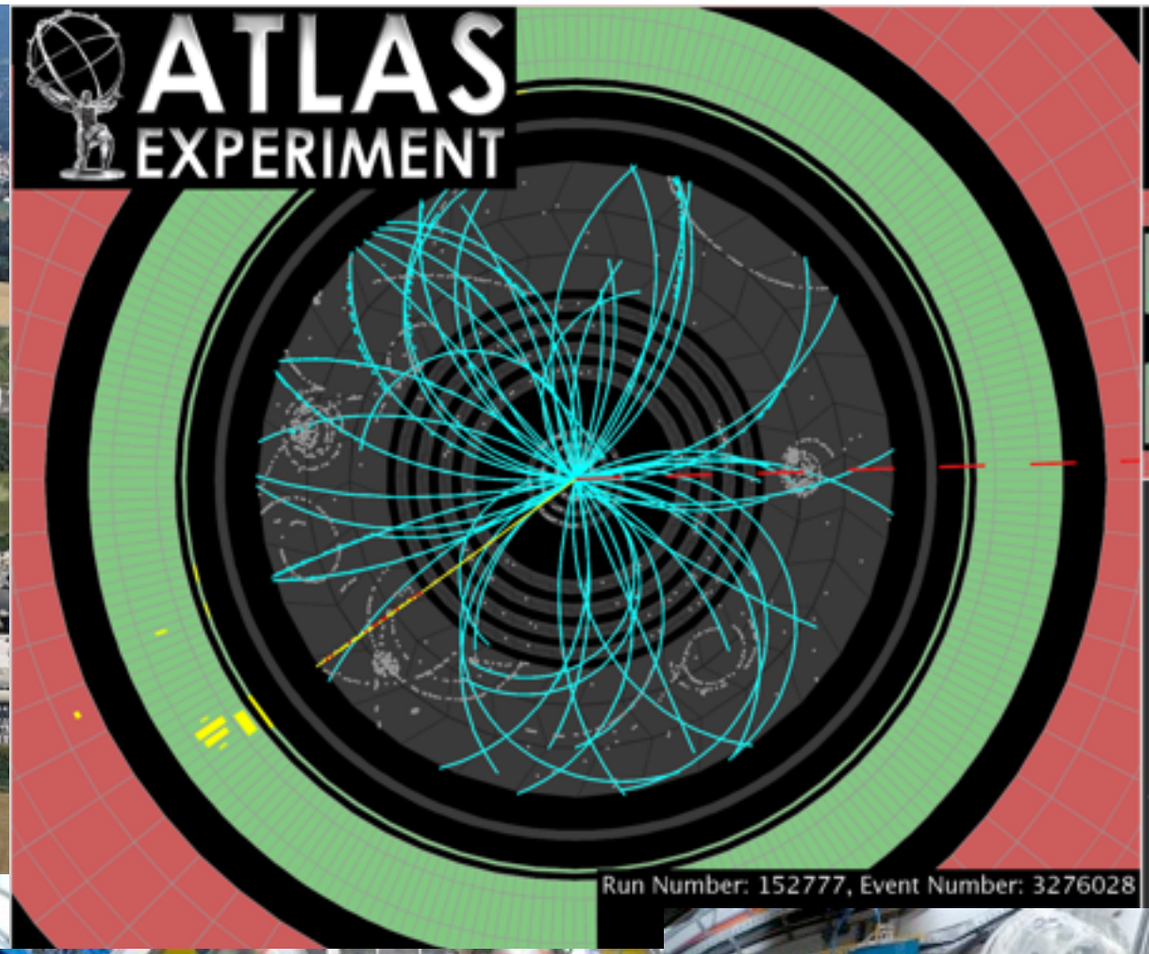
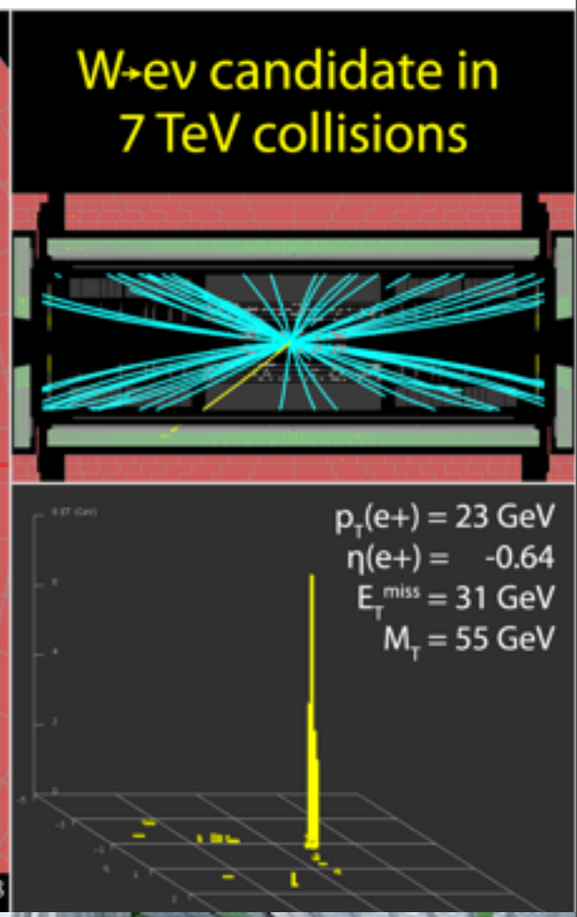
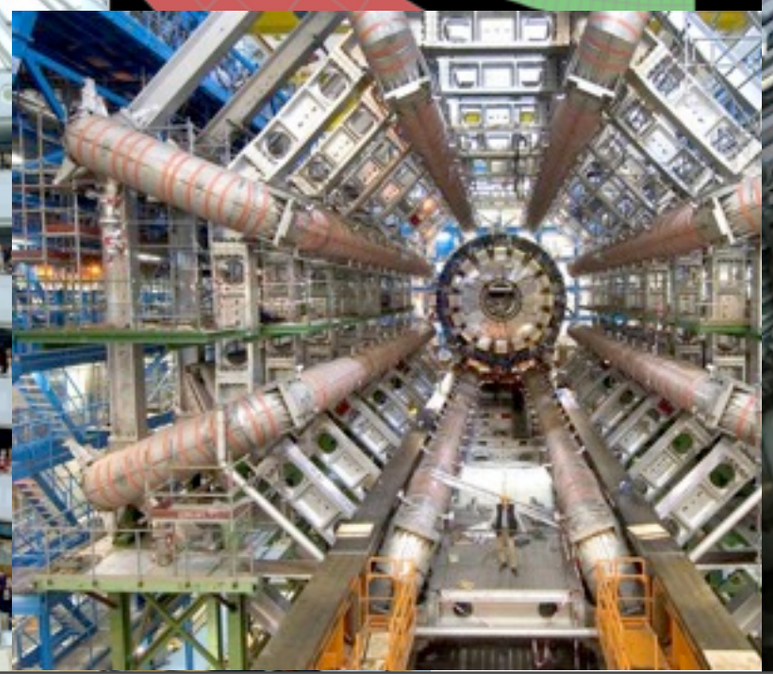
LHC Experimental Update

Thomas Gadfort
BNL







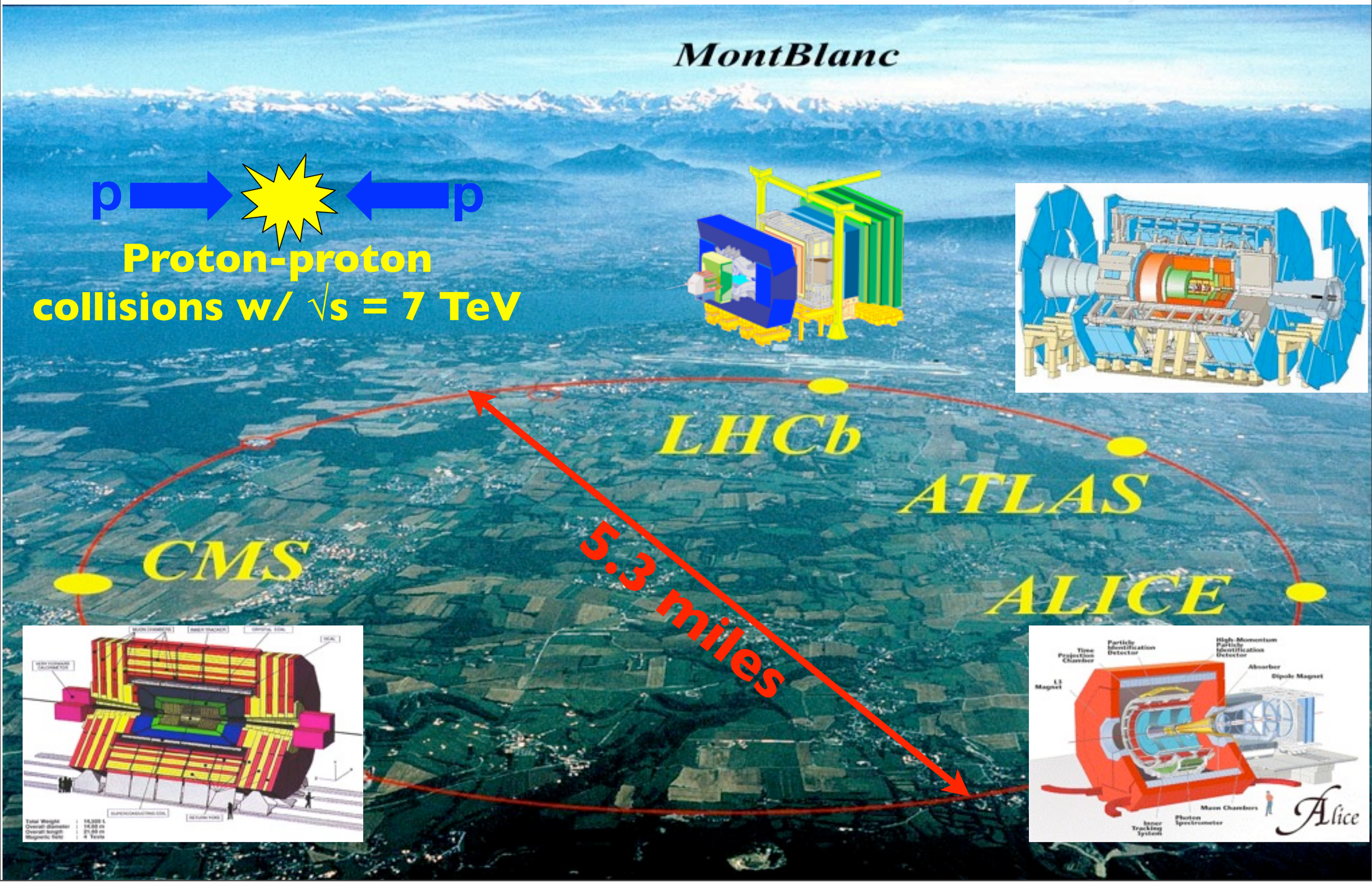
Outline

- Overview of the LHC & ATLAS experiment
- Status of data taking and detector performance
- First physics results
- What can we expect within the next year? What about five years?

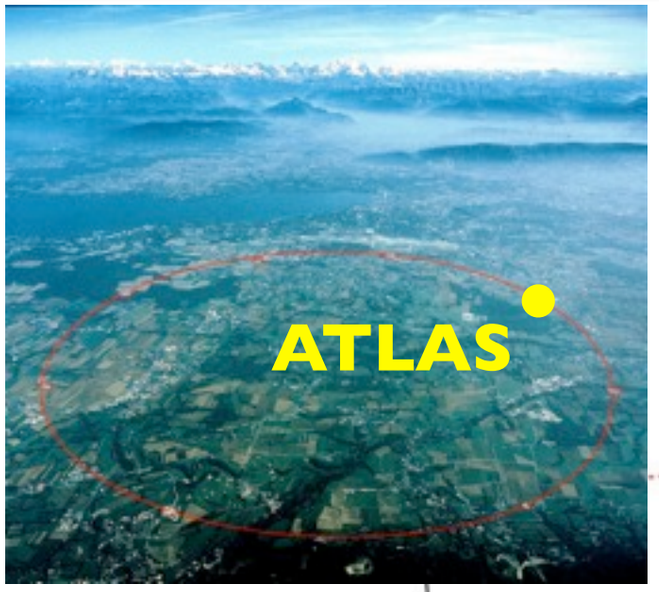
The Large Hadron Collider

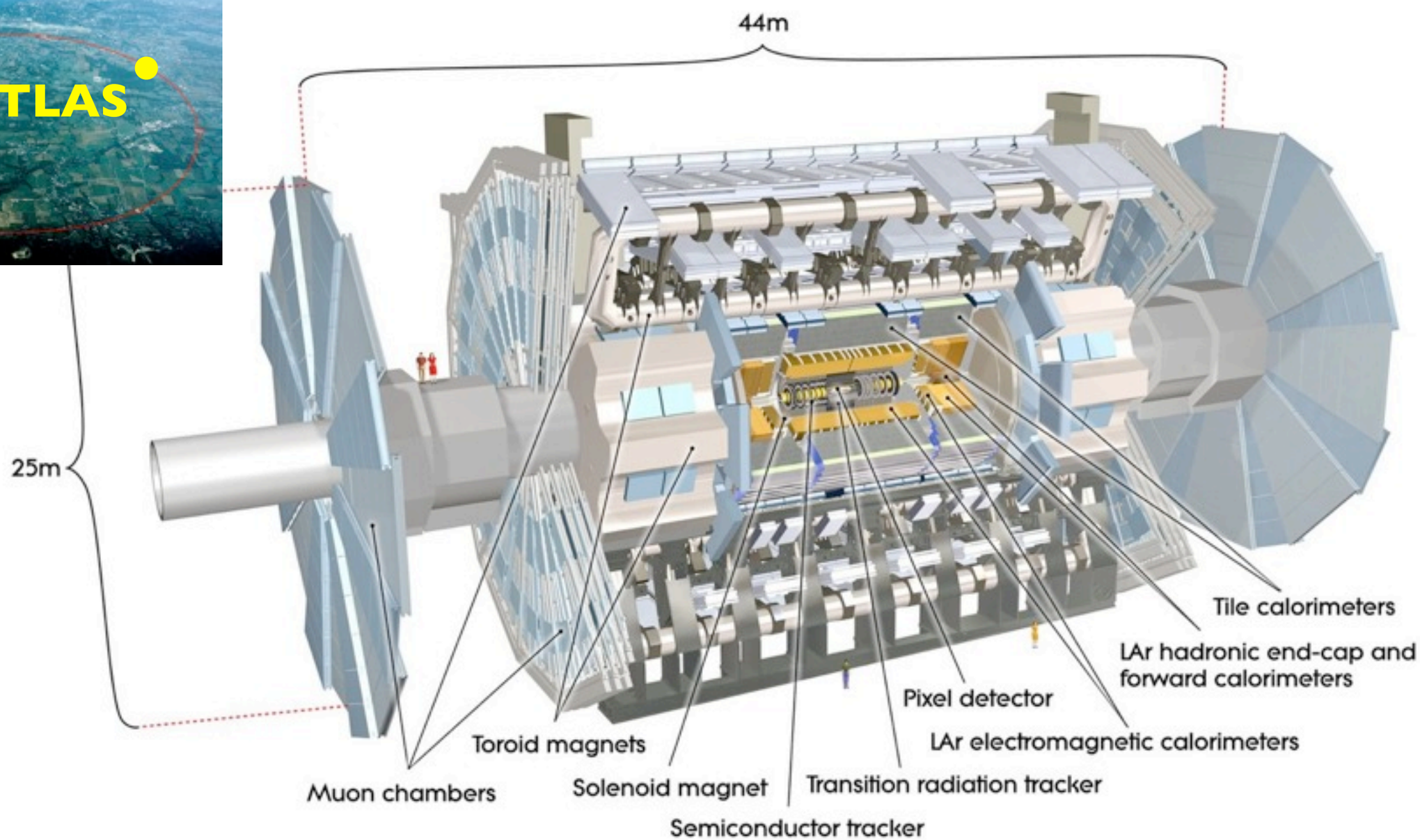
the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY



