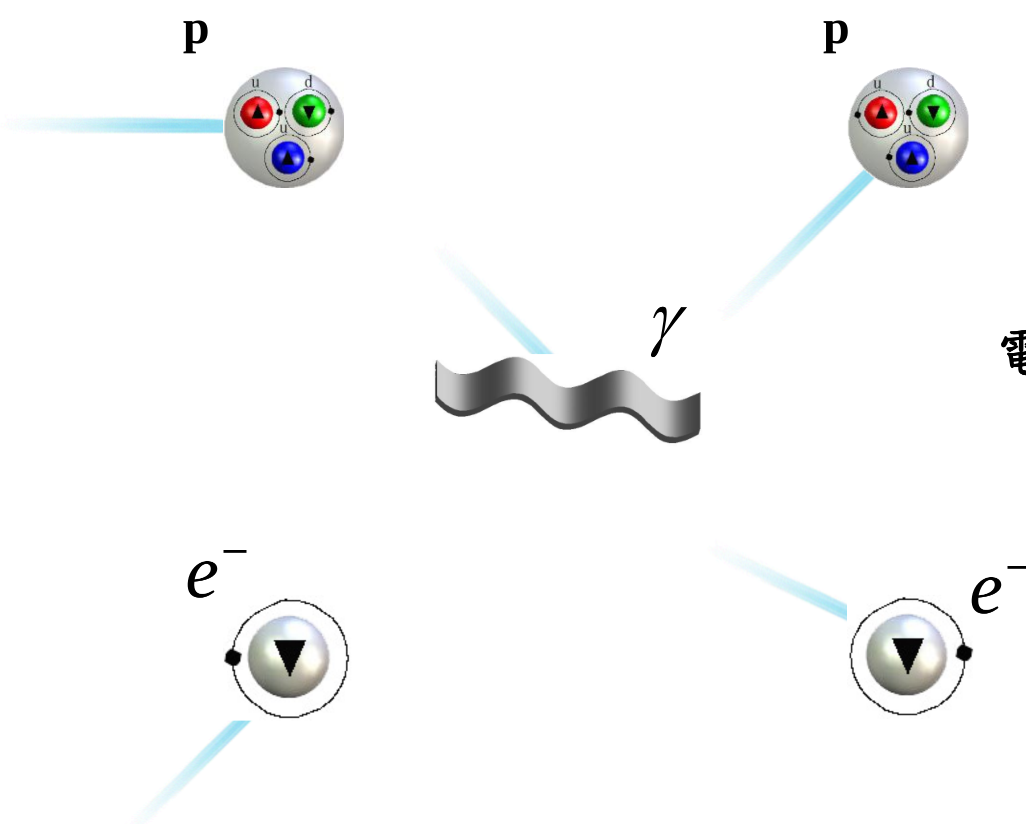
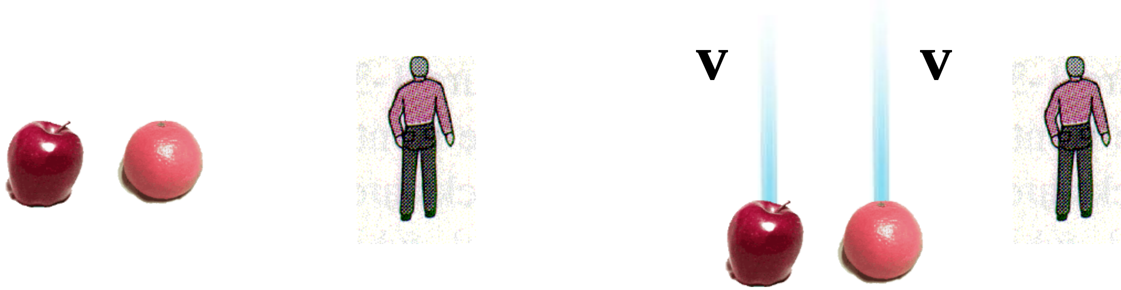
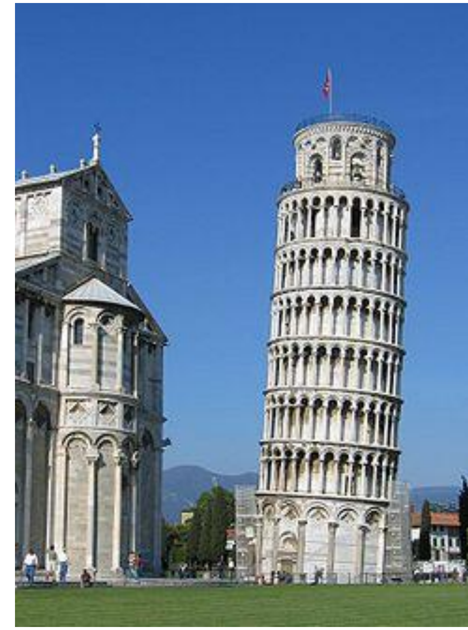
γ
電磁作用



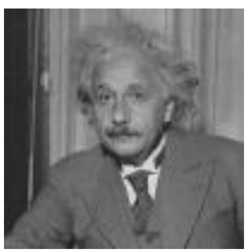
電磁作用

變與不變

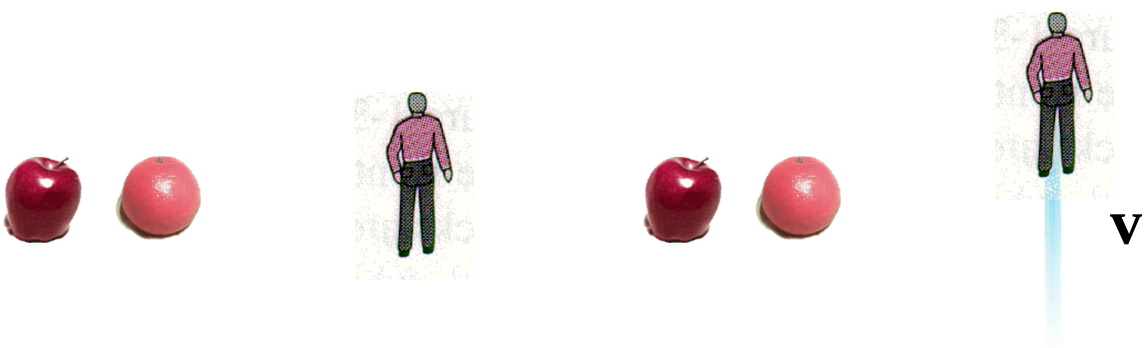




牛頓：有重力場



愛因斯坦：也可能是觀測者自己有向上的加速度



在一點附近

重力作用＝加速座標系

等價原理

太空人在太空中感受不到重力是因為離地球太遠所以重力很小而可以忽略嗎？

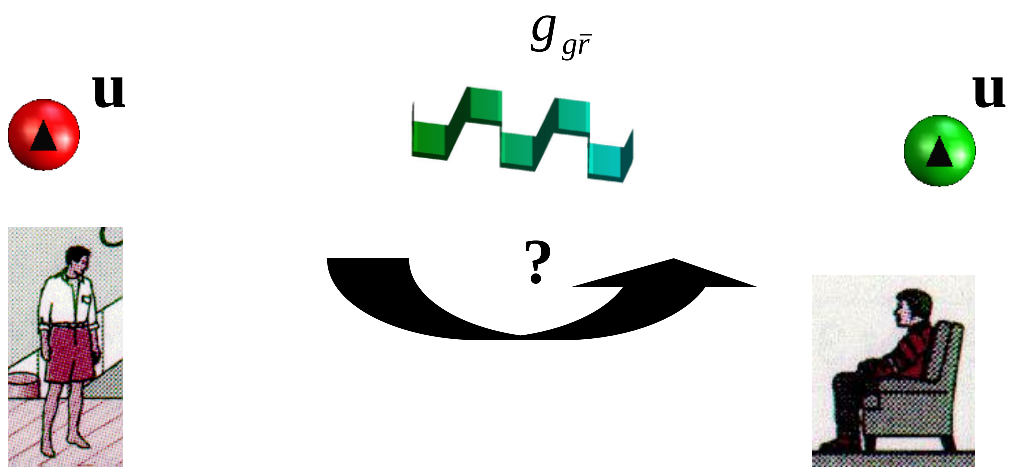
還是因為一直用慣性座標系？

Professor Hawking: "I could have gone on and on"

所有基本粒子狀態的變化均遵守等價原理

在一點附近

狀態的變化＝狀態座標系的選擇



Interaction without breaking symmetry and conservation law. This is called local symmetry.

指紅為綠？

We can have interaction while keeping the symmetry by carefully choosing a coordinate system to describe the states of an elementary particle in a small region around each space-time point.

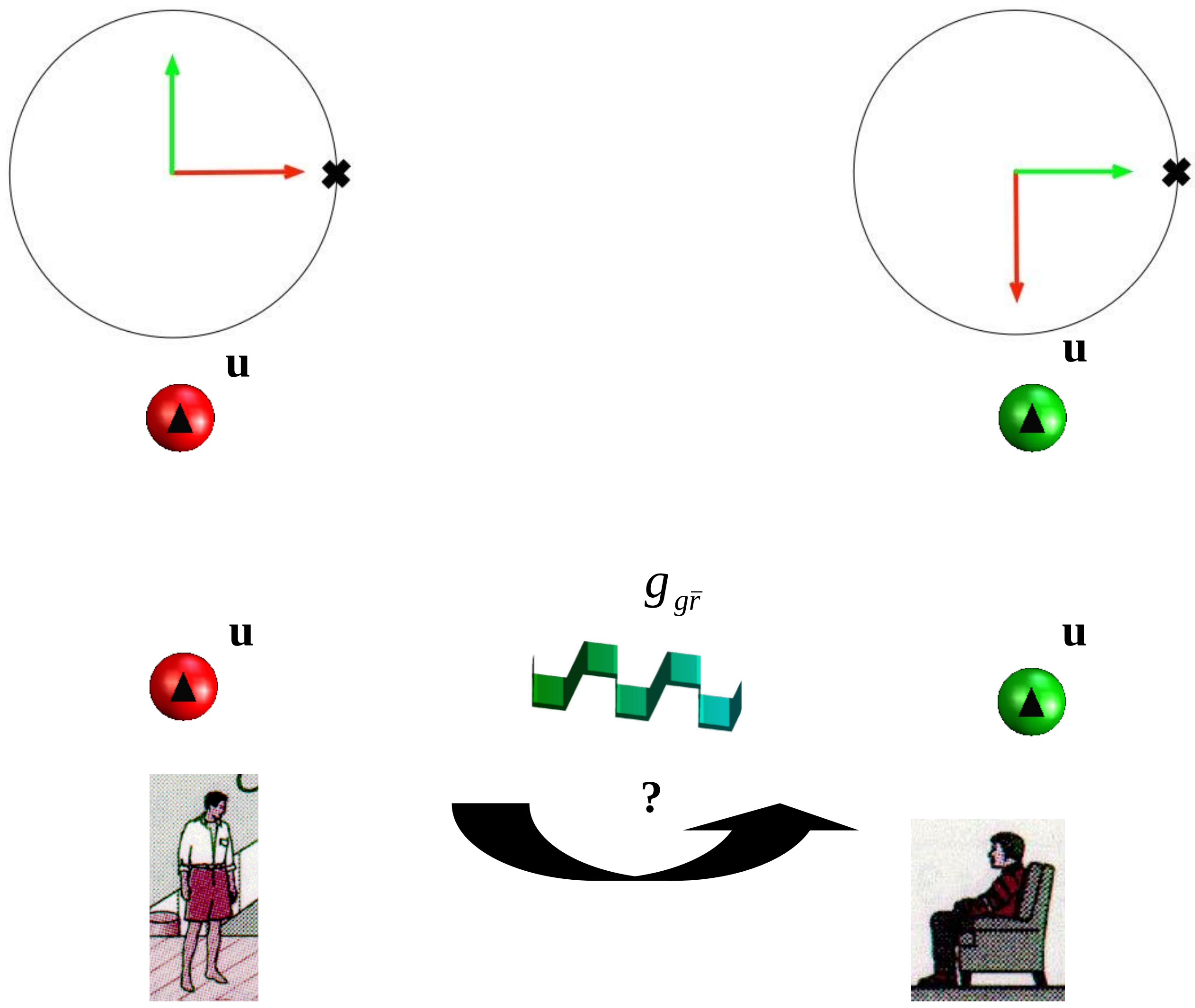
Nature seems to favor this type of interactions.