The ATLAS Detector





"Standard" HEP Detector

IP → Tracking Detector → Calorimeter → Muon System

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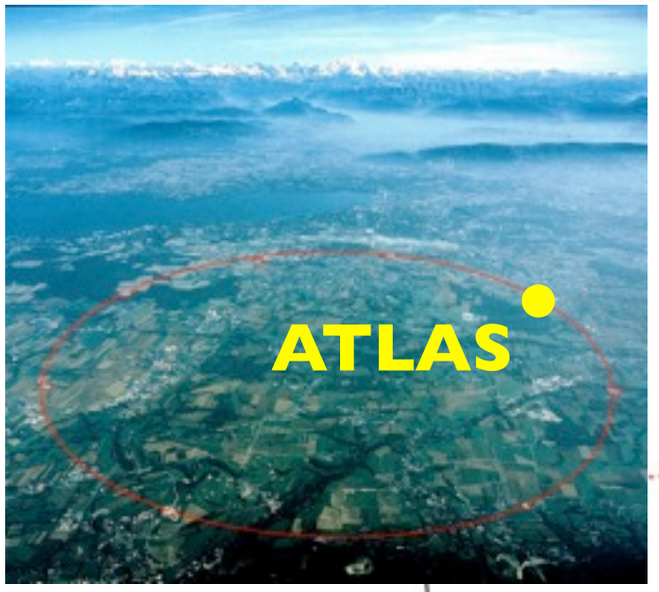

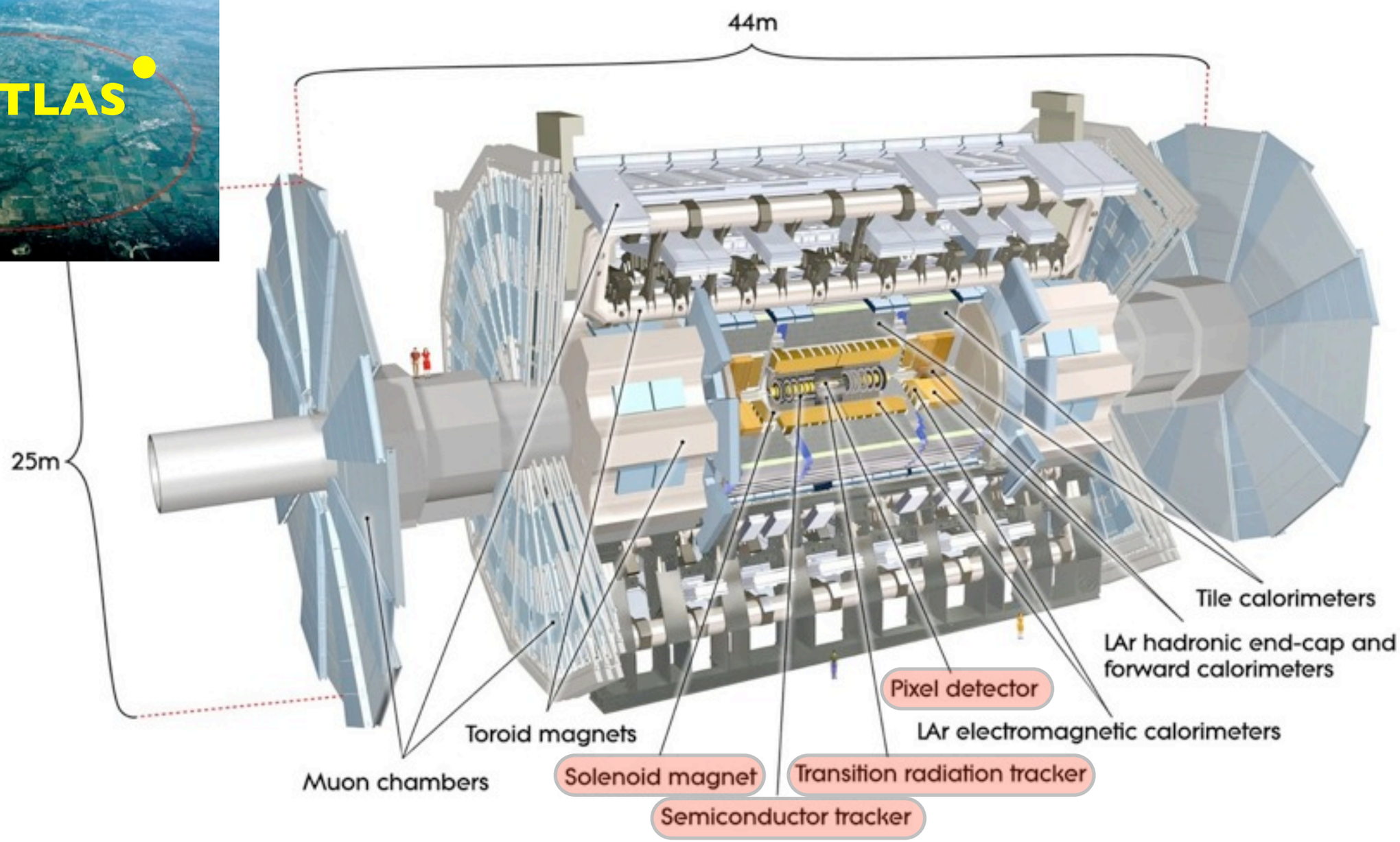

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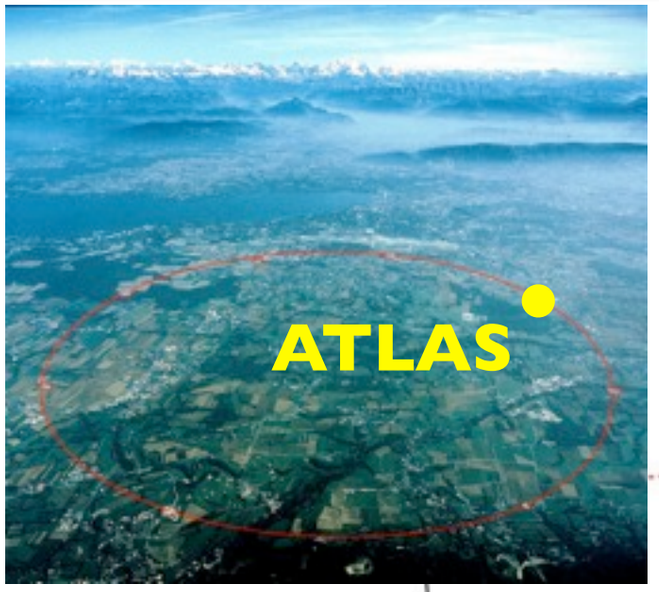

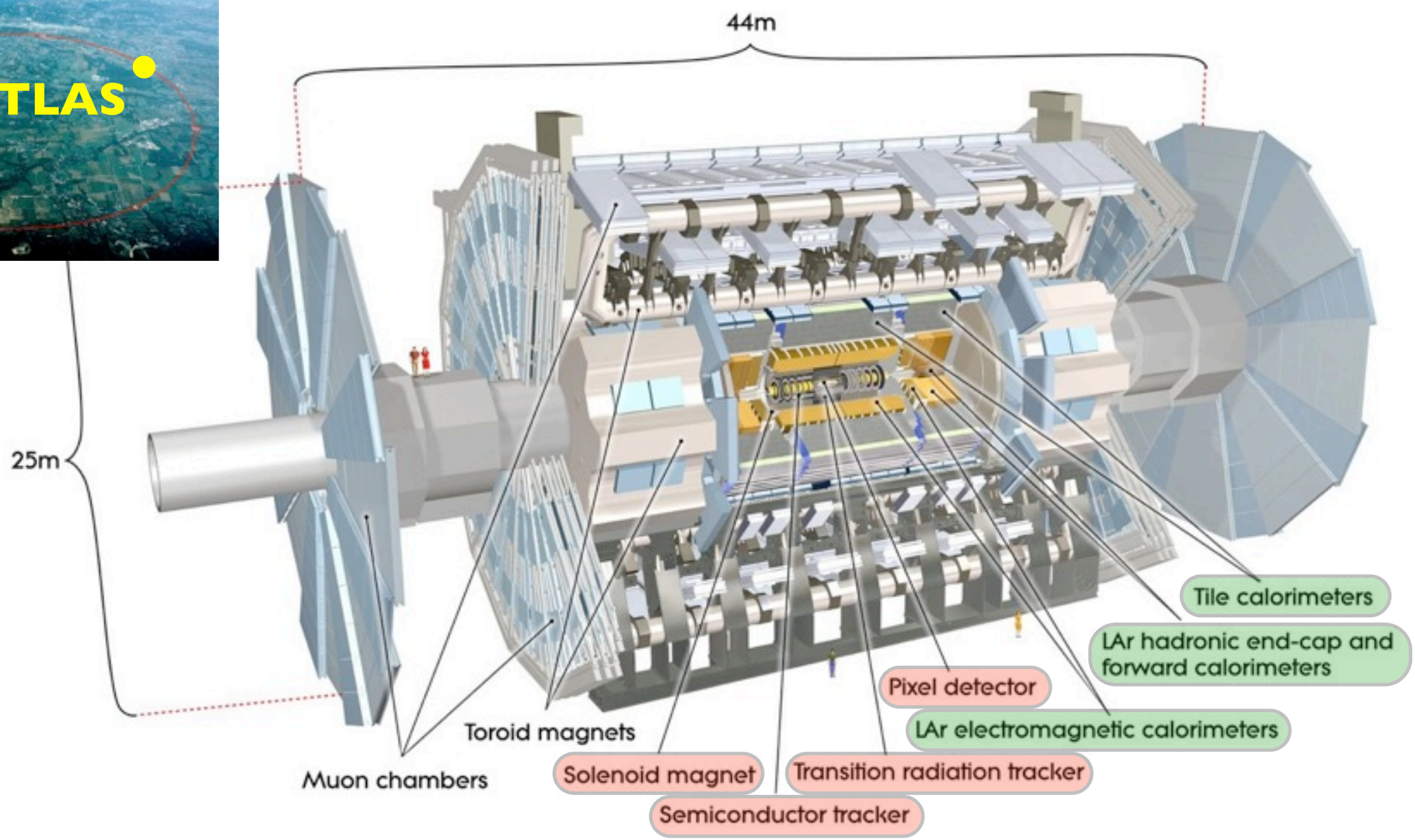

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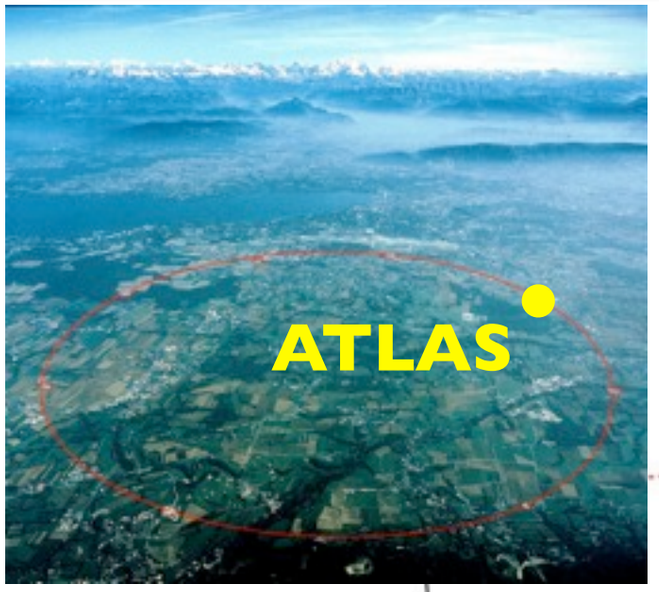

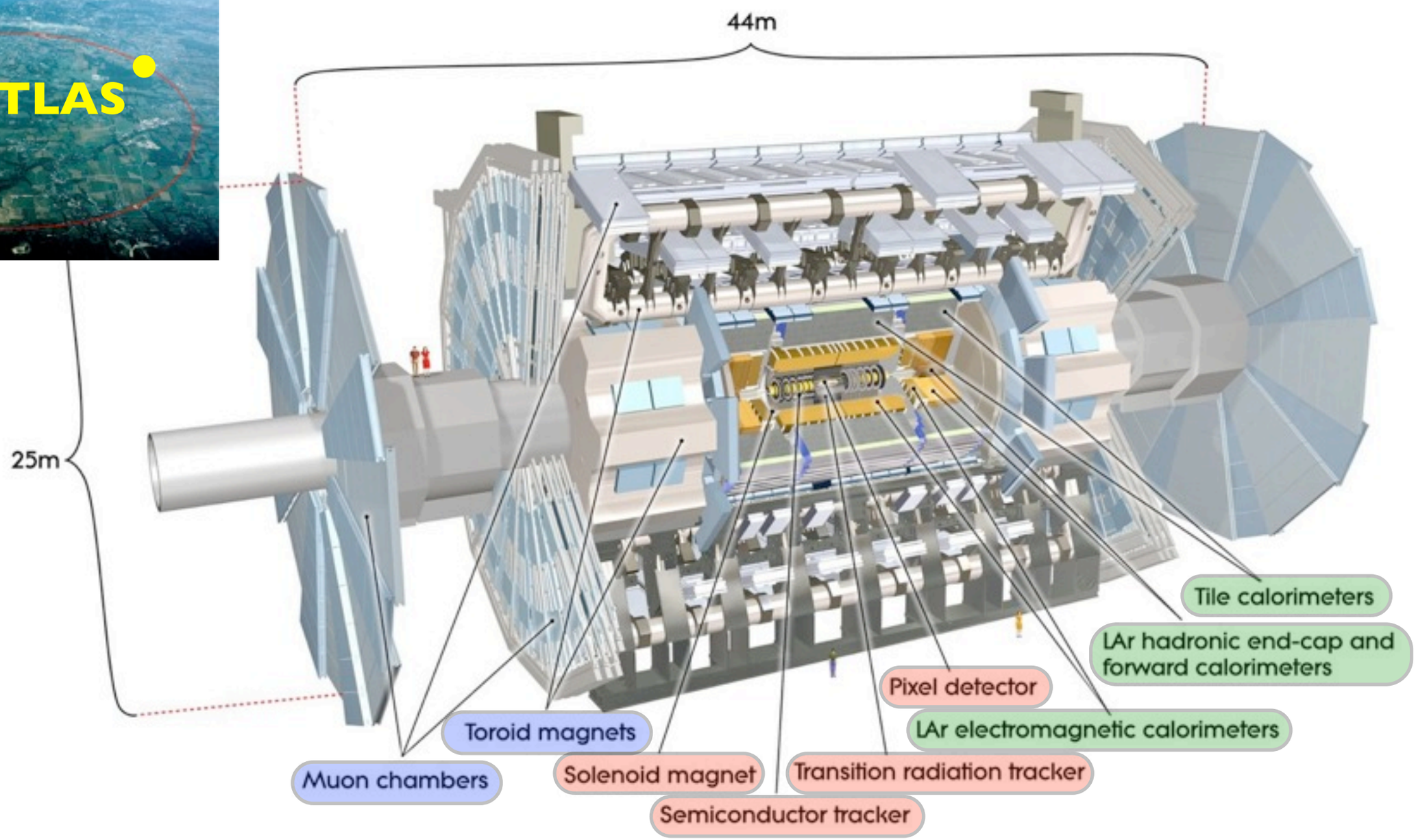

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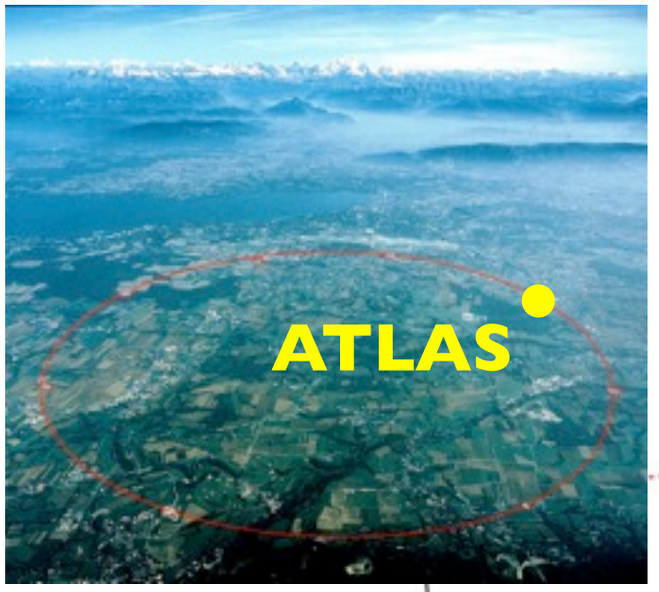
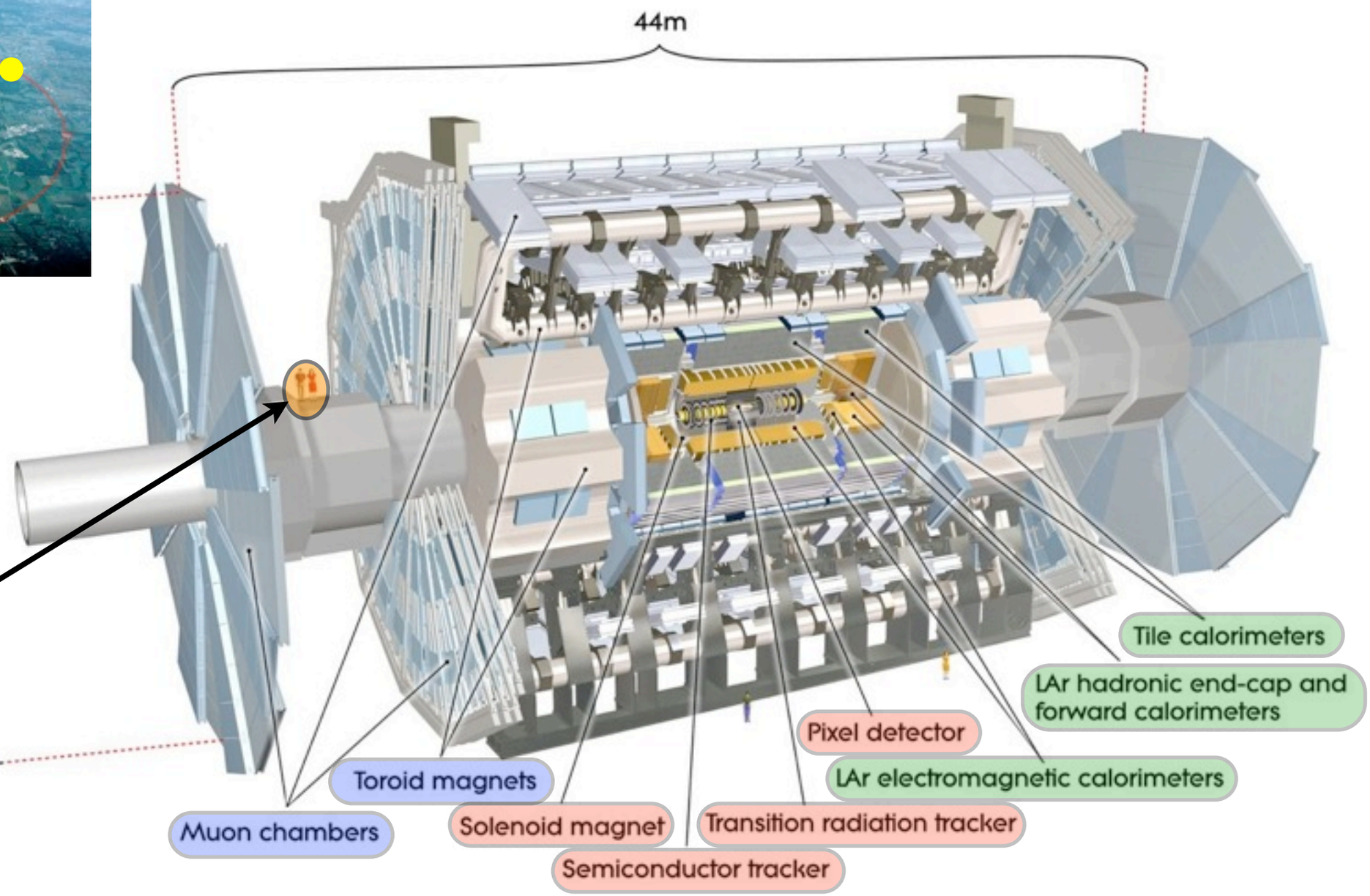




You!

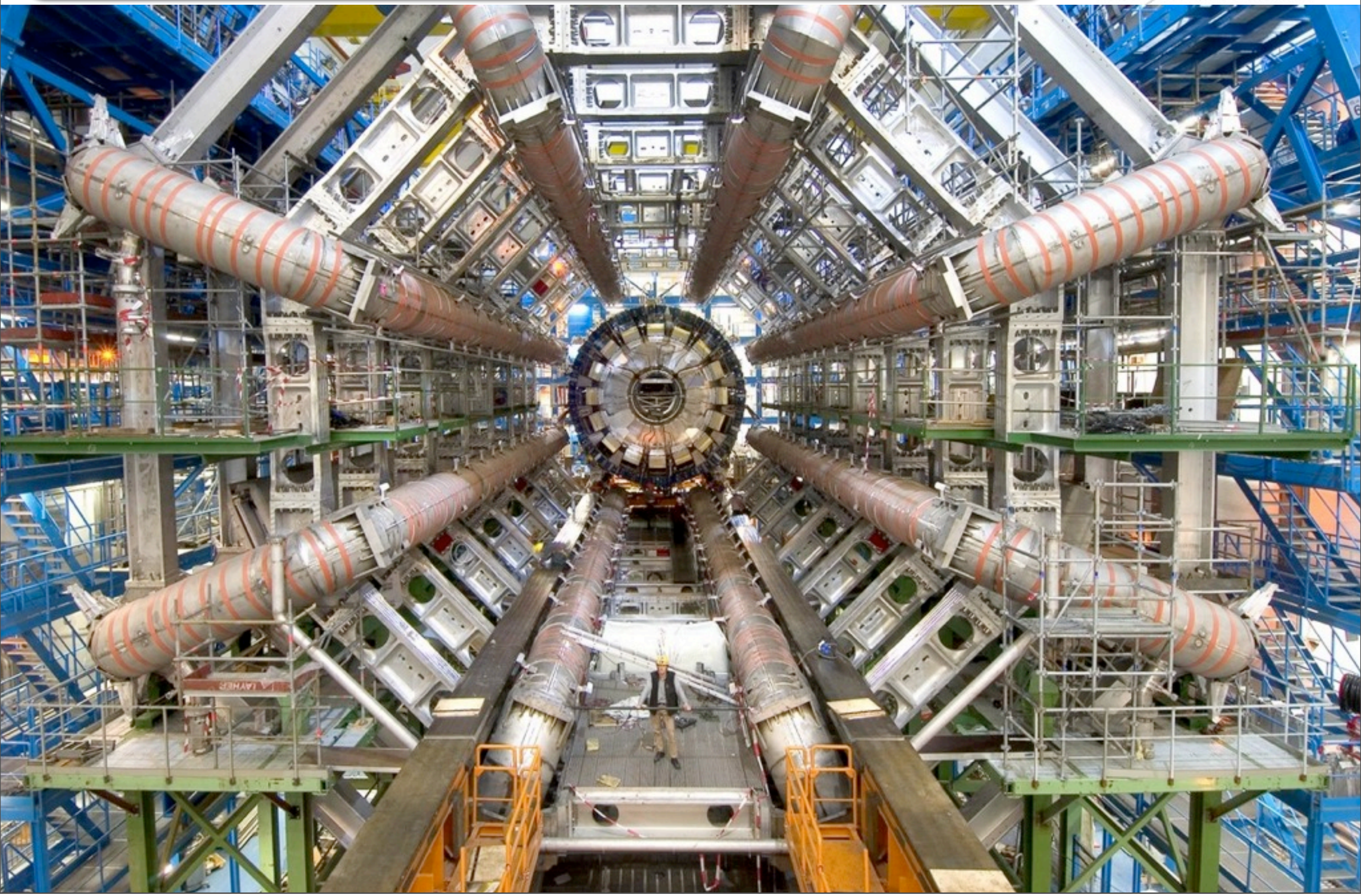
"Standard" HEP Detector

IP → Tracking Detector → Calorimeter → Muon System

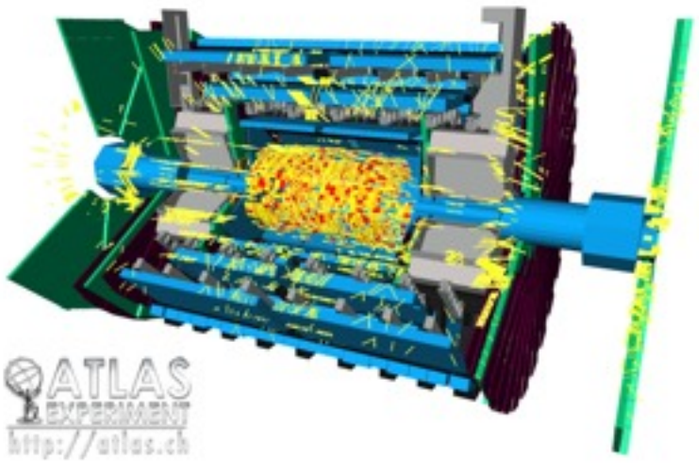
The ATLAS Detector

the ATLAS Experiment

BROOKHAVEN NATIONAL LABORATORY

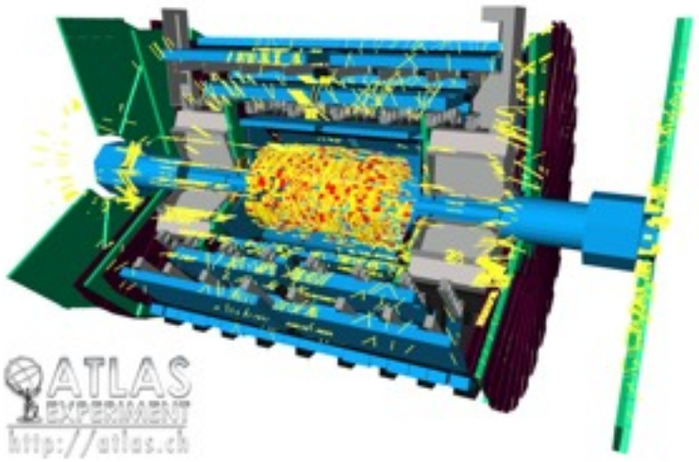


LHC Collision Timeline



September 2008 -
First splash events!