在一點附近只要適當的選擇座標系，那麼雖然有作用力也感覺不到，狀態不會改變，就如同有對稱性一般 。這就是楊振寧先生1954年提出的具有局部對稱性的楊－密爾斯場論，或稱規範場論。

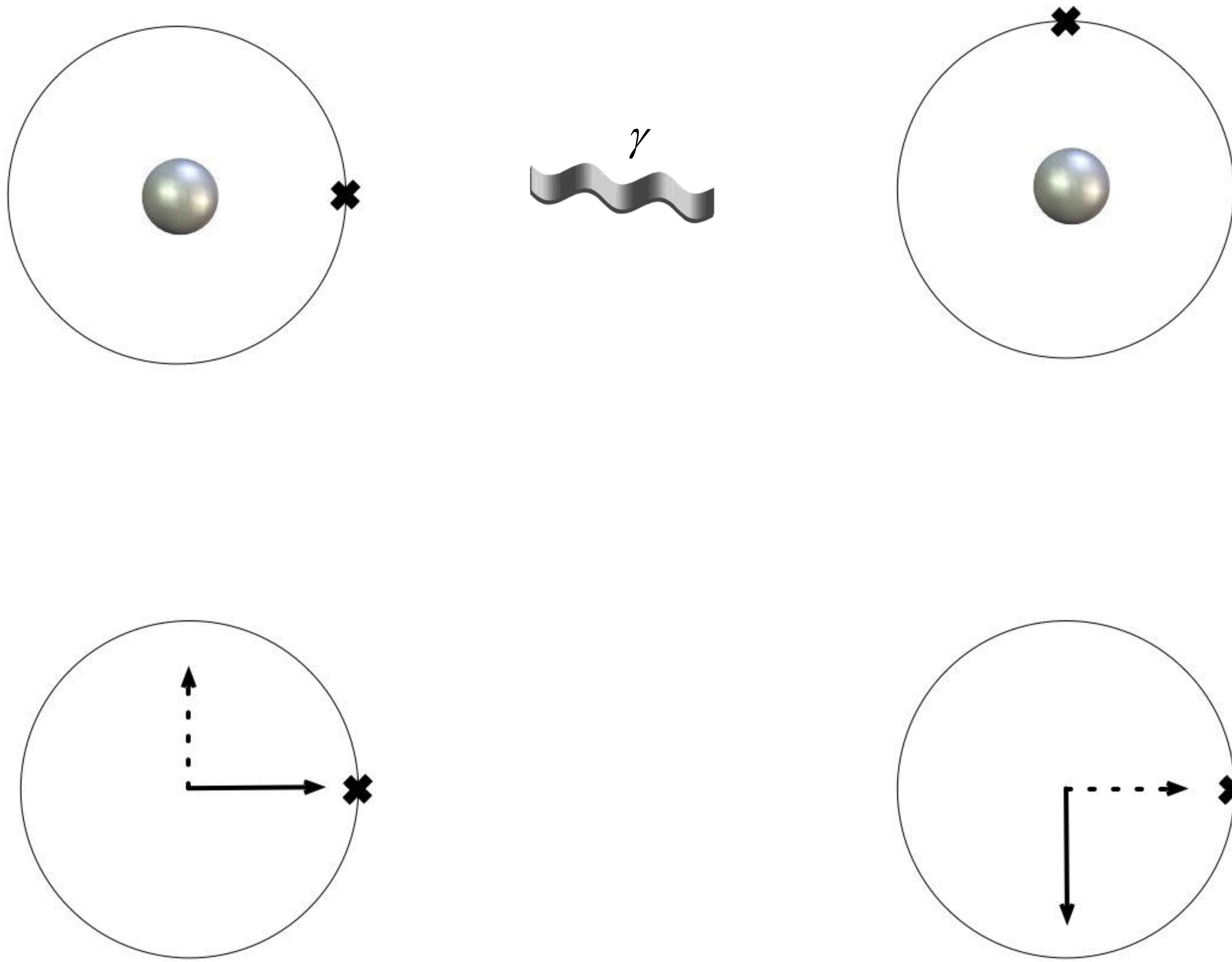
太 極

感覺到外力就知道不是在慣性座標系。隨時隨地隨外力而加速，而改變顏色、上下、電磁相位等狀態就會在一個慣性作標系而感受不到外力了！

局部對稱性存在時，媒介作用的粒子不能有質量。



指紅為綠？

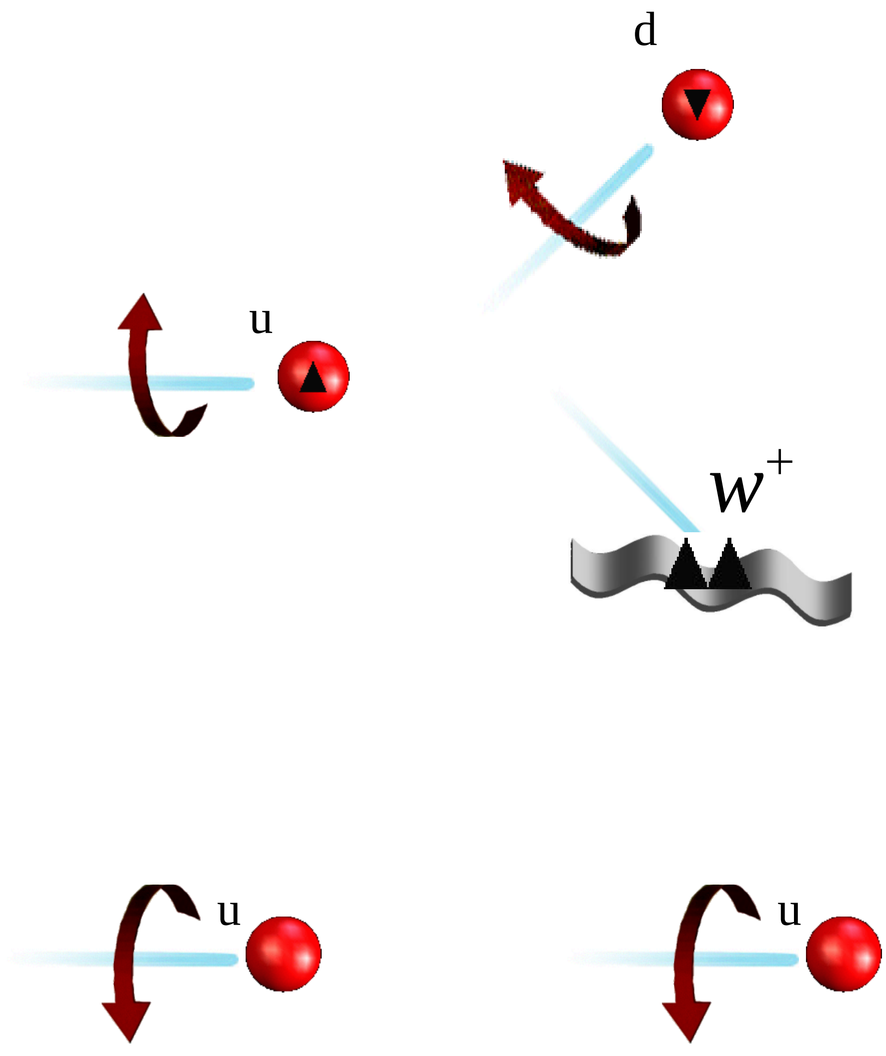

γ

媒介電磁作用的光子沒有質量，媒介強作用膠子沒有質量，但是媒介弱作用的W及Z粒子質量差不多是氫原子的一百倍！和銀原子一樣重。

1956 年楊振寧、李政道發現在弱作用中，左右不對稱。

祇有左旋的基本粒子及右旋的反粒子參與弱作用。

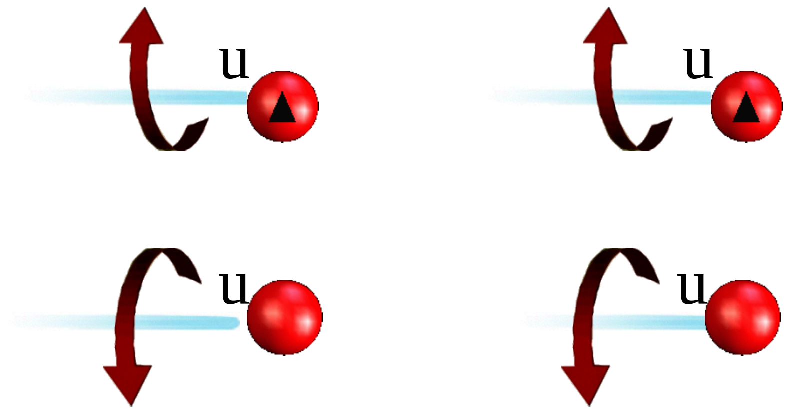
祇有左旋的基本粒子及右旋的反粒子有上、下的狀態。



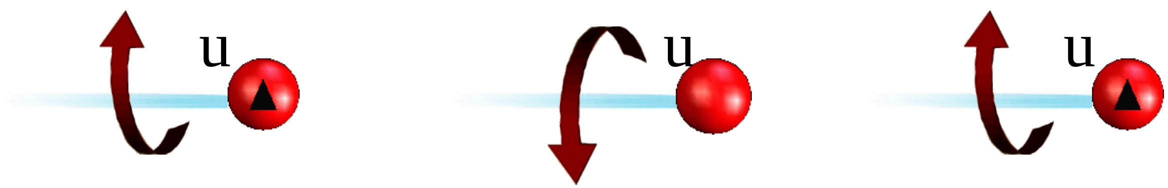
狄拉克 1928

愛因斯坦的相對論成立的話

質量 $m=0$



質量 $m\neq 0$



左旋的粒子有 $\left(\frac{m}{2E}\right)^2$ 的機會變成右旋

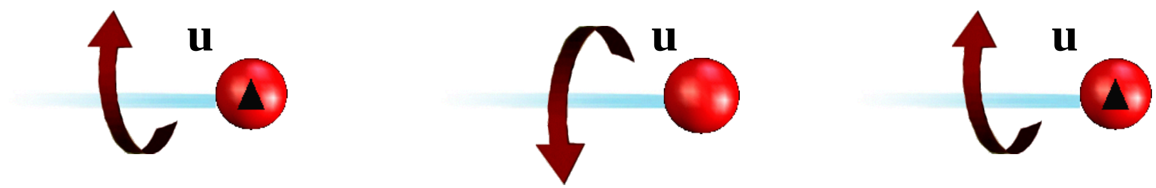
若質量不為零，沒有作用的基本粒子運行時，

不能在”純”的左旋或”純”的右旋的狀態，而是

在左旋與右旋的疊加狀態。

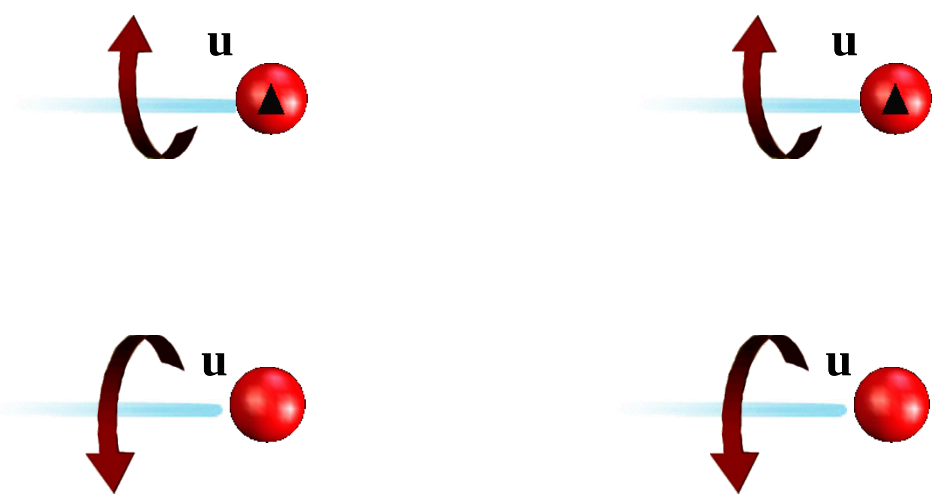
左右不對稱 ⇒ 基本粒子質量為零

否則違反慣性定律。



慣性定律：沒有弱作用時，