LHC Collision Timeline



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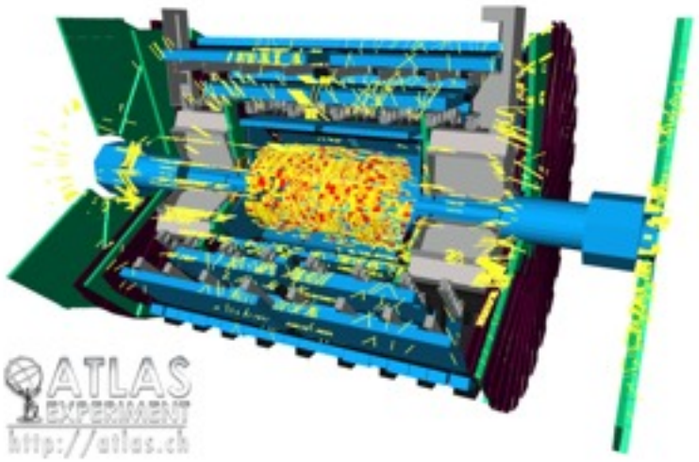

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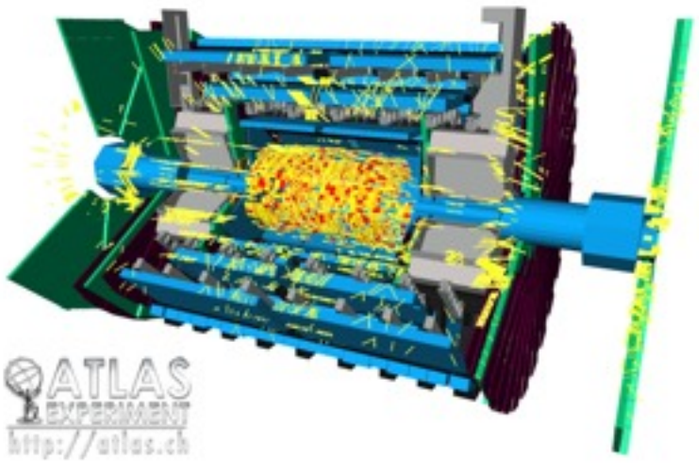

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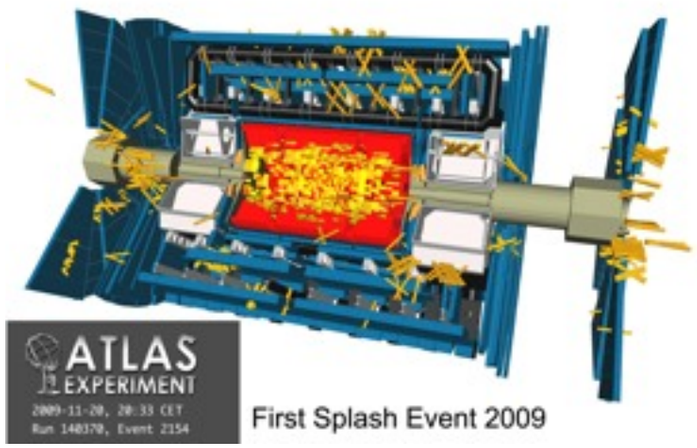

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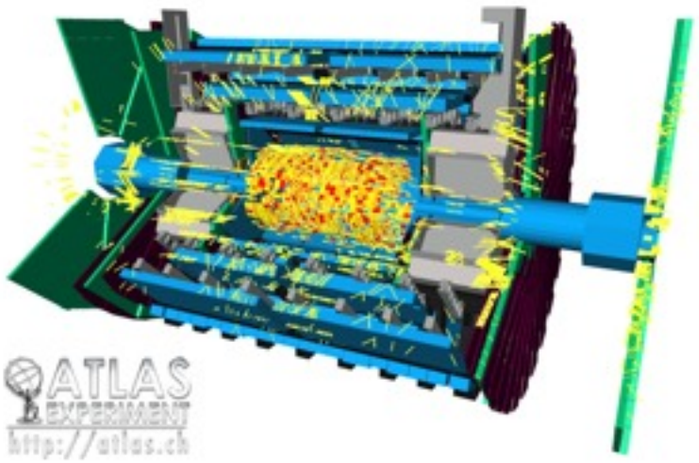

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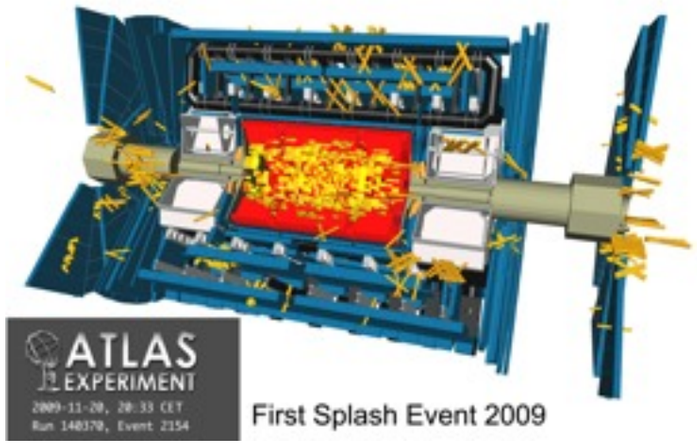

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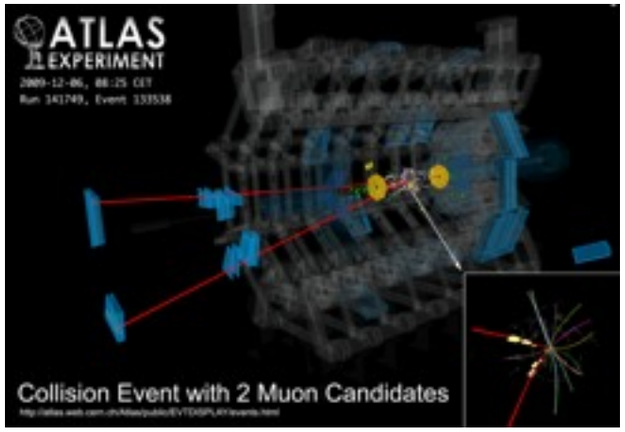

November → January
Collected ~1M 900 GeV Minbias
events + few 2.36 TeV collisions!

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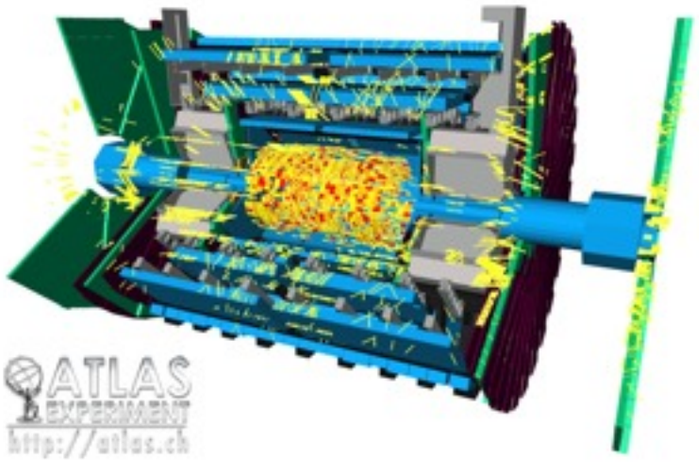

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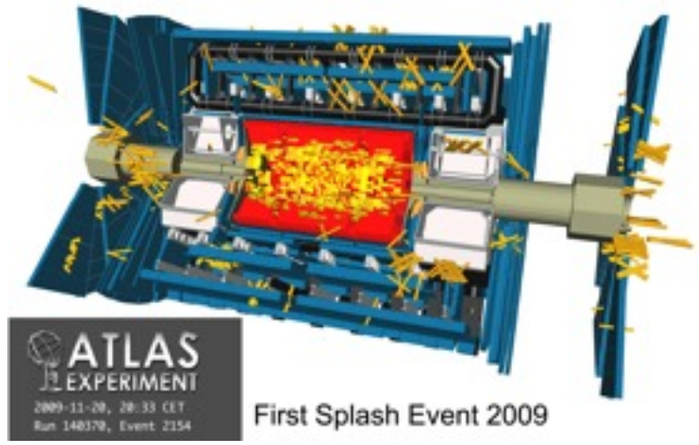

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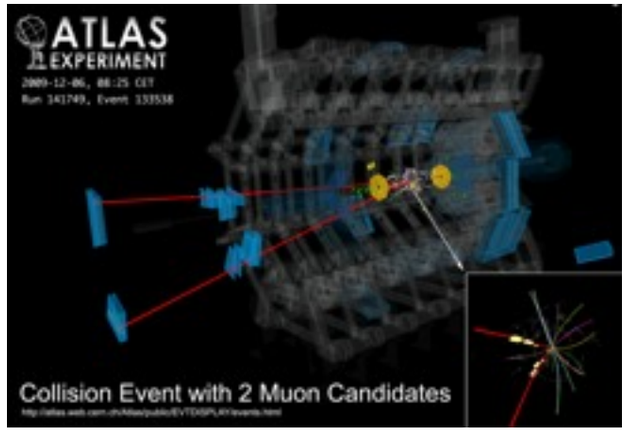

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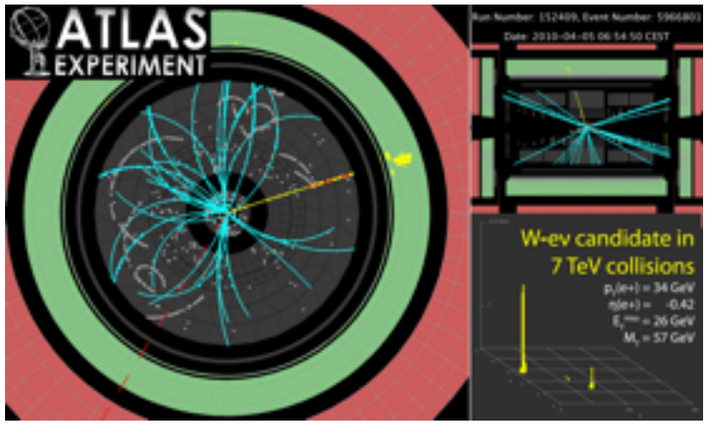
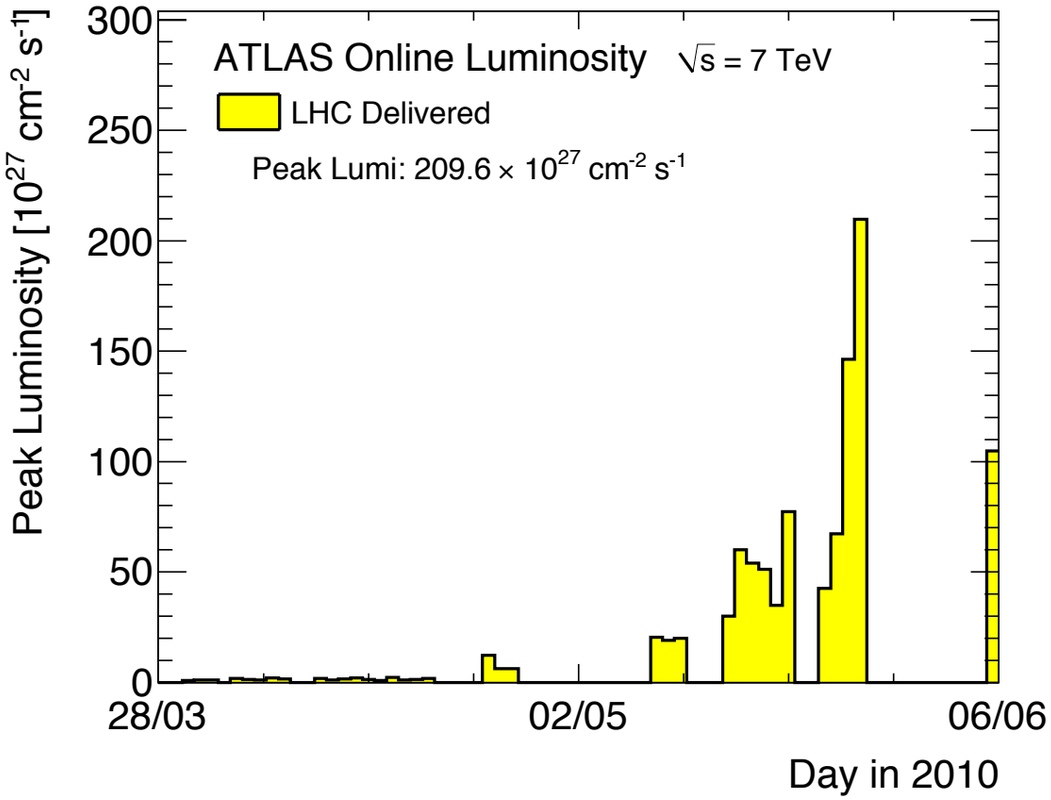
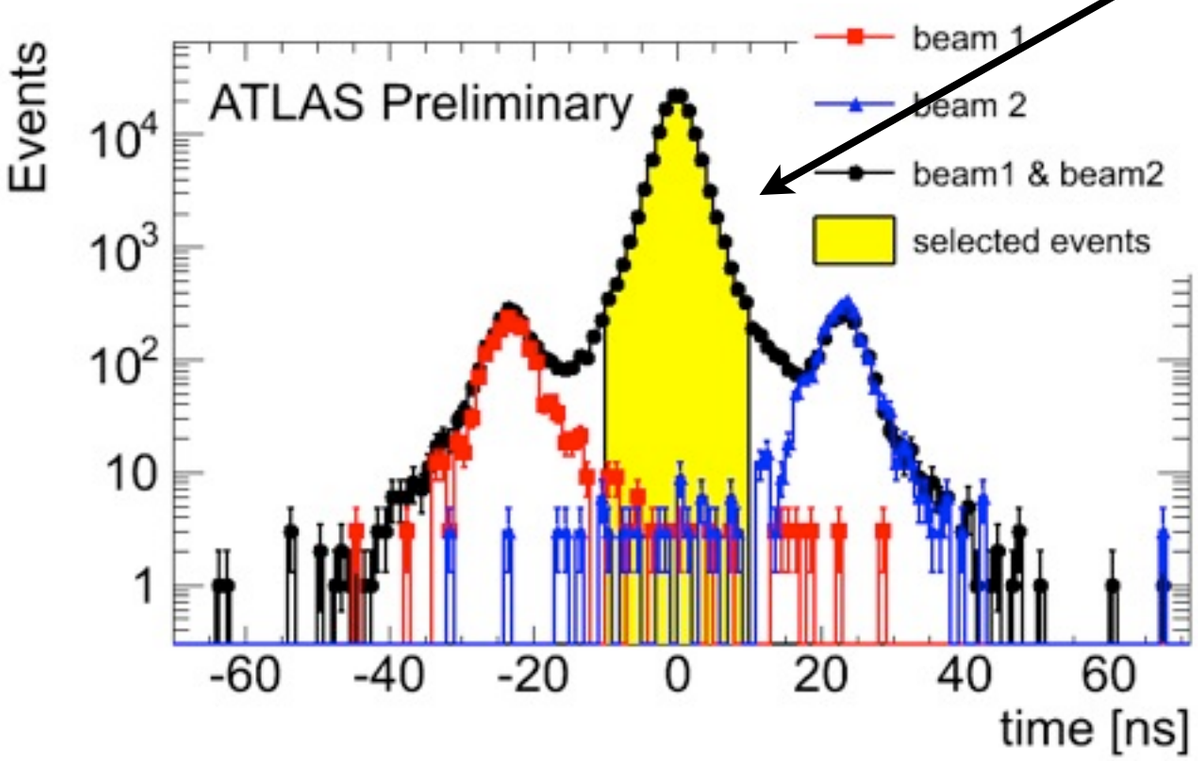


March → present day
Collecting 7 TeV collision data!