上下狀態不能改變，弱作用的荷也不能改變。

質量 m=0



任何複雜的變化都是由有限的幾個基本變化組成。

基本變化就是基本粒子狀態的改變。

基本變化遵循慣性定律及等價原理。

宇宙演化的法則似乎非常簡單，惟一的問題是所有的基本粒子都不能有質量！

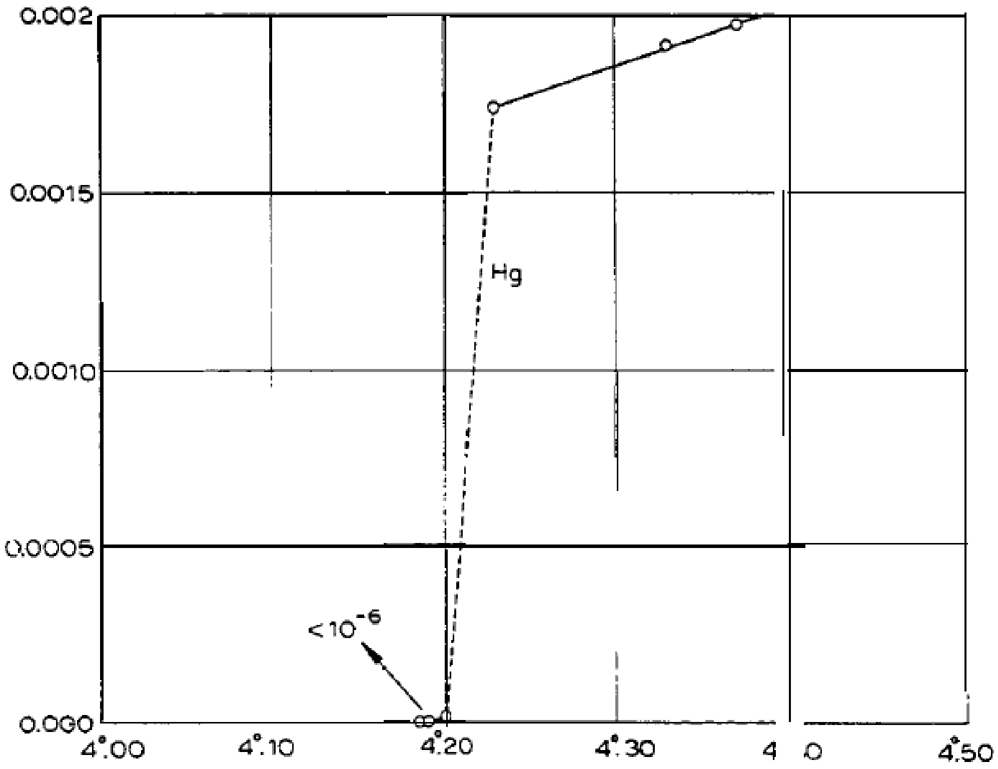
A failure of reductionism?

超 導 與 質 量

Heike Kamerlingh Onnes

The Nobel Prize in Physics 1913

"for his investigations on the properties of matter at low temperatures which led, inter alia, to the production of liquid helium"



Thus the mercury at 4.2°K has entered a new state, which, owing to its particular electrical properties, can be called the state of superconductivity.

Bardeen

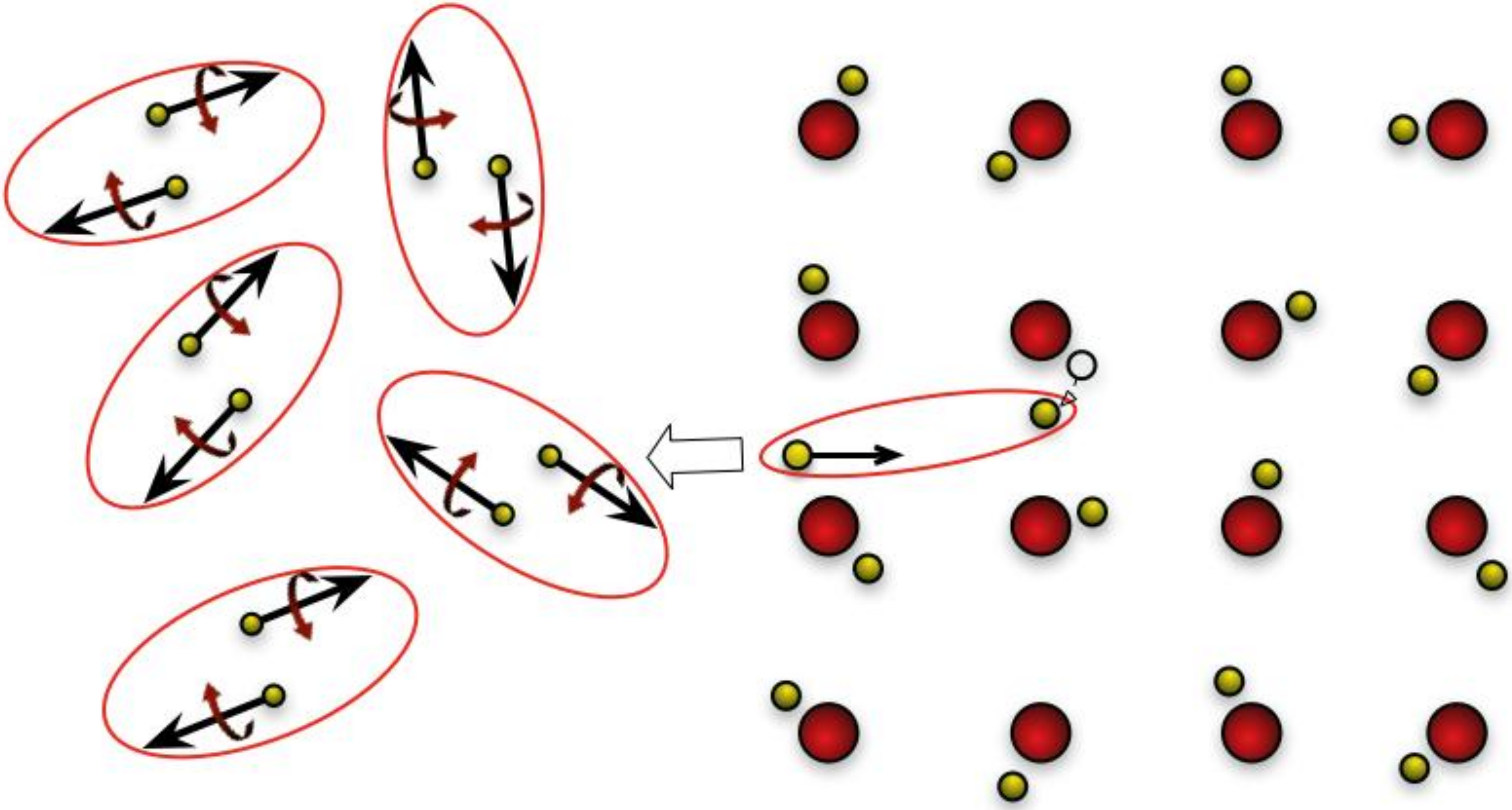
Cooper

Schrieffer

The Nobel Prize in Physics 1972

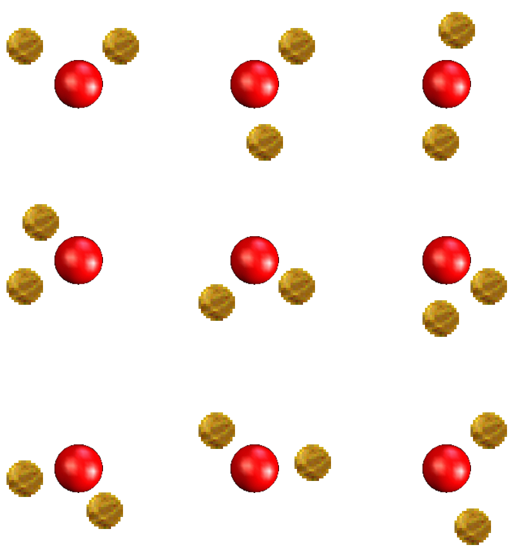
"for their jointly developed theory of superconductivity, usually called the BCS-theory"

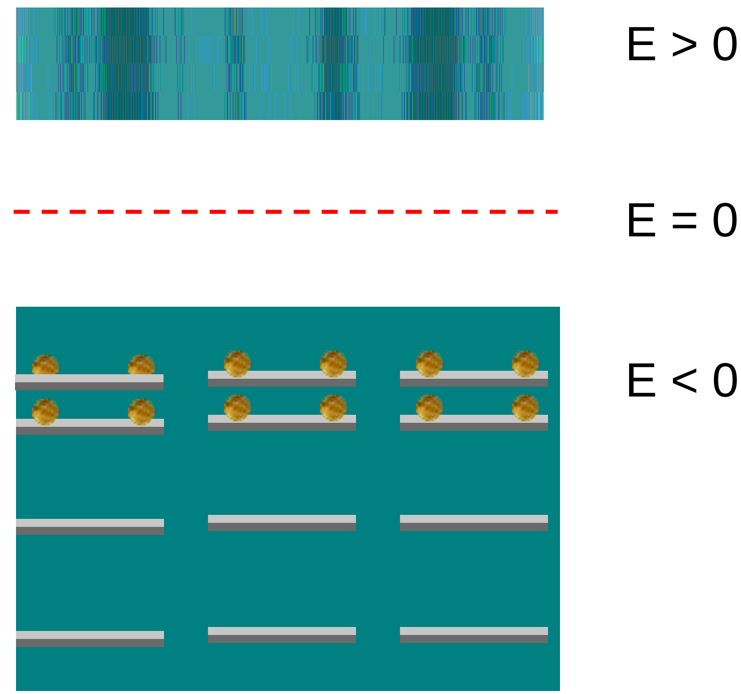
在超導體中有一些電子自發的配對。這些電子對都在同樣的狀態，因此相位也都一樣。

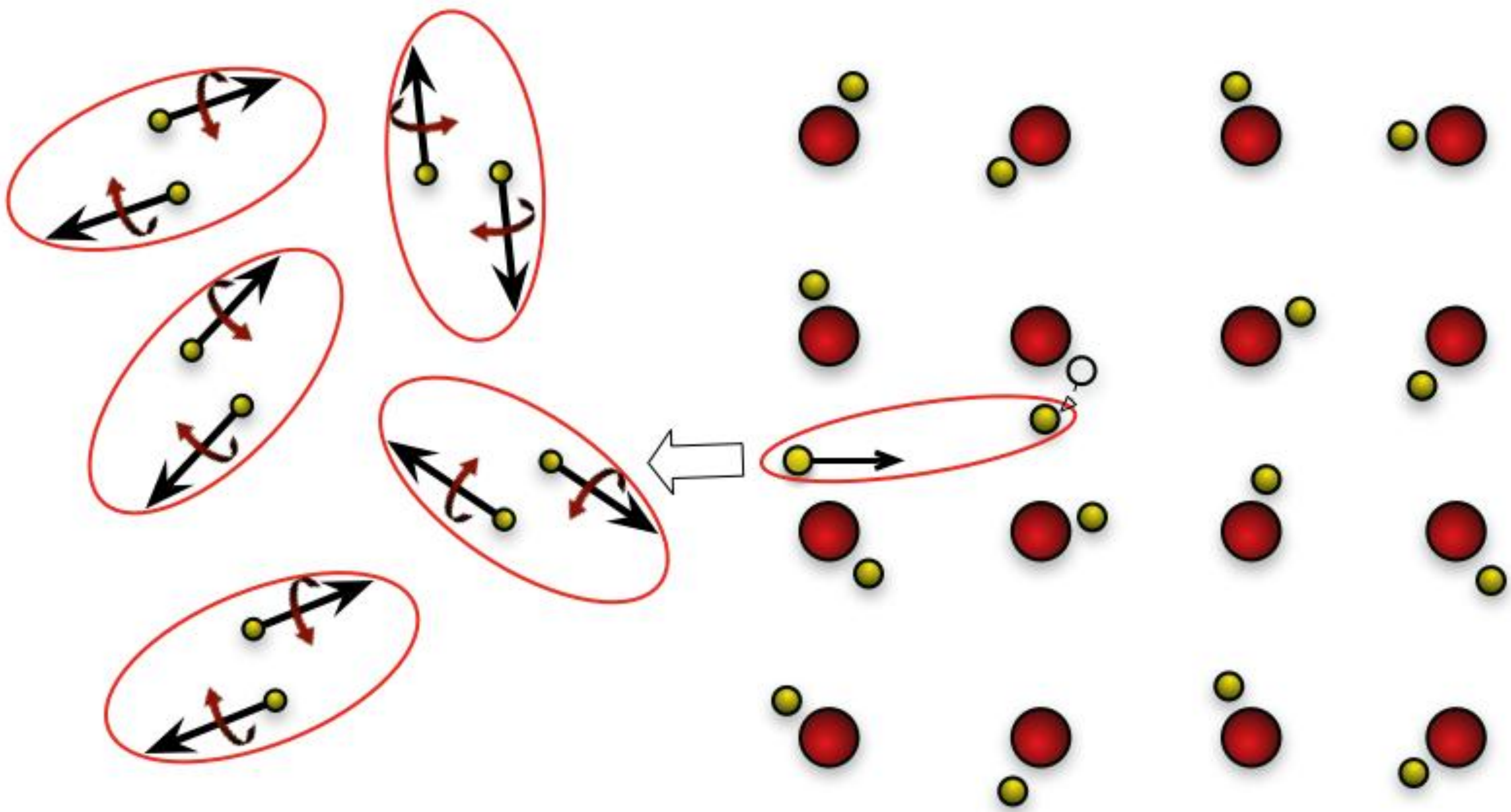


晶體

Rigidity and Zero Resistivity







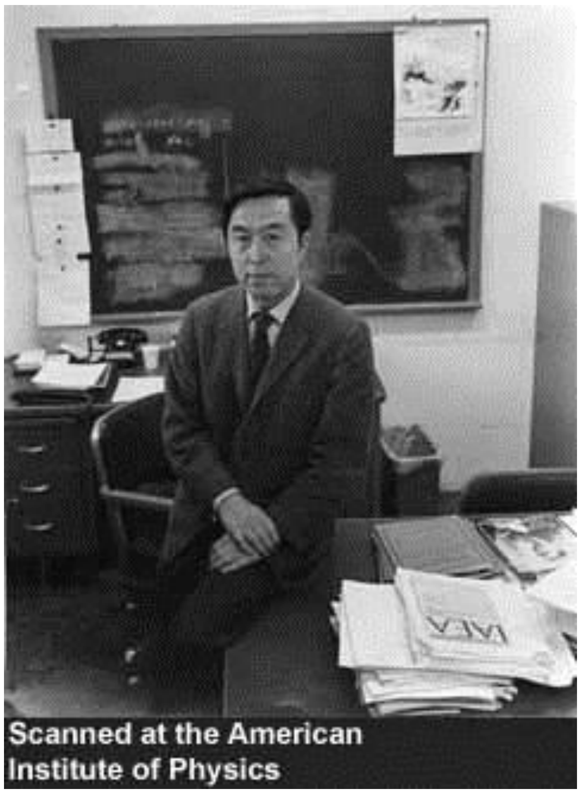
In the presence of a condensate of electron pairs, a propagating electron has a finite amplitude to change into a hole by paring itself with a lattice electron. The new pair is injected into the condensate.

超導體中運行的電子可以變成電洞，電荷看似不守恆！

電磁相位的局部對稱性被破壞了！

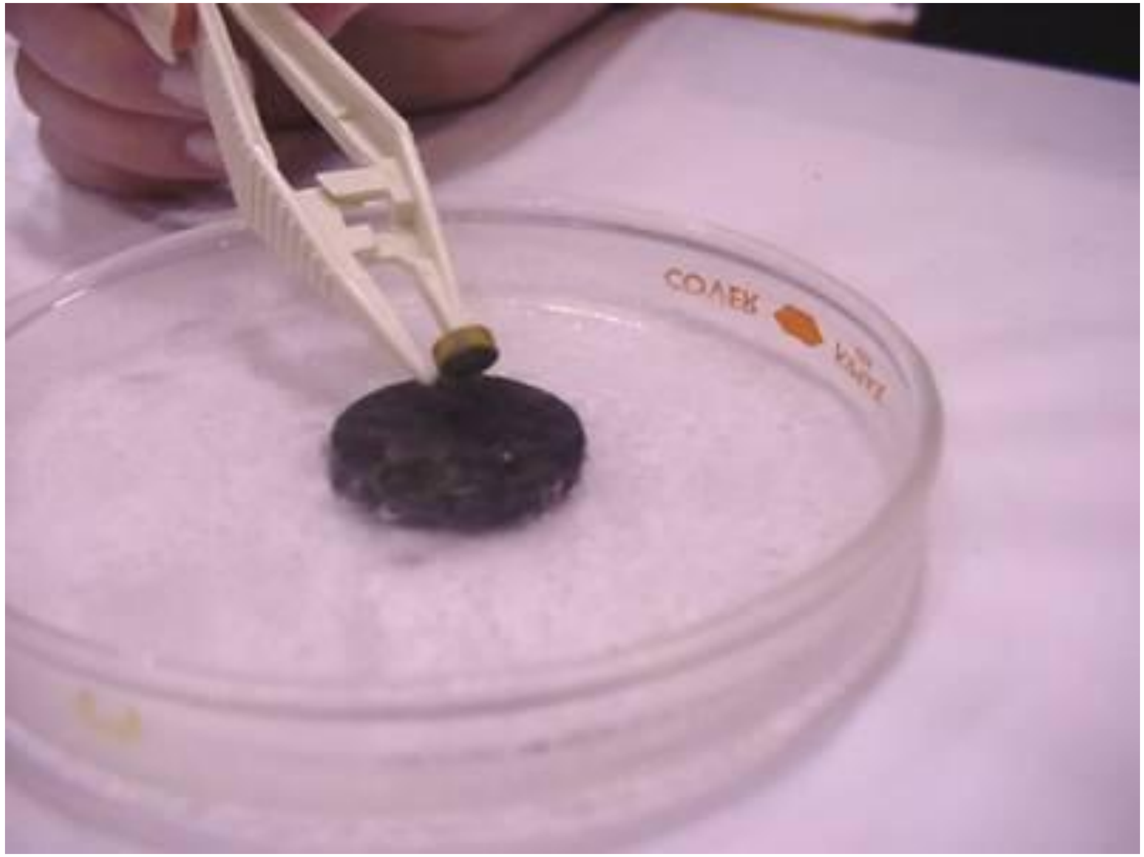
電磁相位局部對稱性被破壞後，媒介電磁作用的光子就可以有質量！

1960　　南部陽一郎 Nambu



超導體中光子的質量不為零

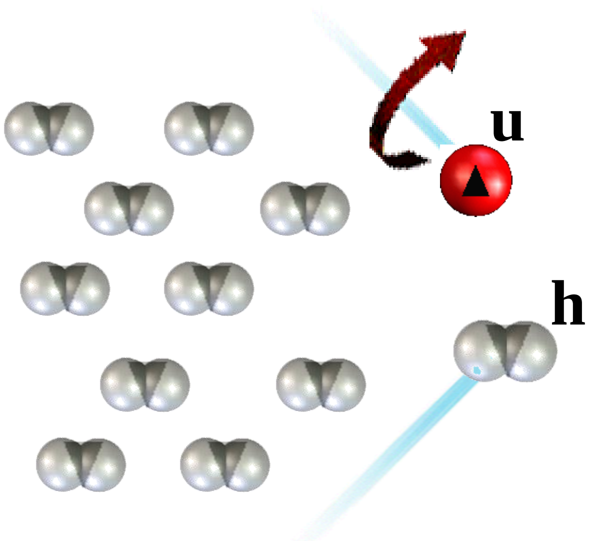
靜電場或靜磁場一進入超導體強度就會以指數率衰減

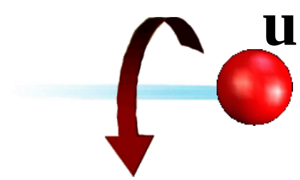


靜磁場無法穿過超導體。外加靜磁場時超導體表面產生電流，電流產生的磁場在超導體內抵消外加的磁場。電流使超導體像一個電磁鐵，排斥產生外場的小磁鐵而使它浮在空中。

如果宇宙對弱作用像一個超導體，則媒介弱作用的W及Z粒子就可以有質量！

也就是說所謂的“真空”其實有許多帶有弱荷的粒子沉積在同一個狀態，像超導體中的電子對！

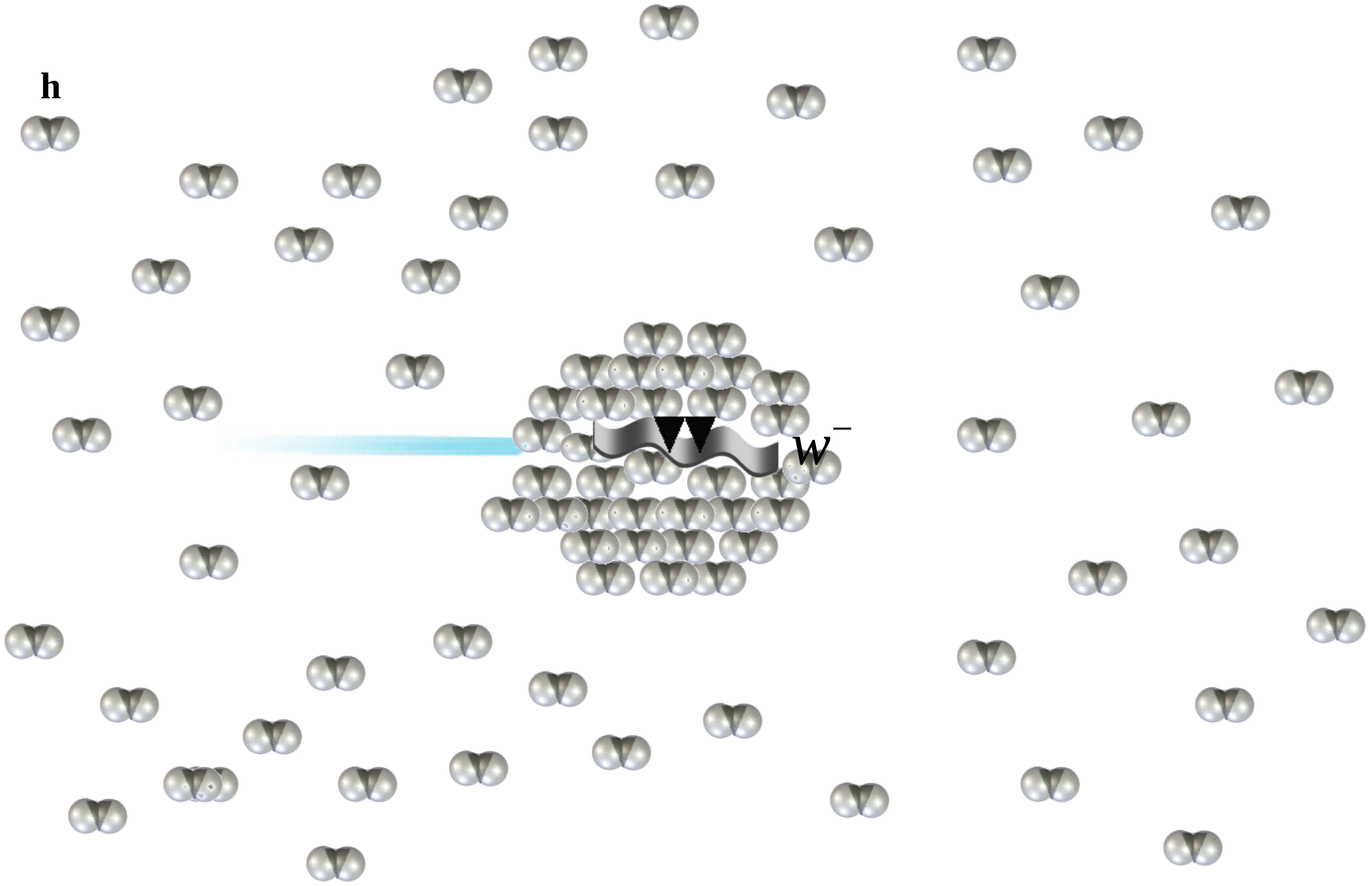




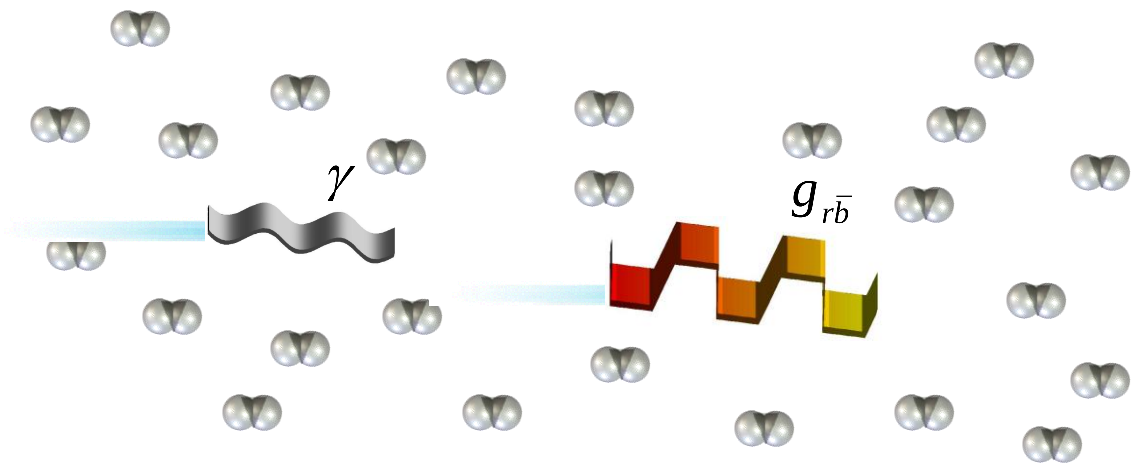
帶弱荷1/2的左手的上夸克運行時可以變成不帶弱荷的右手的夸克！夸克有質量不再成問題！