ATLAS Data Taking



- LHC began with **1** bunch crossing at $\mathcal{L} \sim 10^{27}$ [cm^{-2} s^{-1}]
- Start by recording every event at these luminosities with MBTS coincidence hits.



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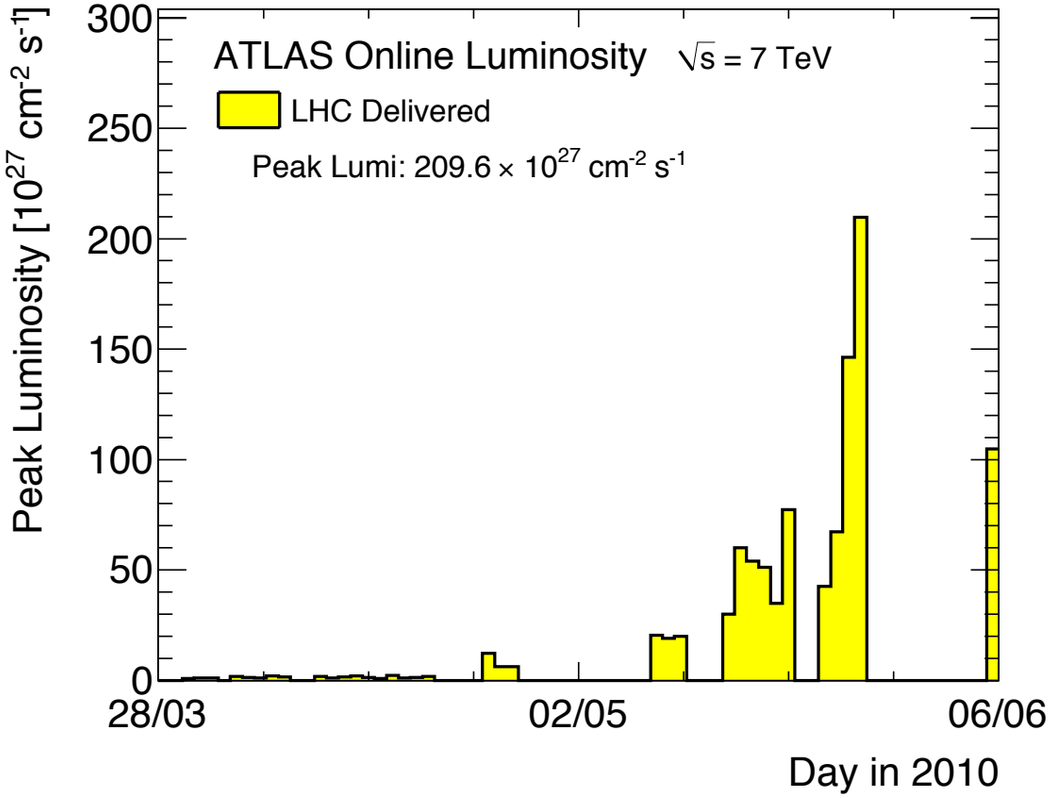

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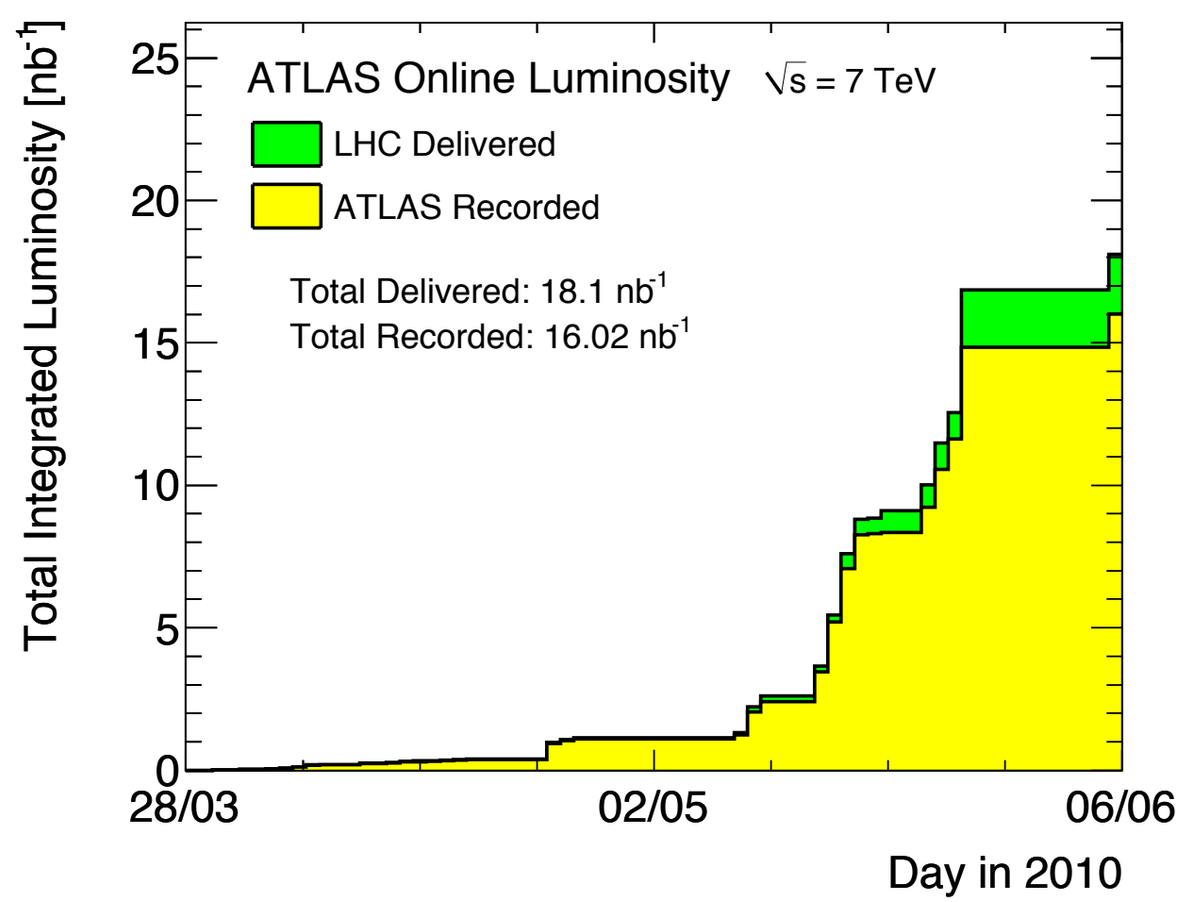
- Start by recording every event at these luminosities with MBTS coincidence hits.

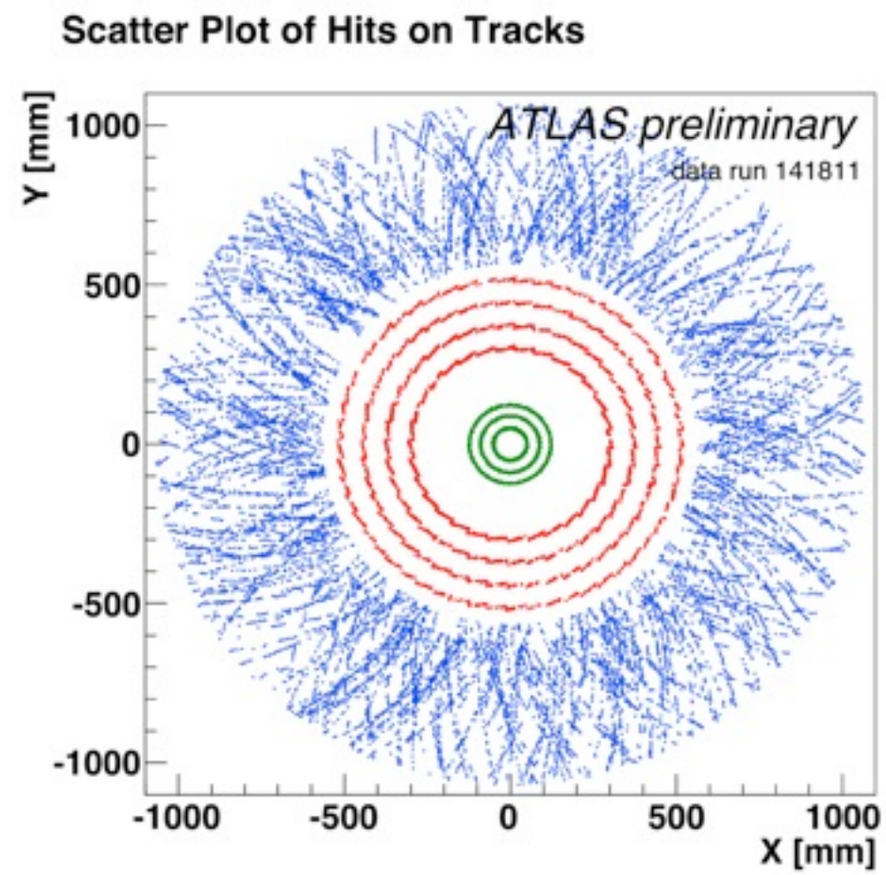
- Peak $\mathcal{L} \sim 10^{29}$ [cm^{-2} s^{-1}] → start prescaling minbias triggers.
- Currently, require L1 trigger on calorimeter energy or muons.

ATLAS has $\int \mathcal{L} dt \sim 16$ nb^{-1}.



Detector Performance: Tracking

- Hits in the inner detector. **Pixel** and **SCT** layers clearly present as are **TRT** tracks.