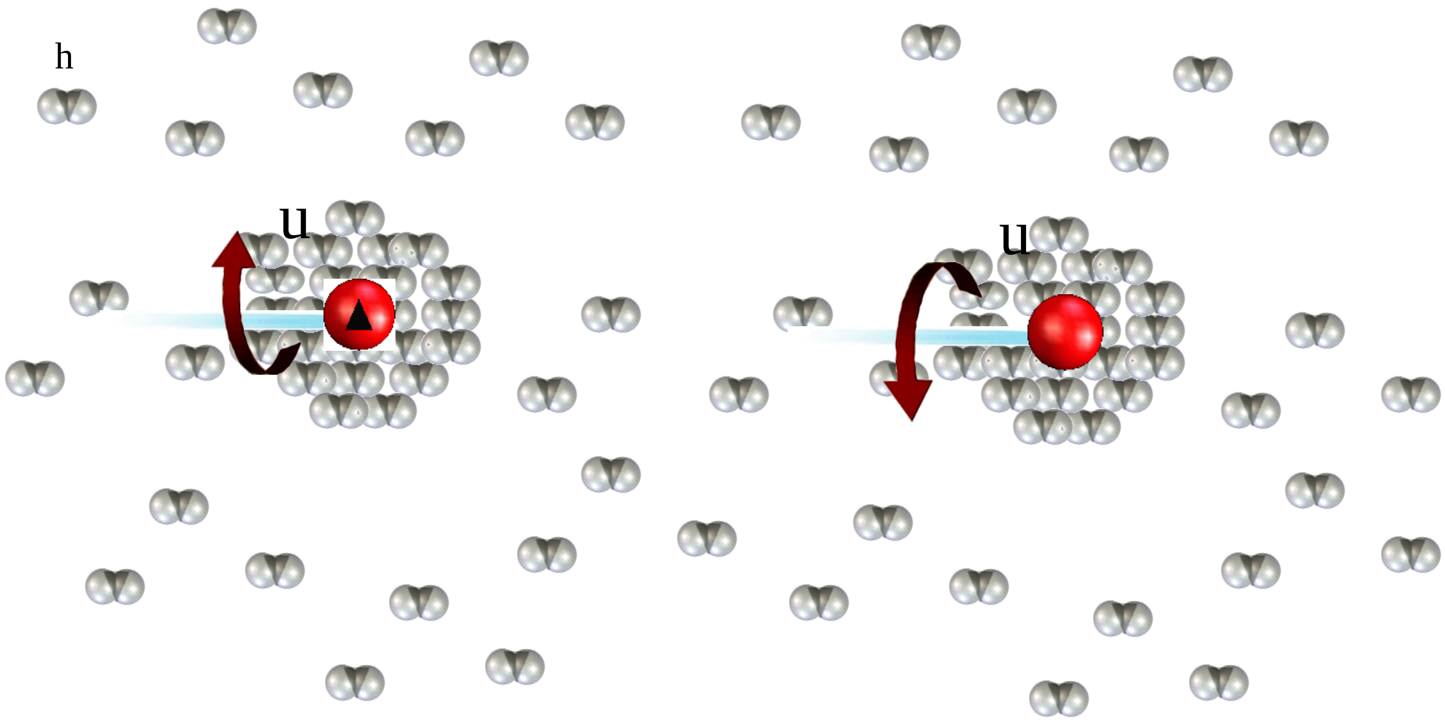
弱作用的荷看似不守恆，
因此上下狀態變換的局部
對稱性被破壞了！W及Z粒
子有質量不再成問題！

$W^{\pm}$及**Z**具有上下的狀態，行進時會與沉澱的希格斯粒子作用，因而變重，無法再以光速前進。



光子與膠子沒有上下的狀態，不會與沉澱的希格斯粒子作用，所以質量仍為零。

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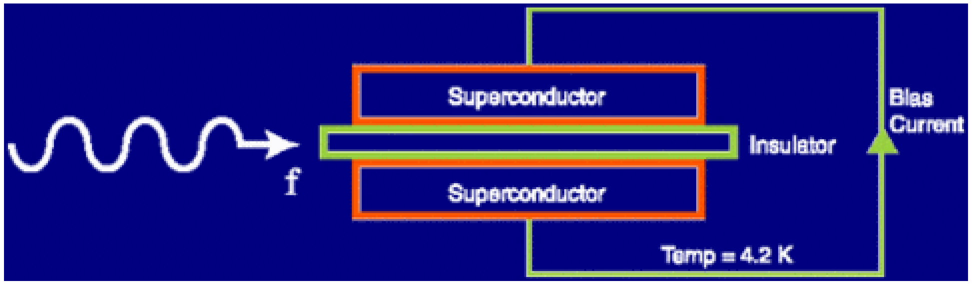


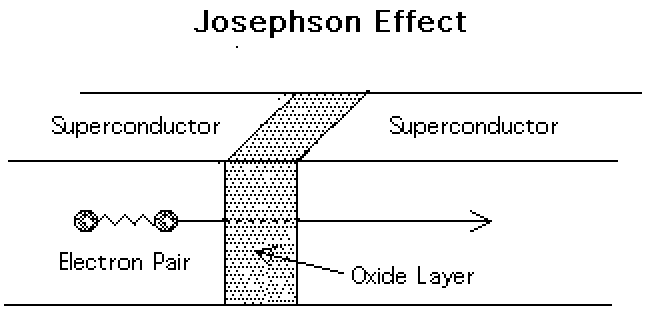
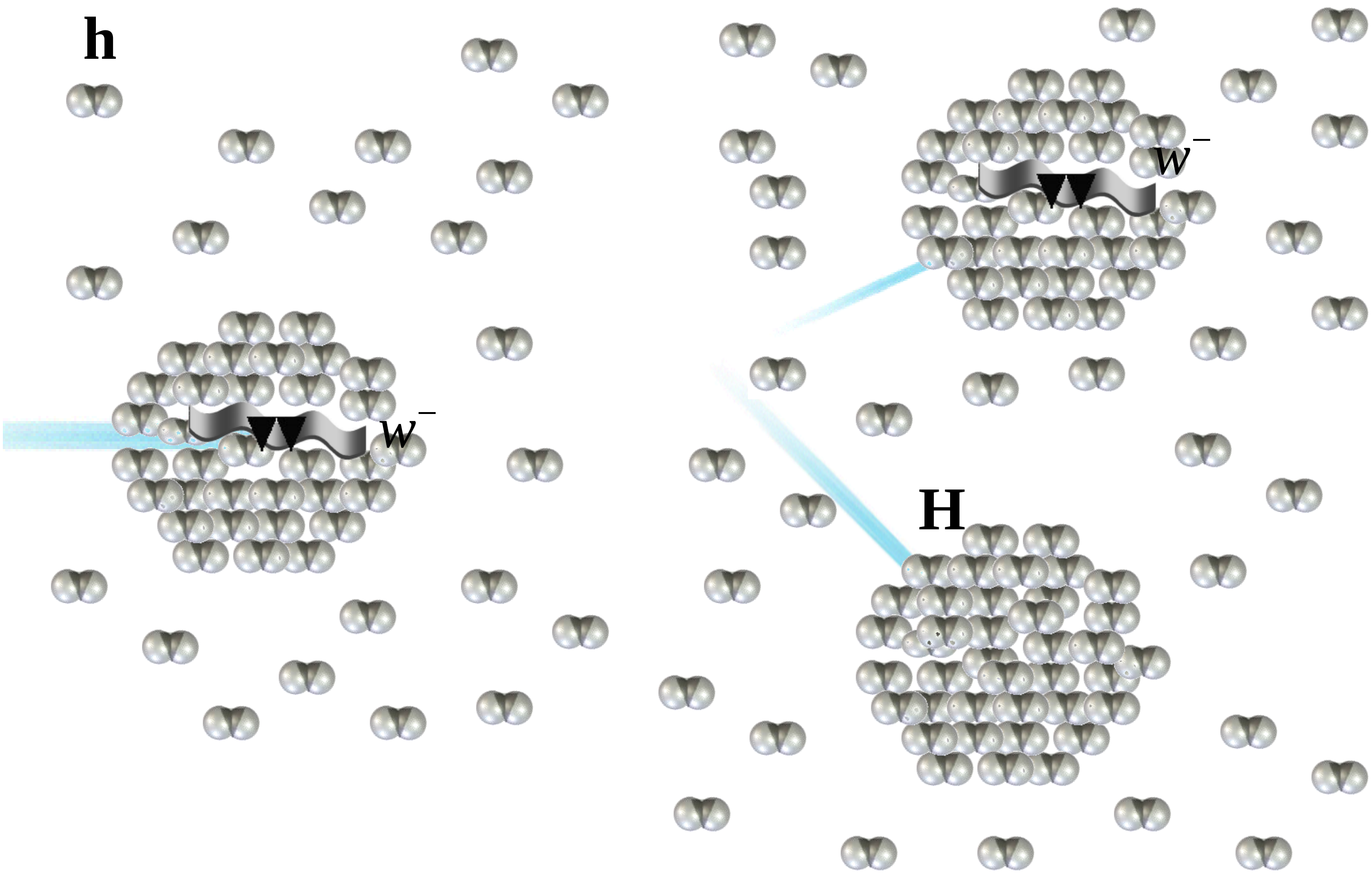


Fig. 13

凝態科學家只要拿兩個超導體中間夾一層薄的絕緣體就可以觀測到電子對的流動。
粒子科學家不知道如何能找到兩個不同的宇宙再夾一個沒有弱作用的小宇宙！

希格斯粒子雖充滿宇宙中，衹有當它的
密度發生變化的時候，才能偵測到。



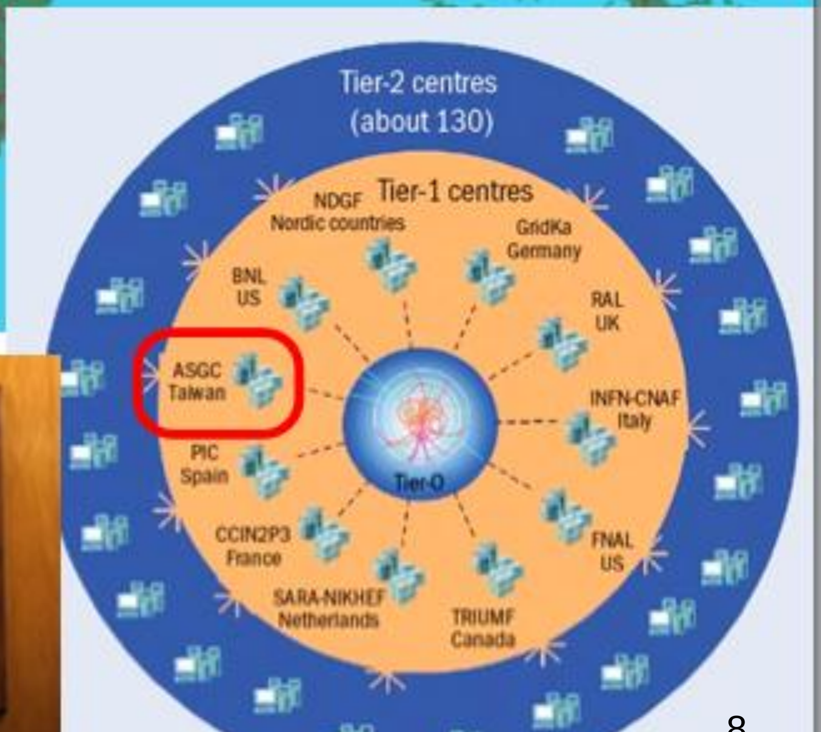
明天的計算

Presenter: Shih-Chang Lee

台灣為全球網格亞洲中心

歐洲粒子物理中心(CERN)為高能物理研究需要，在 1990 年代創立全球資訊網(WWW)，大幅影響了人類生活型態。2000 年初，CERN 決定提升 WWW 功能而創立全球網格(WLCG)，建立跨國合作新平台，以即時收集並分析資訊。中央研究院應 CERN 邀請，於 2005 年成為全球網格唯一的亞洲中心。

ASGC was established to join the international collaboration centered at CERN to build a platform for distributed computing to support e-Science.



5 SEPTEMBER 2008 VOL 321 SCIENCE

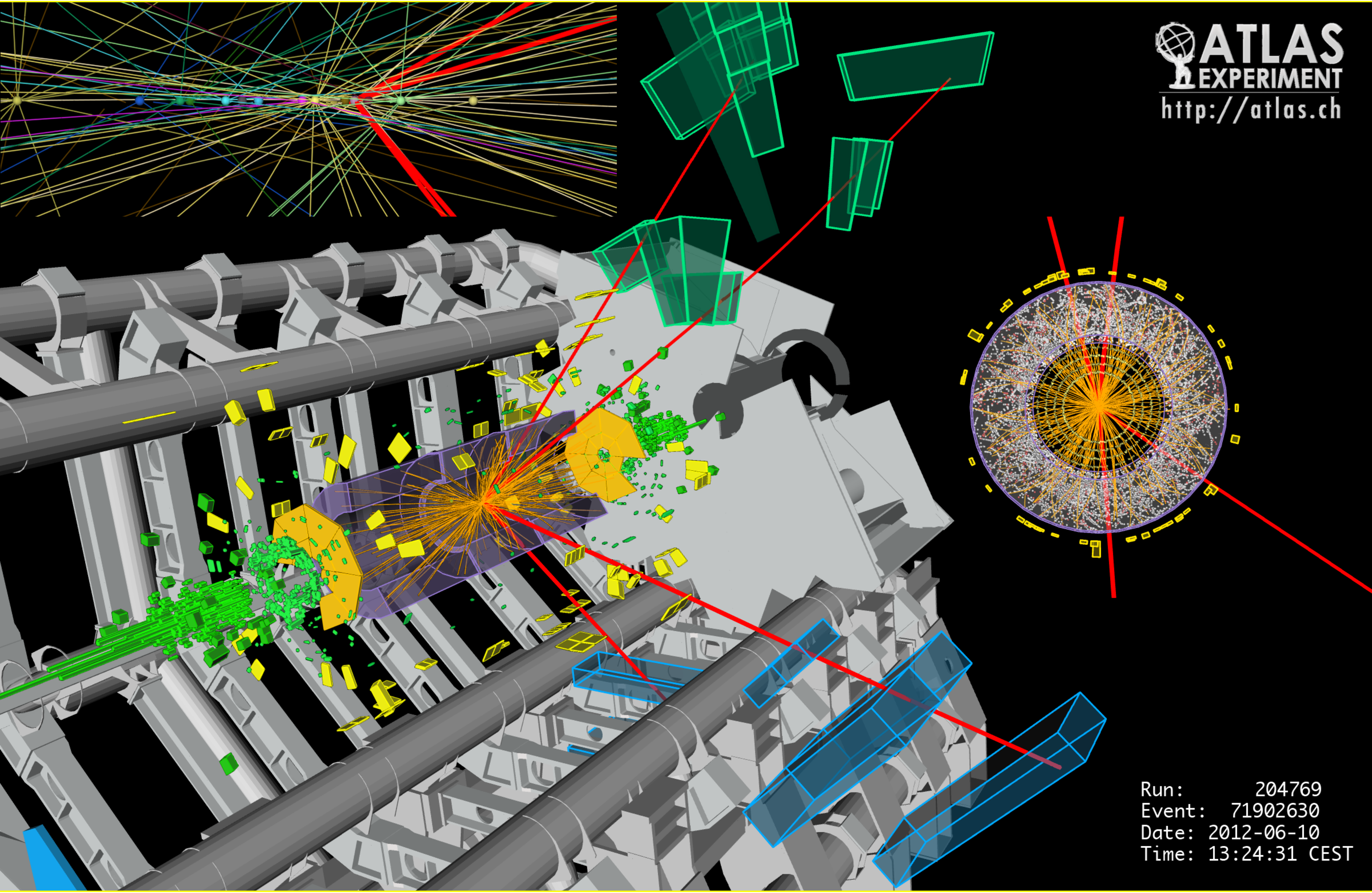
Distributed Computing is used to support some of the most visible science projects such as:

LHC Experiments: Major discovery is expected to be announced this year;

(Observation of a new particle was announced on July 4, 2012. ASGC processed 10% of data used by physicists around the world to search for this new fundamental particle.)

AMS Experiment: Scientists are eagerly waiting for the announcement of the first result on anti-electron spectrum this year.

Nearly 1 Billion channels of 0 and 1 need to be processed into particles every 50ns.



Global Effort → Global Success

Results today only possible due to extraordinary performance of accelerators – experiments – Grid computing

Observation of a new particle consistent with a Higgs Boson (but which one…?)

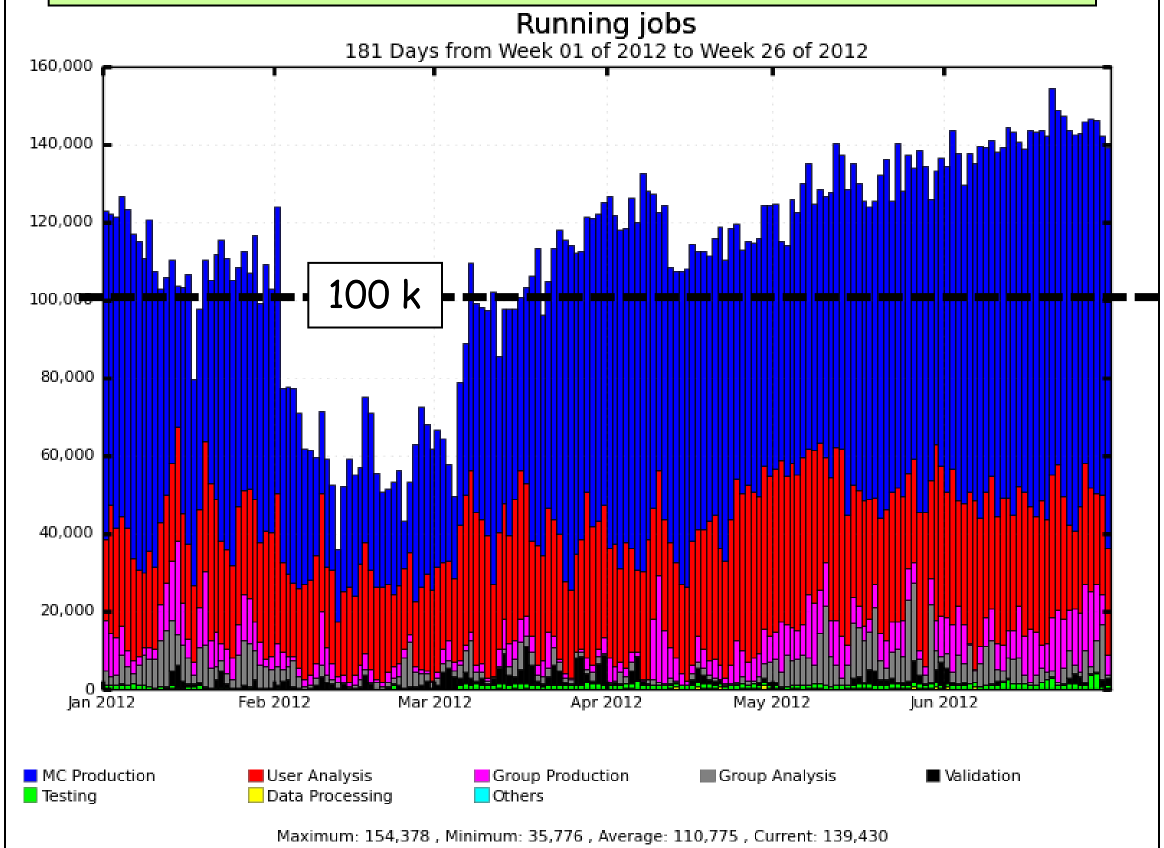
Historic Milestone but only the beginning

Global Implications for the future

R-D Heuer

It would have been impossible to release physics results so quickly without the outstanding performance of the Grid (including the CERN Tier-0)

Number of concurrent ATLAS jobs Jan-July 2012



Includes MC production, user and group analysis at CERN, 10 Tier1-s, ~ 70 Tier-2 federations → > 80 sites

> 1500 distinct ATLAS users do analysis on the GRID

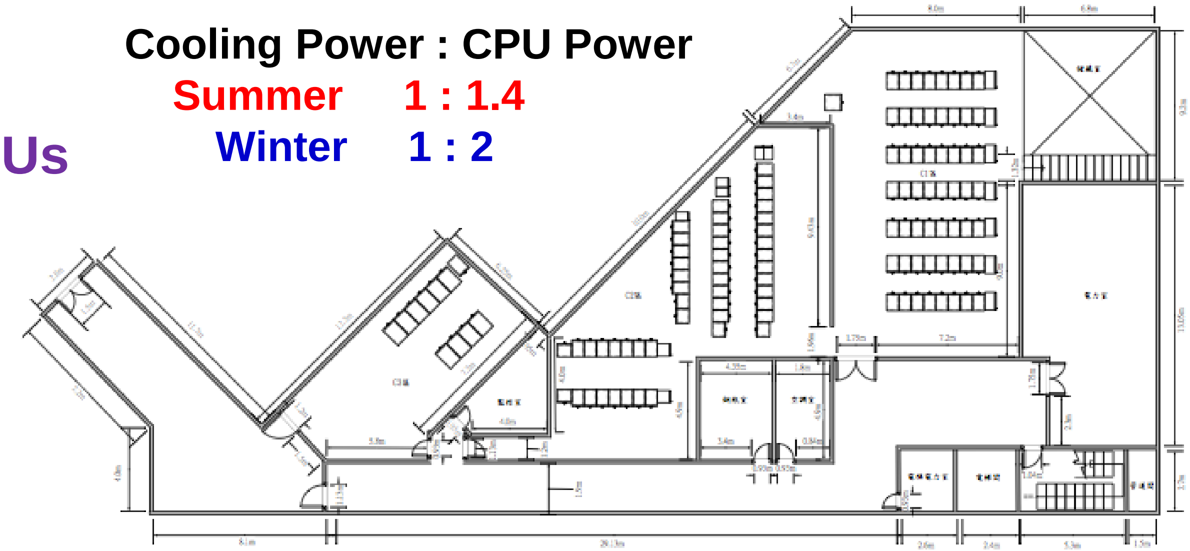
- ❑ Available resources fully used/stressed (beyond pledges in some cases)
- ❑ Massive production of 8 TeV Monte Carlo samples
- ❑ Very effective and flexible Computing Model and Operation team → accommodate high trigger rates and pile-up, intense MC simulation, analysis demands from worldwide users (through e.g. dynamic data placement)

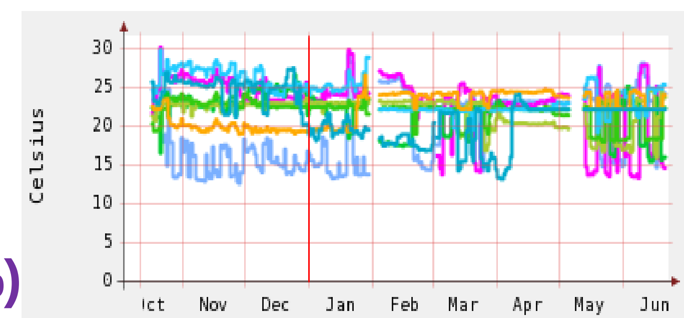
ASGC Computing Center

- **Total Capacity**
  - 2MW, 400 tons AHUs
  - 93 racks
  - ~ 800 m^2
- **Resources**
  - 15,000 CPU Cores
  - 9 PB Disk
  - 5 PB Tape
- **Rack Space Usage (Racks)**
  - AS e-Science: 54.1 (58.4%)
  - ASCC: 8.4 (9.0%)
  - IPAS: 6.0 (6.3%)
  - Free: 24.5 (26.3%)

Cooling Power : CPU Power

Summer	1 : 1.4
Winter	1 : 2





Monitoring the power consumption and temperature of every piece of equipment every 10 seconds.