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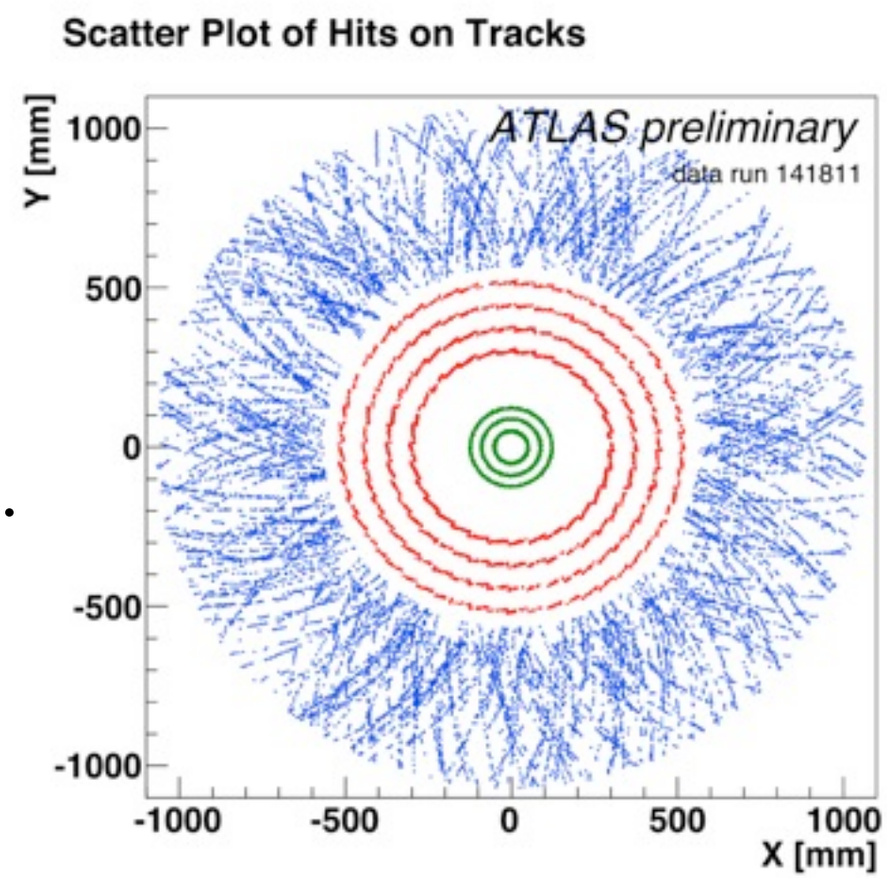
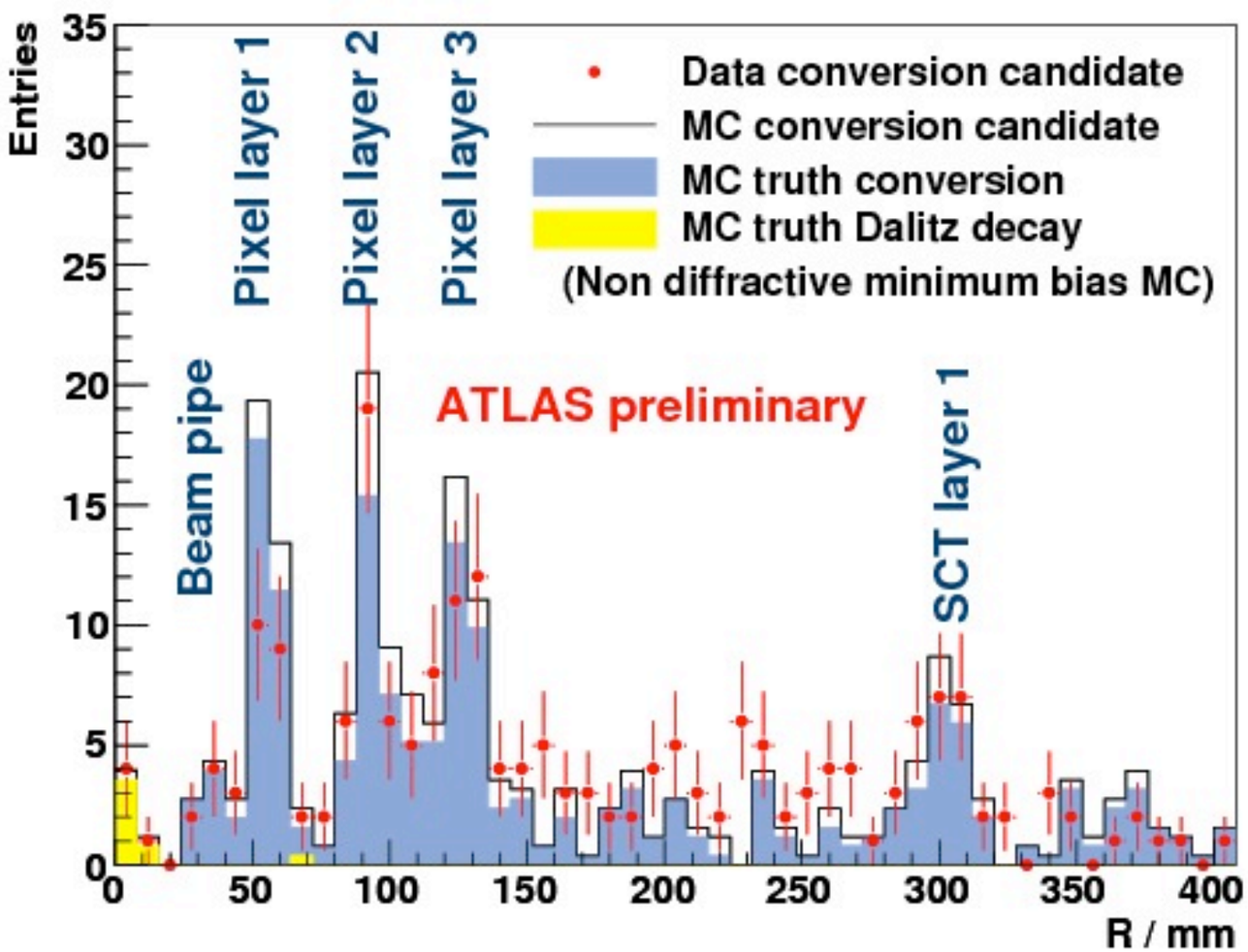
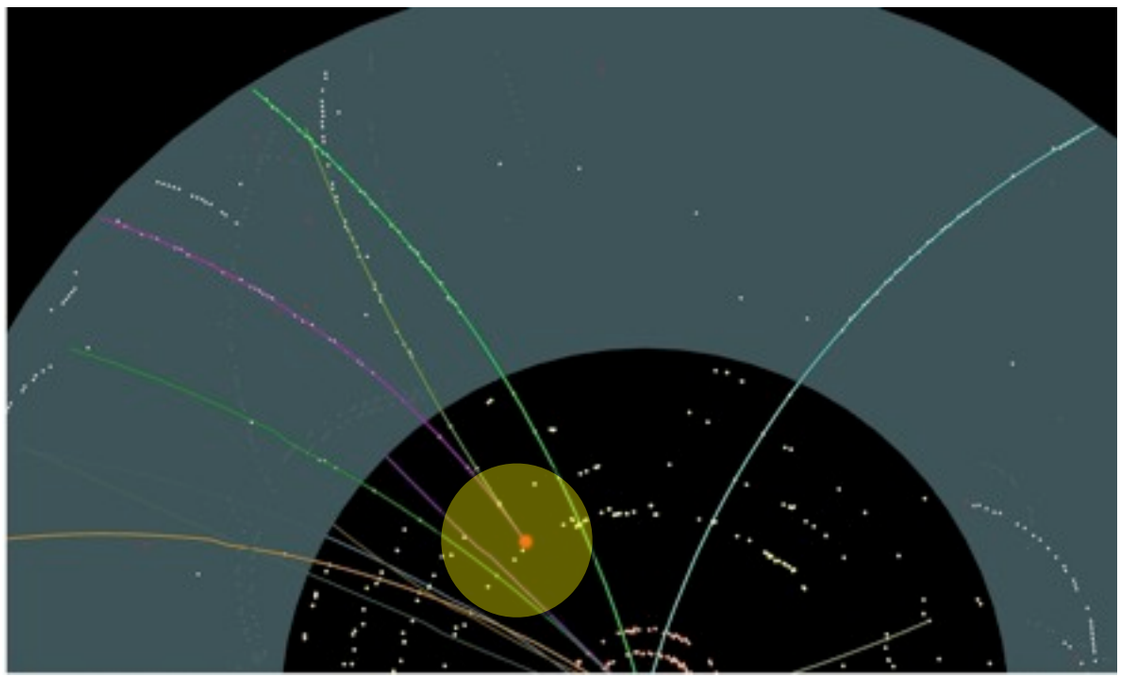


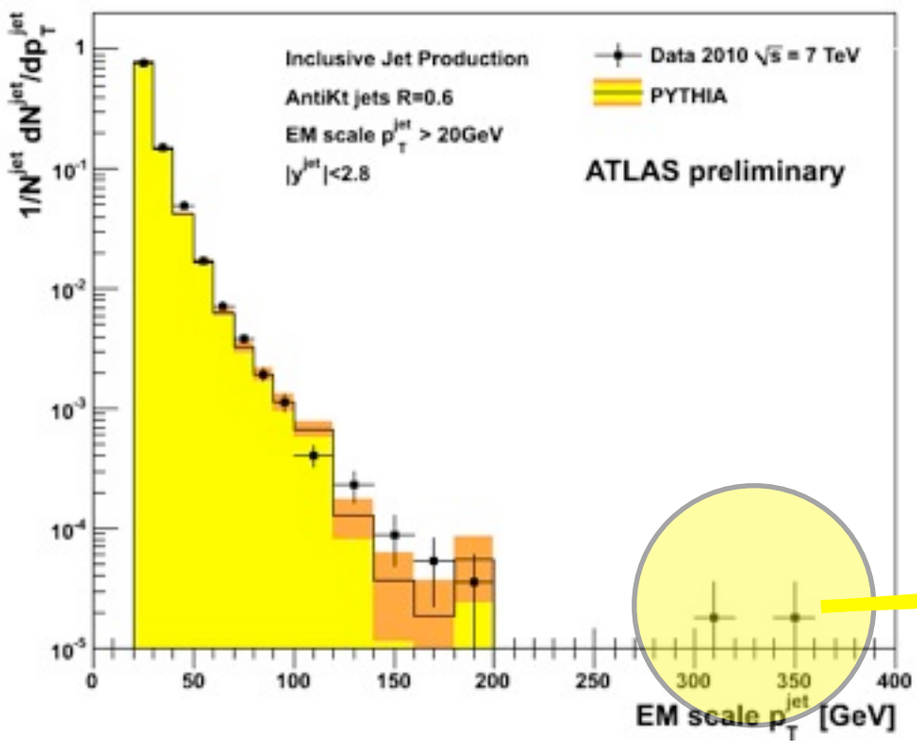
- Photon conversions help map detector material.

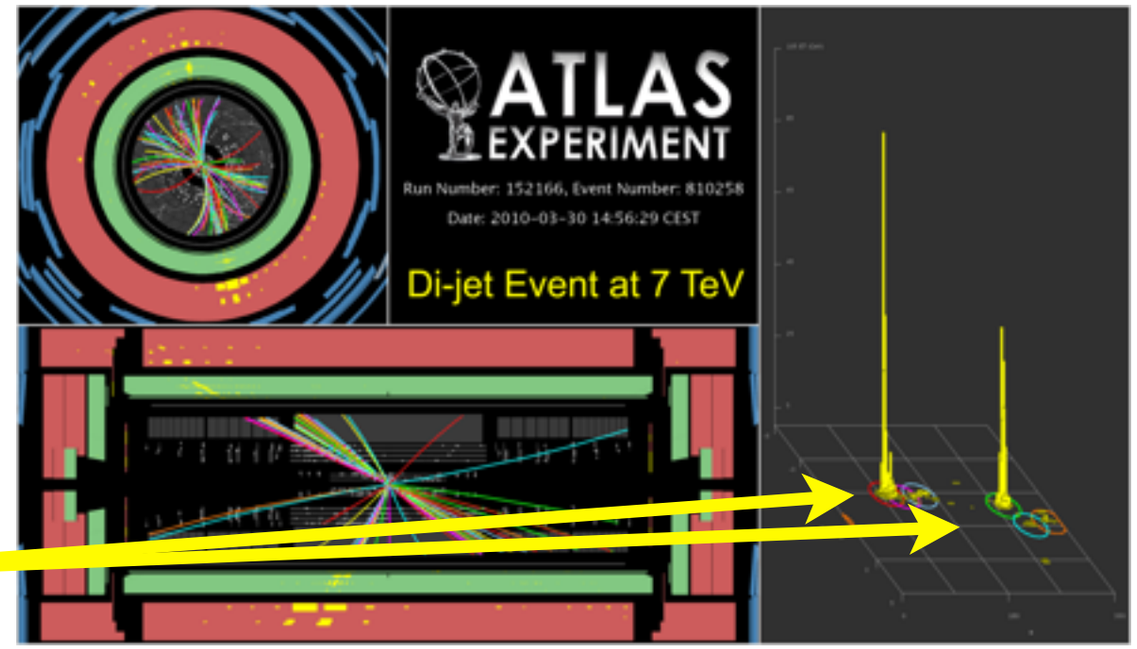




Detector Performance: Calo & Muons

- Calorimeters (LAr + Tile) behaving very well!





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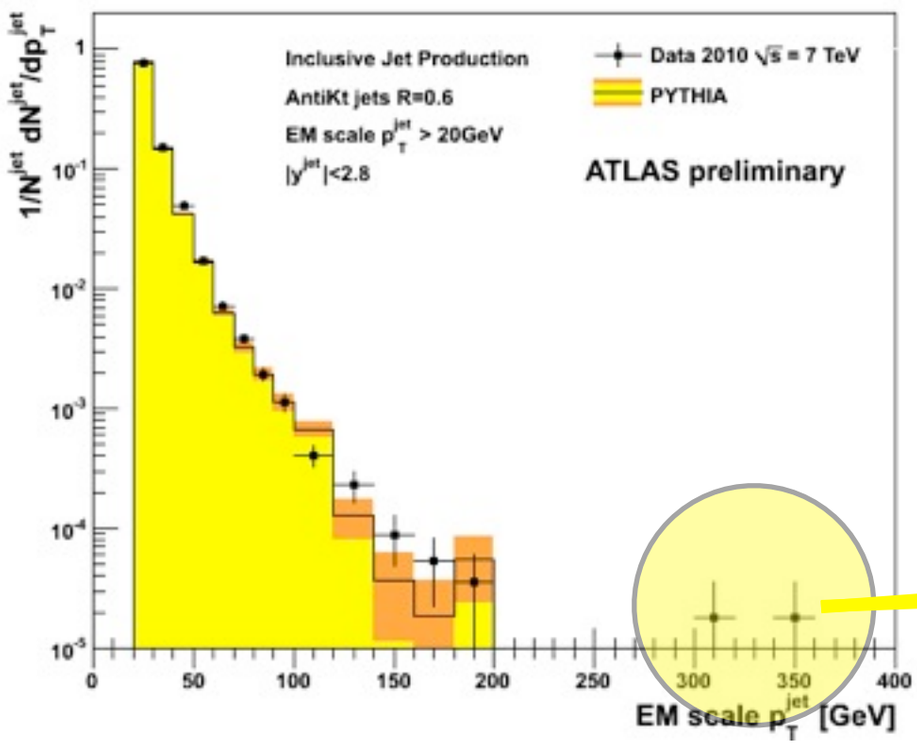
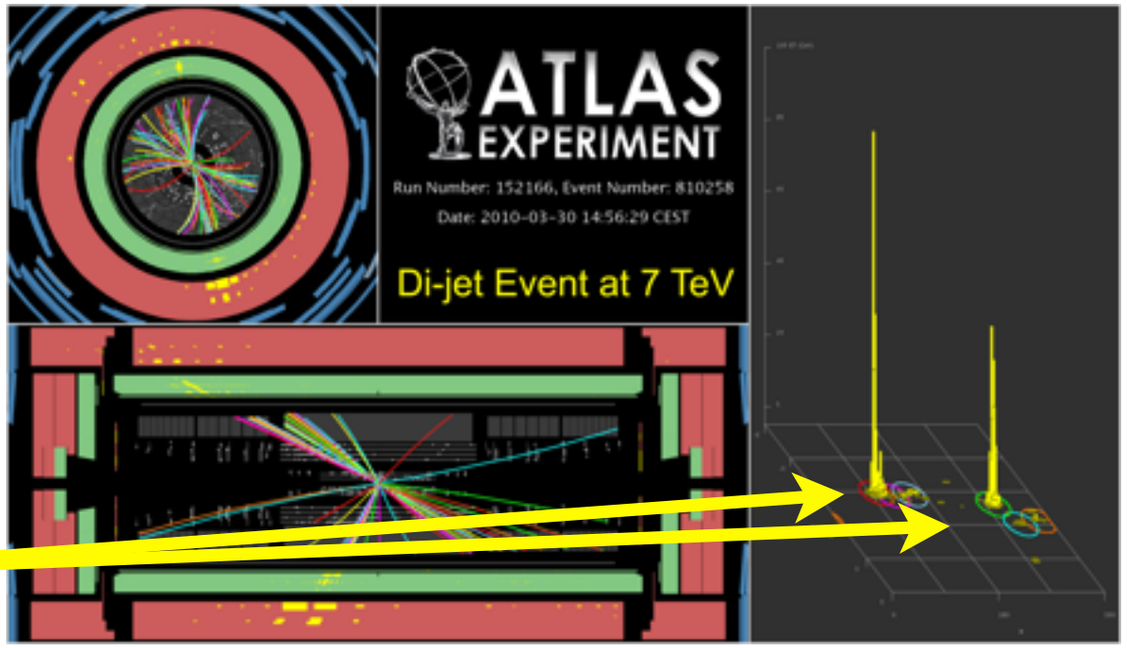
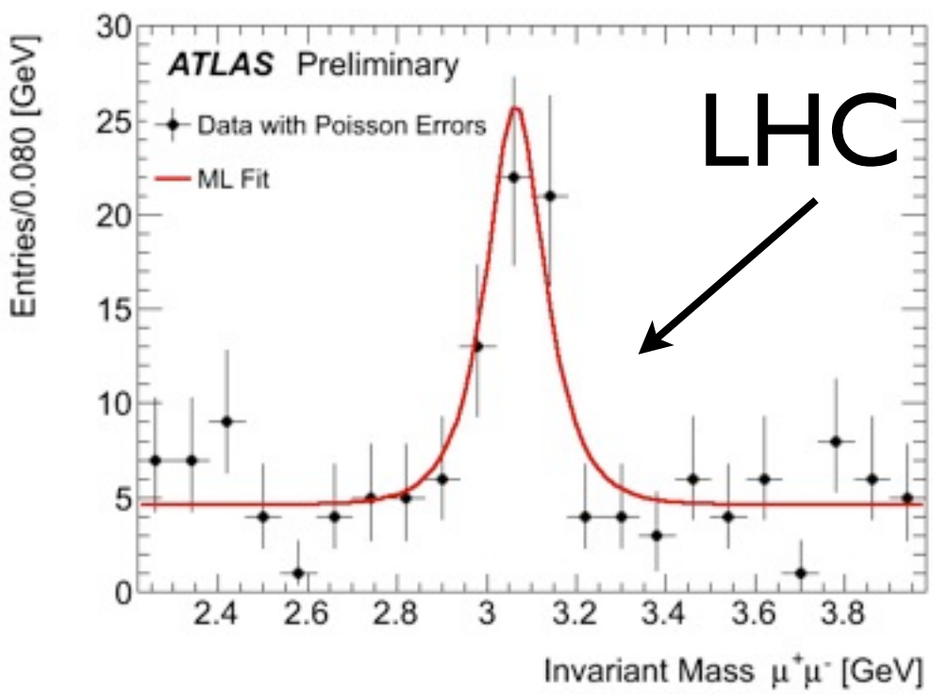