= Number of

Computing Elements of ASGC

	Purpose	# blades	# core per blade	# core	Location	# total core
HPC	HPC_10G	163 (IBM)	12	1956	C1C4,C1C5,C1E6,C1F4,C1F5	5092
	HPC_DDR	248(HP)	8	1984	C2A10,C2A11,C2A12	
	HPC_QDR	96(HP)	12	1152	C1G3,C1G4,C1G5	
WLCG	ASGC-T1	353(IBM)+92(IBM)=445	8	3448	C1B6,C1B7,C2A8,C2B1,C2B2,C2B3,C2B4,C2B5,C2B6,C2B7	6172
	ASGC-T2	191(IBM)+38(HP)=229	4(IBM), 8(HP)	1068	C1B3,C1B4,C2A1,C2A2,C2A3,C2A4,C2A5,C2A6,C2A7,C2B2,C2B4,C2B5	
	Tape server	9(Quanta),14 (IBM)	4	92	C3A1	
	Core service	197(IBM)+50(IBM)+16(HP)+14(IBM)+20 (Quanta)	4,8,12	1564	C1C4,C2A1,C2A2,C2A4,C2A5,C2A6,C2A7,C2A8,C2B1,C2B2,C2B3,C2B4,C2B5,C2B7,C2D2,C2D4,C2D5,C2E2,C2E3,C2E4	
Testbed	Cloud	138(HP)+13(IBM)+64(DELL)	8,12	1976	C1B1,C1B2,C1B3,C1B4,C1G1,C2B3,C2B7	3904
	batch02	61(IBM)+16(HP)+86(IBM,pending)=163	4,8	1092	C1B4,C1B5,C1B6,C2A2,C2A4,C2A5,C2A7,C2A8,C2B1,C2B2,C2B3,C2B4,C2B5,C2B6,C2B7	
	as-ce01	30 (IBM)	8	240	C2B2,C2B4,C2B5	
	VM	53(IBM)	4	212	C2A1,C2A4,C2A5,C2A9	
	T3	32(HP)	12	384	C1E7	
Storeroom		49(IBM)+40 (Quanta)	4	356		356

15524

Storage Elements of ASGC

3U 16bay
Nexsan

		3TB	2TB	1TB	Total chassis	Raw space (TB)	Total device
CASTOR	C2D C2E		30	19+8	57	2184	1464
DPM (T1&T2)	C3A	10	48		58	3024	1392
ASGC-UI	C2E		1		1	48	24
AMS (t3se02)	C1E	6			6	288	96
HPC_10G	C1B C2A		10		10	320	360
DB,NFS	C2D		1	4	5	144	120
Dynamic pool	C2D C2E	10	22	16+8	56	2448	1440
Total chassis		26	105	55	193		
Total space(TB)		1728	4880	1512		$\boxed{8456}$	
Total device		576	2440	1512			4896

Building a Platform for Distributed Cloud Computing to Support e-Science and Digital Resource on Demand.

Building efficient cloud centers

CE, SE, NE monitoring and control;
Building VM manager

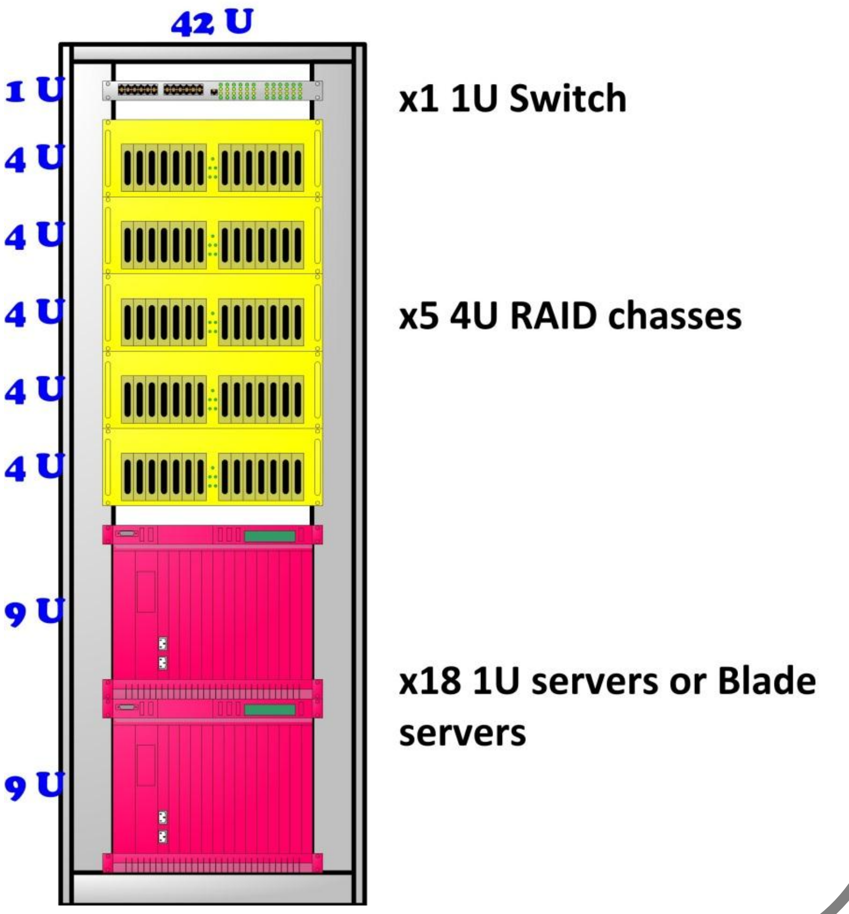
Connecting cloud centers by grid

Collaborating with CERN to develop distributed job and data management
Building cloud interface to grid

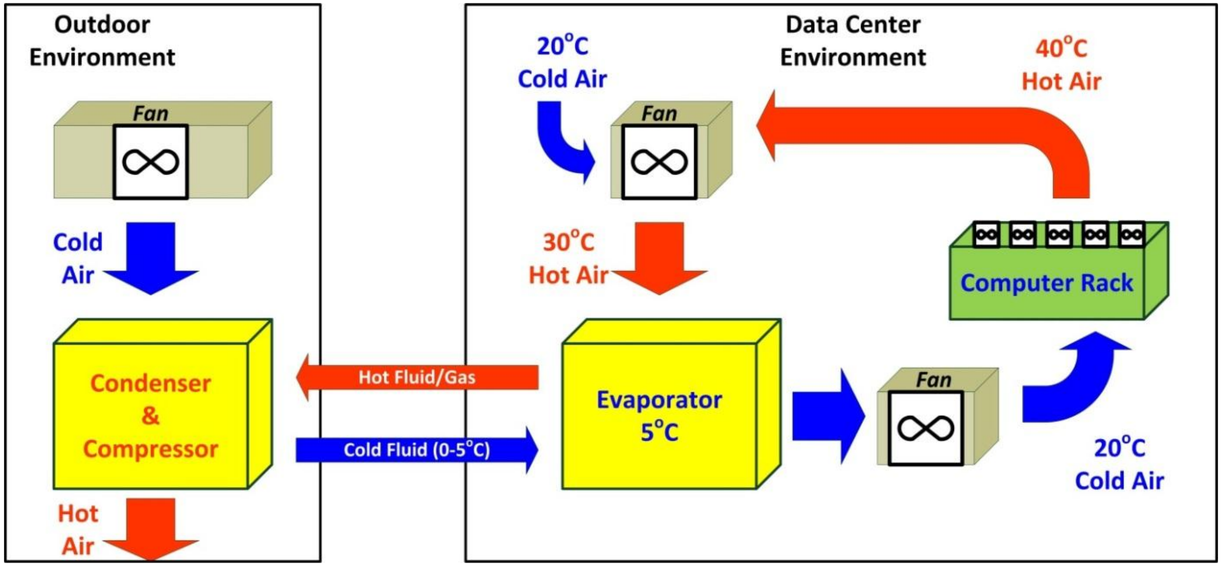
DiCOS (Distributed Cloud Operating System)

Single Rack Data Center

- It consists of
  - 1 Pbyte storage
  - 1000 CPU cores
  - One switch
- Power consumption
  - 10 kW to 15kW
- Easy to expand and rearrange
  - Use as the private cloud in a research group or a company.
  - A basic unit in a data center

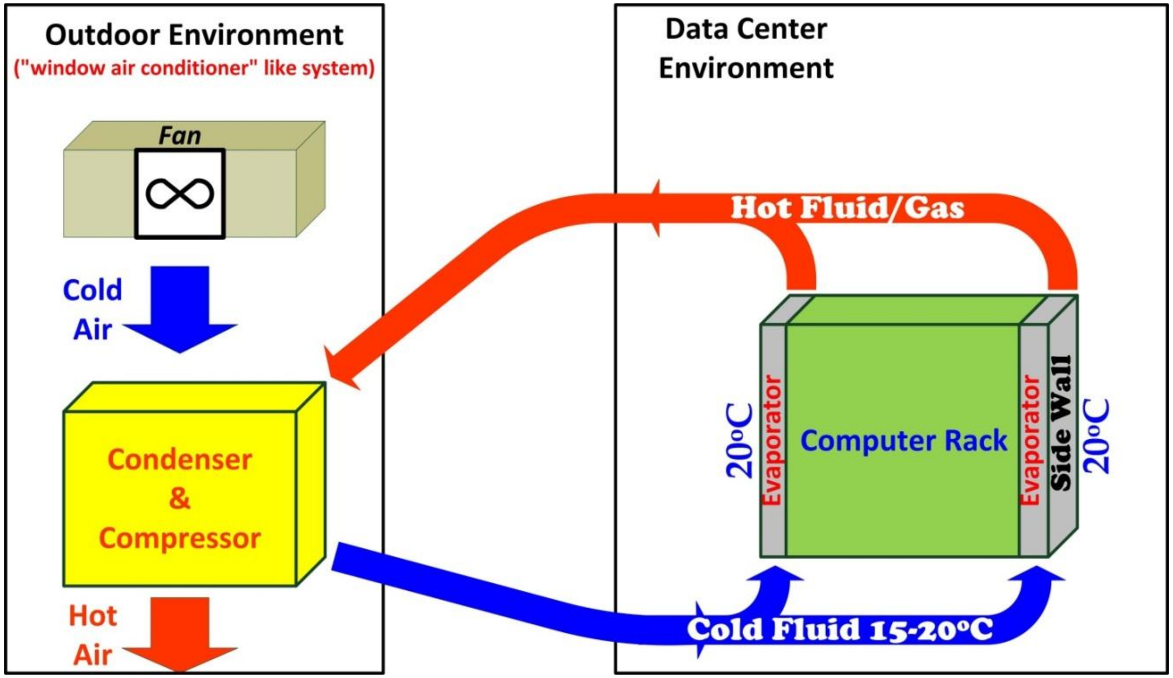


Traditional Cooling Architecture



- Air is used as the heat transfer medium.
- Dedicated air flow design is required.
  - Fans are needed to guided the air flow.
  - Various infrastructures are needed.
- Very noisy (~ 90dB)
- Evaporator temperature is set ~ 0-5°C.
- Typical PUE of a data center = 2 (1:1)
  - ASGC PUE = 1.5 in winter and 1.7 in summer.
- 2MW data center (PUE = 2→1.3)
  - Save 2M NTD per month
  - Save 320 tons CO_2 per month