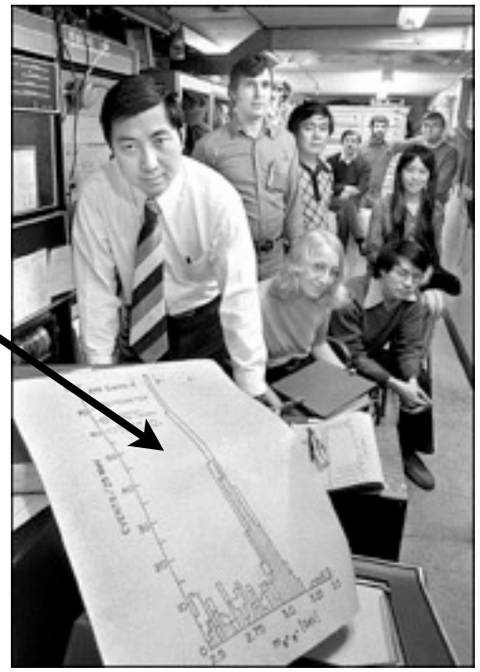


- Combined muon spectrometer and ID tracks easily find J/ψ.



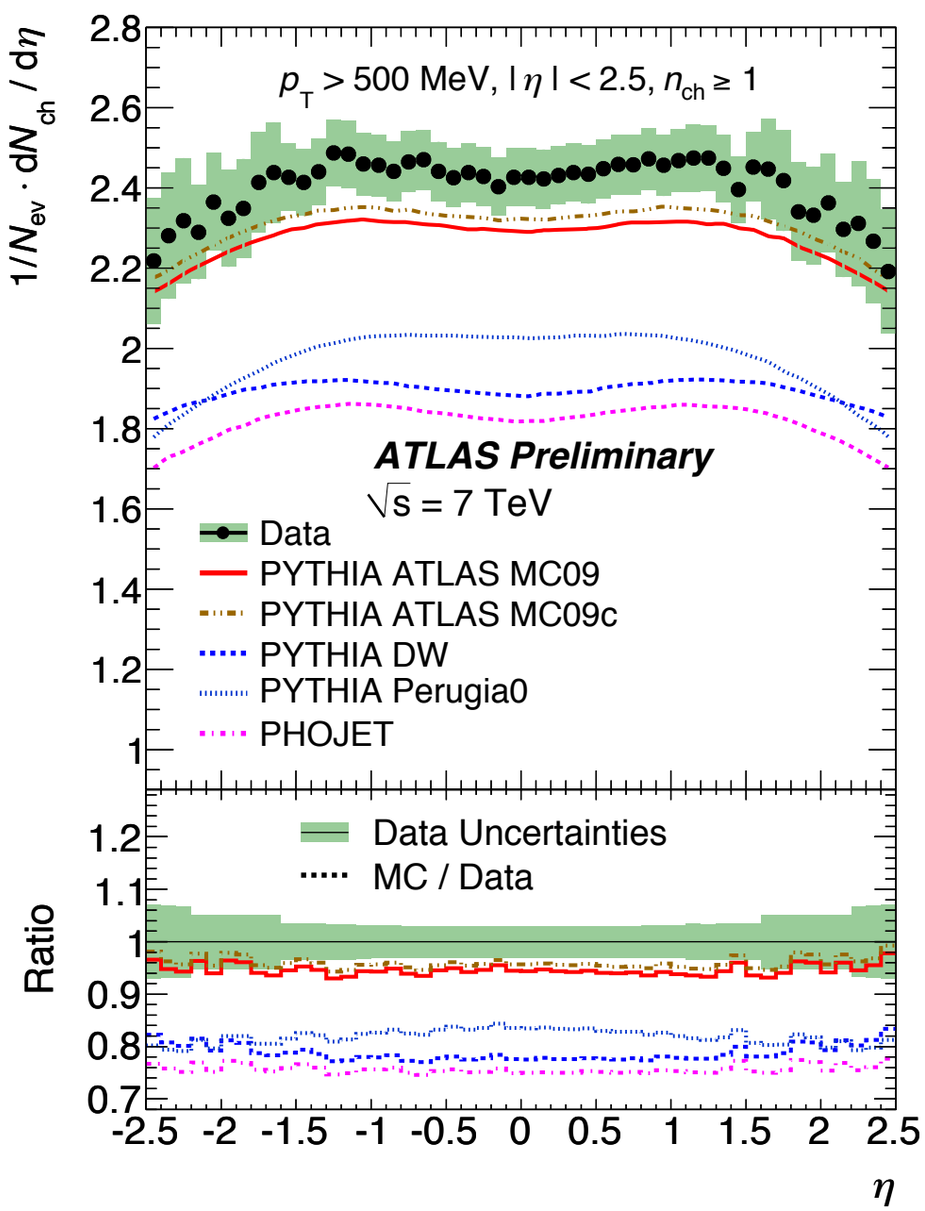
LHC

AGS

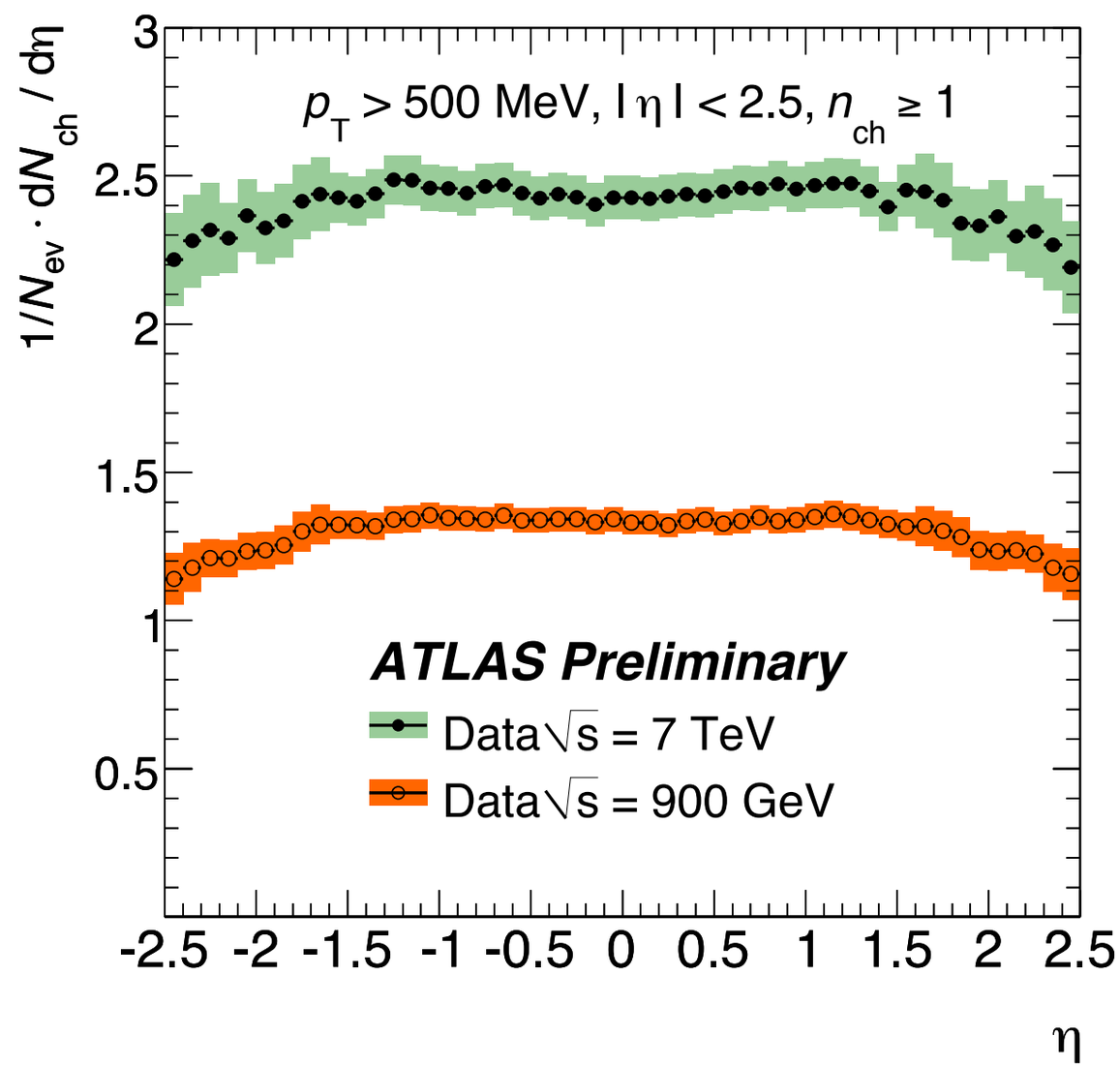


Early Results

- Charged Particle Multiplicity (n_{ch}) @ 7 TeV
  - Select events with at least one track w/ p_T > 500 MeV
  - Correct for detector effects (e.g. trigger, tracking efficiency)
  - Comparisons now available for several Pythia Tunes.



All tunes produce too few particles w/ varying levels of agreement in p_T spectrum.