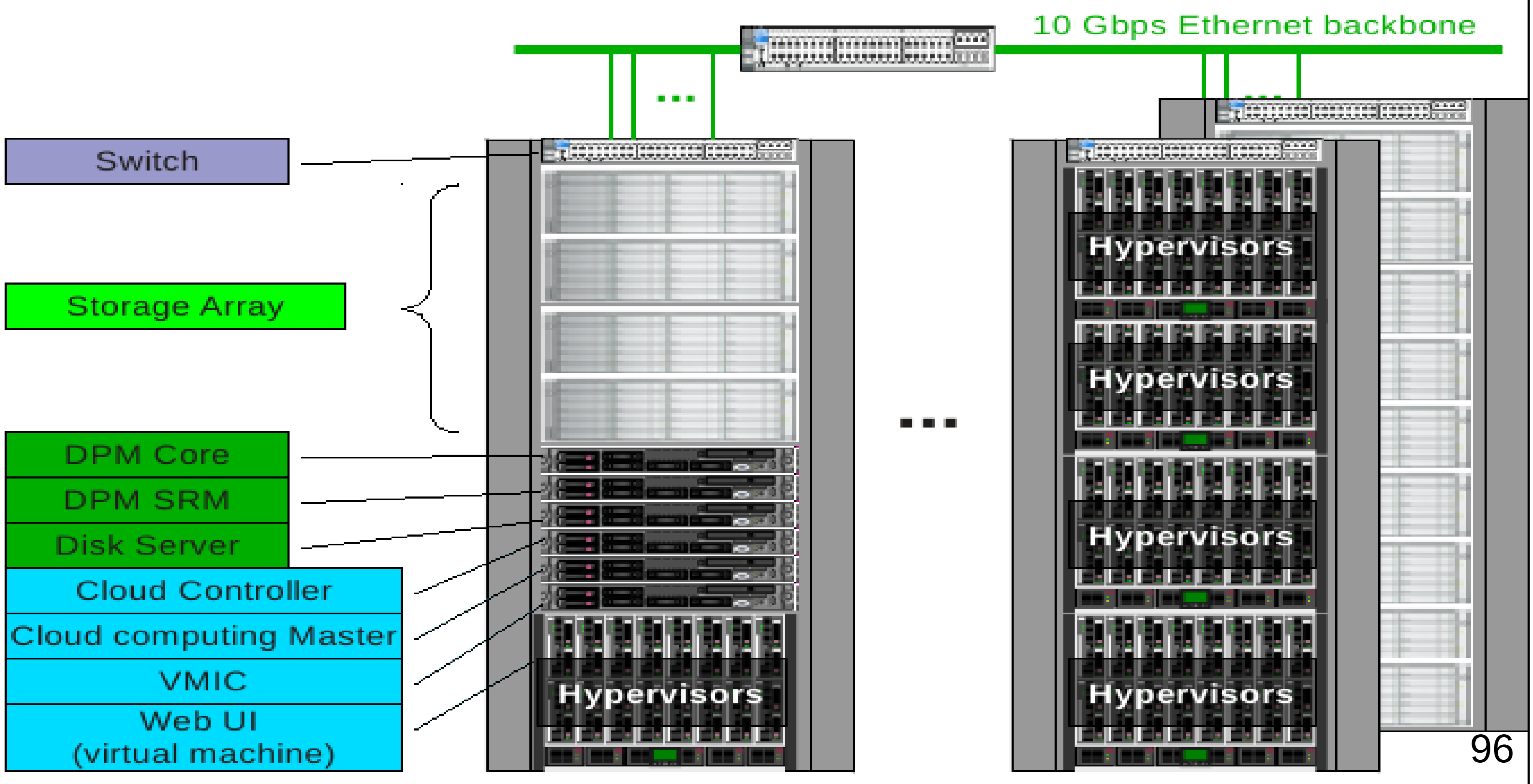
New Cooling Architecture



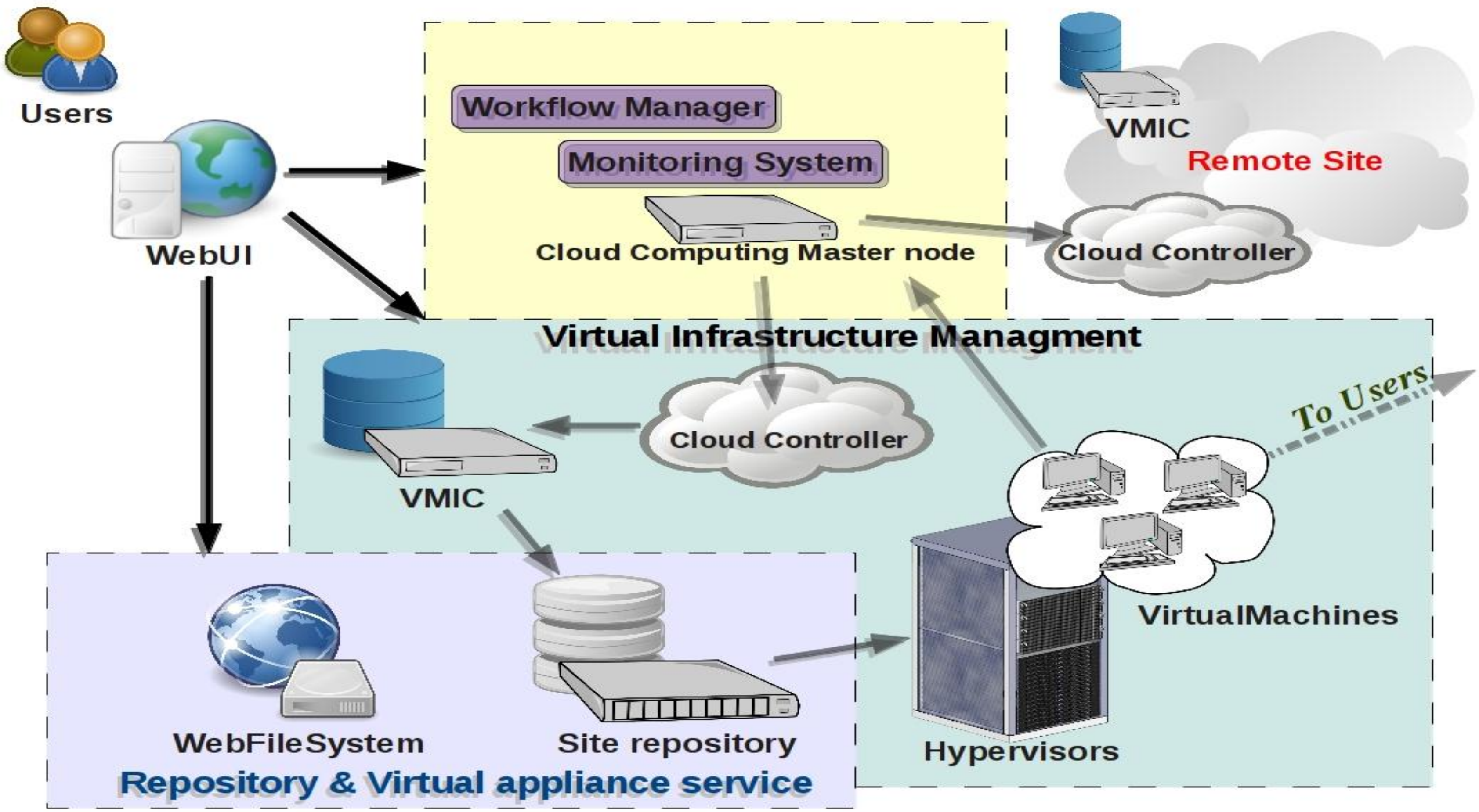
- **Conductional cooling from inner parts to rack sidewalls.**
- **Use rack sidewalls as evaporators.**
- **Flow refrigerant through it.**

Scalable Architecture

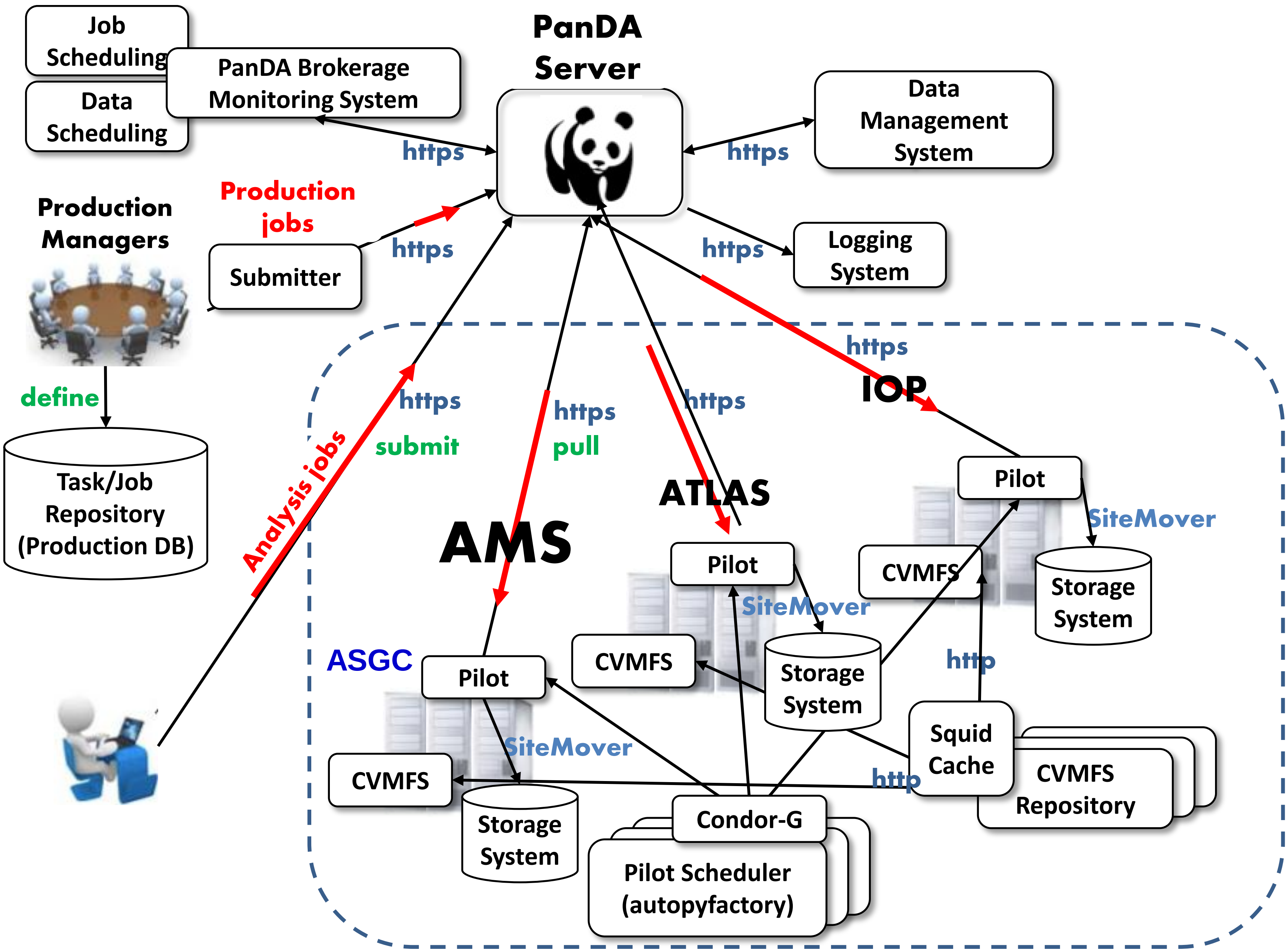
- IaaS and PaaS over the Grid, Cloud and DesktopGrid
- System components would occupy only 3 nodes for current minimum setup
- Flexible configuration from a home facility to a mid-size data center



ASGC Distributed Cloud Infrastructure



PanDA: Production and Distributed Analysis System



ASGC Manpower

Teams	Staffs
Management & General Support	林誠謙、嚴漢偉、陳文水、李家茵、廖慧如
Operation	黃振維、張為仁、廖學億、陳俊成、吳宗訓、林建宏、褚昶銓、張力中
Cloud &Grid Technology	李宏德、申俊瑋、簡禎儀、廖舒婷、尤靖雅、賴彥丞、孫允斌
Application Development	陳信言、廖聰明、王璽凱
International Collaboration and Dissemination	沈一慧、黃珮華、沈德修、王祖惠、齊敏宏

Outlook for 2013-2014

- Distributed Cloud Computing Software deployed in our data center
- Single Rack Cloud Centers deployed and tested
- Support applications in internationally collaborated projects in environmental science, earth science and bio-medical science.

Theory *vs.* Experiment

Theorists deal with 0 and 1

Experimentalists deal with numbers between (0, 1)

Given data, what is the probability *f* that a certain model be true?

$$\underbrace{f(H_i|data)}_{\text{posterior}} = \underbrace{f(data|H_i)}_{\text{likelihood}}\,\underbrace{f(H_i)}_{\text{prior}}\,/\,\underbrace{Z}_{\text{partition function}}$$

$$H_1 = SM(\lambda_1, \lambda_2, \cdots)$$

$$H_2 = BSM(\mu_1, \mu_2, \cdots)$$

$H_3 =$ **data fitting models**

$\cdots$

Posterior becomes the prior of a new measurement.

Partition function is a normalization constant equals to the sum over all models and model parameters of the numerator.

Since calculating the partition function Z is difficult, people usually try to find the parameters for which the likelihood is a maximum and use Gaussian approximation around this maximum so that the normalization is known. The availability of huge computing power could change the situation. Tools and concepts developed for dealing with quantum or thermal fluctuations can be used to deal with statistical fluctuation and vice versa.

Likelihood model is based on mathematics.

For fitting, we usually choose Gaussian distribution based on the Central Limit Theorem.

For classification, we usually choose binomial distribution.

Instead of likelihood, we often use negative log likelihood which is called a Loss Function or a Cost Function. When the likelihood is 1, the Loss Function is 0. Maximizing likelihood is the same as minimizing loss.

The usual task of data analysis is to find the theoretical model or to build a phenomenological model that maximizes the likelihood.

For the Bayesian approach, we also need to know the likelihood for models away from maximum likelihood.