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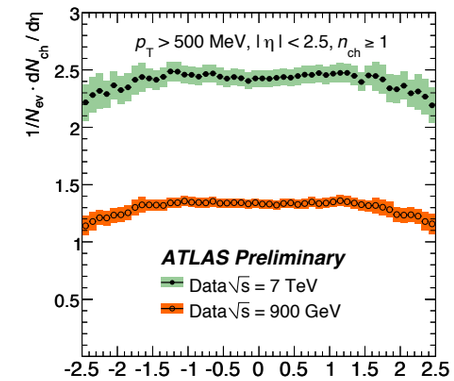
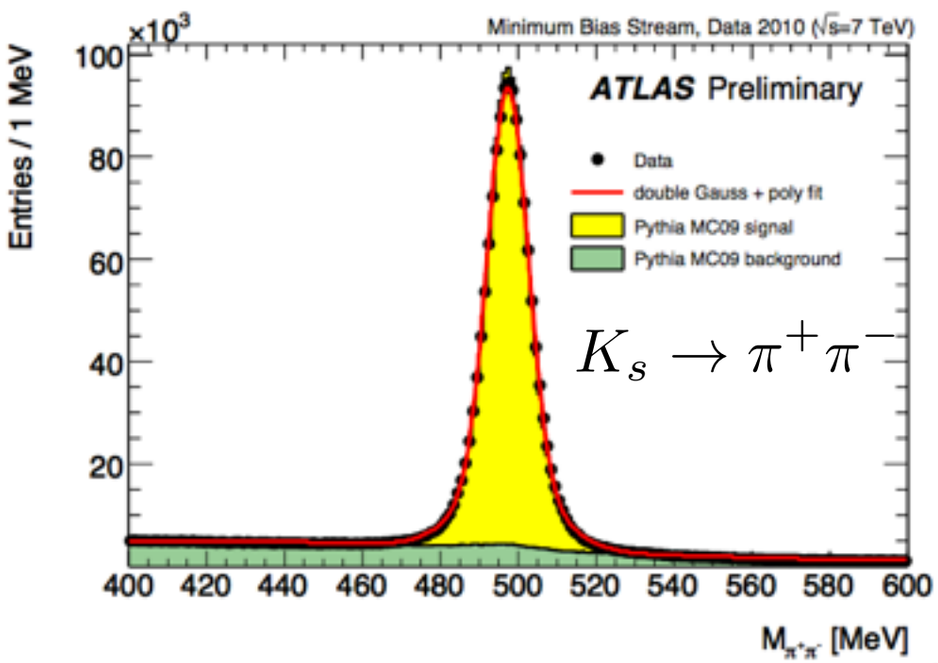
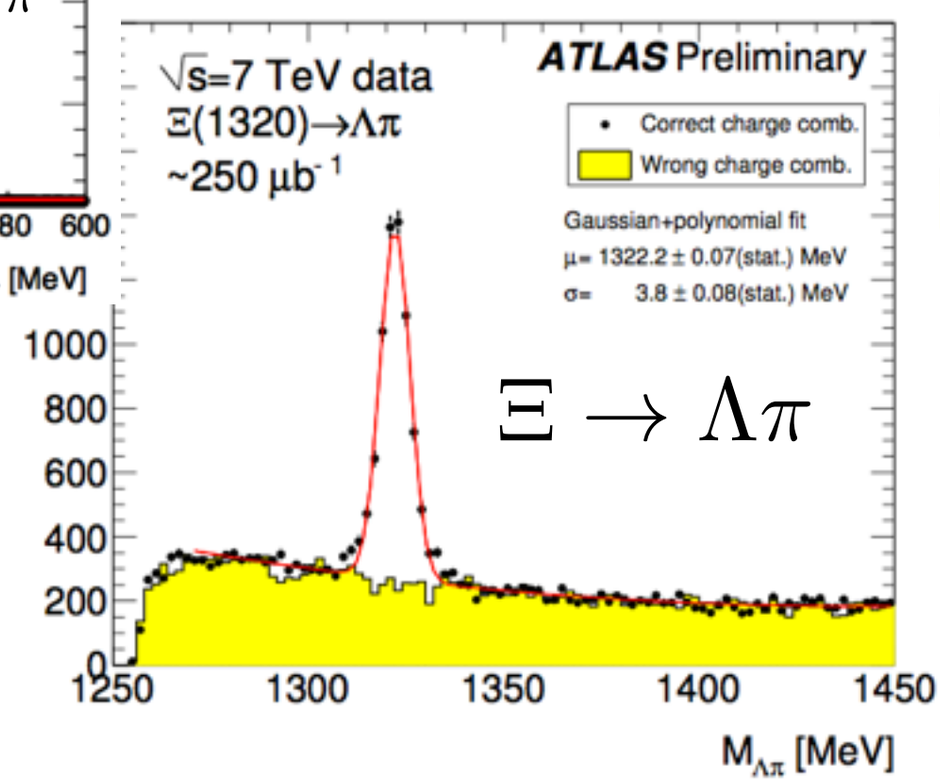
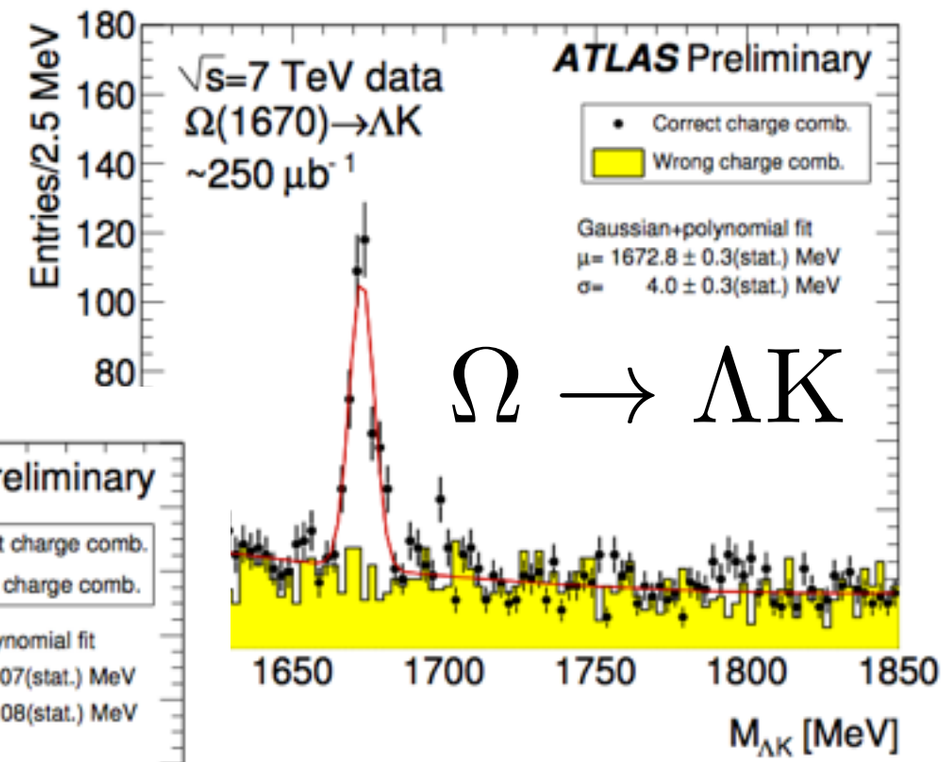
- Meson and Baryon Resonances









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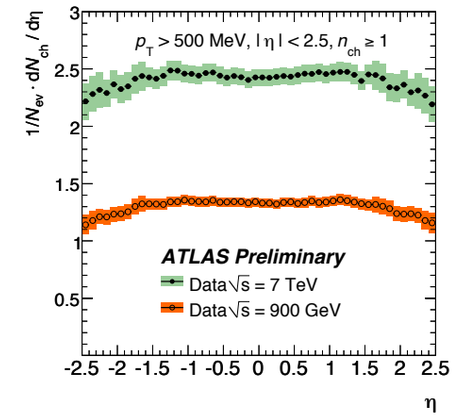

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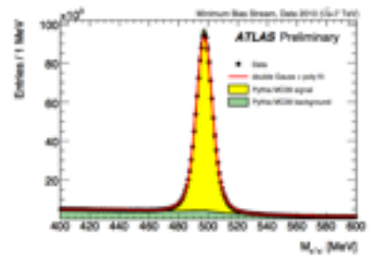
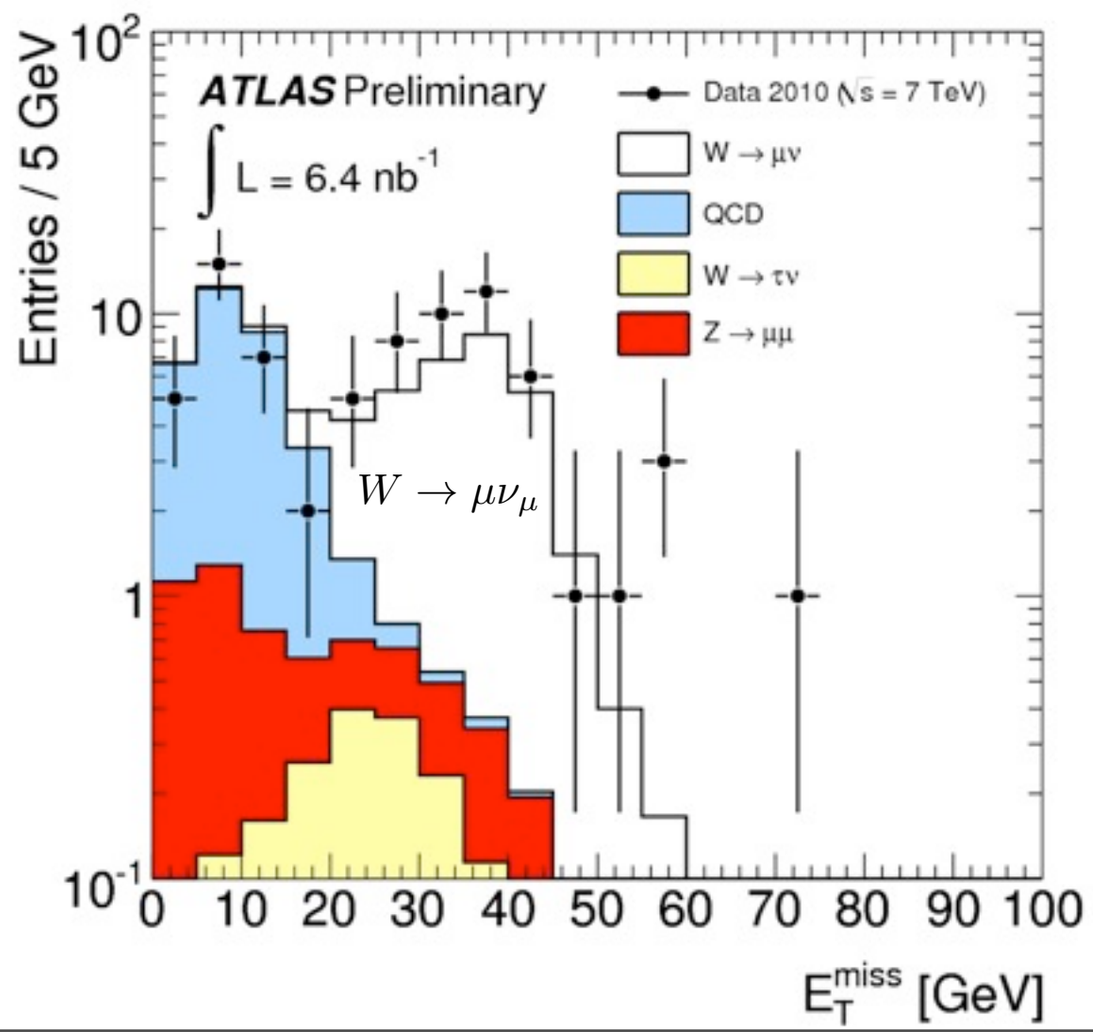
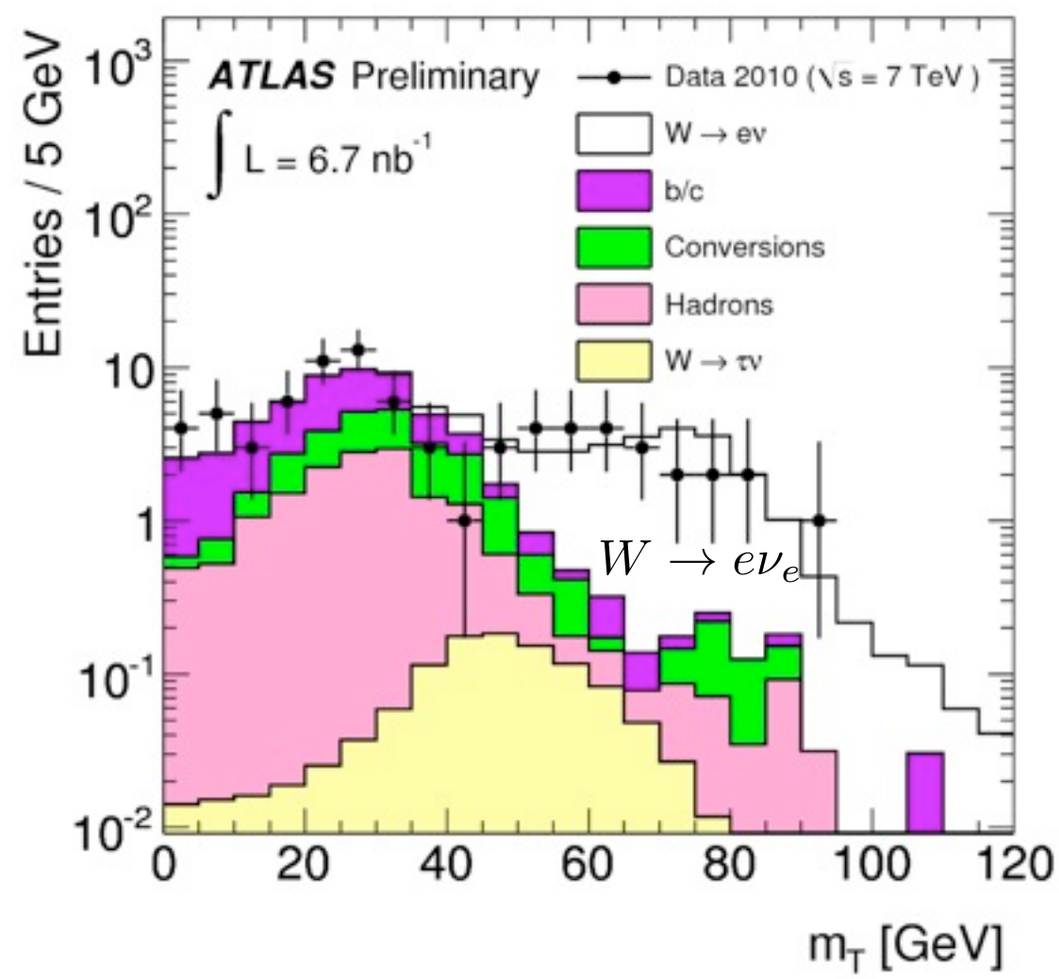


- W and Z boson observation





LHC Physics In The Coming Year

- We will run at 7 TeV until we collect 1 fb^{-1}.

Summer 2010	End of 2010	Fall 2011
$\sim 1\ pb^{-1}$	$\sim 100\ pb^{-1}$	$\sim 1000\ pb^{-1} = 1\ fb^{-1}$

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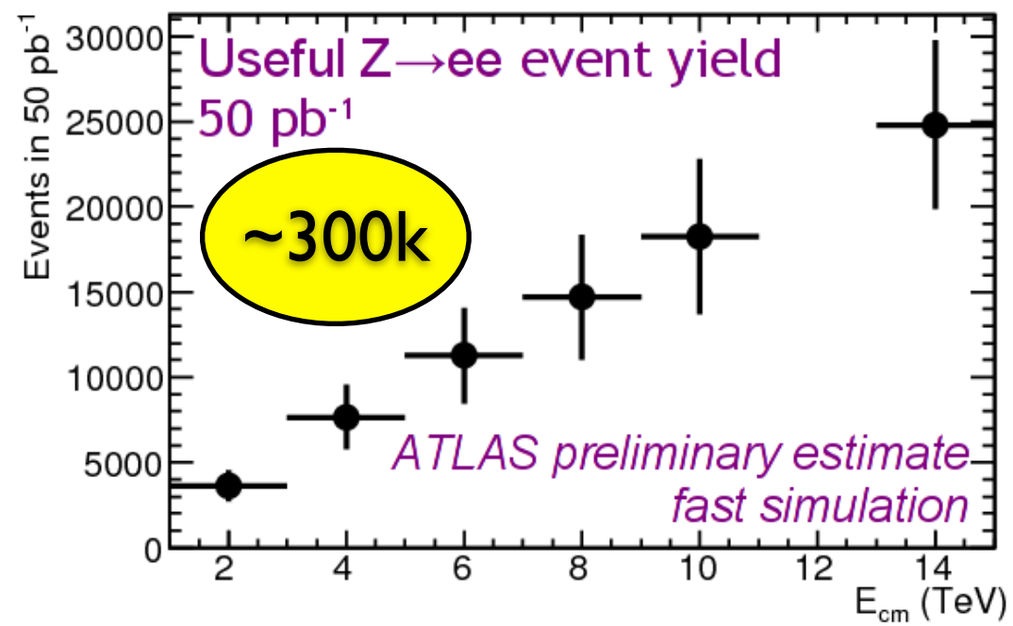
- Resonances are great! → Calibrate lepton/photon energy and momentum scales.
  - $Z \to ee/\mu\mu/\tau\tau$; $J/\psi \to ee/\mu\mu$; $\pi^0 \to \gamma\gamma$



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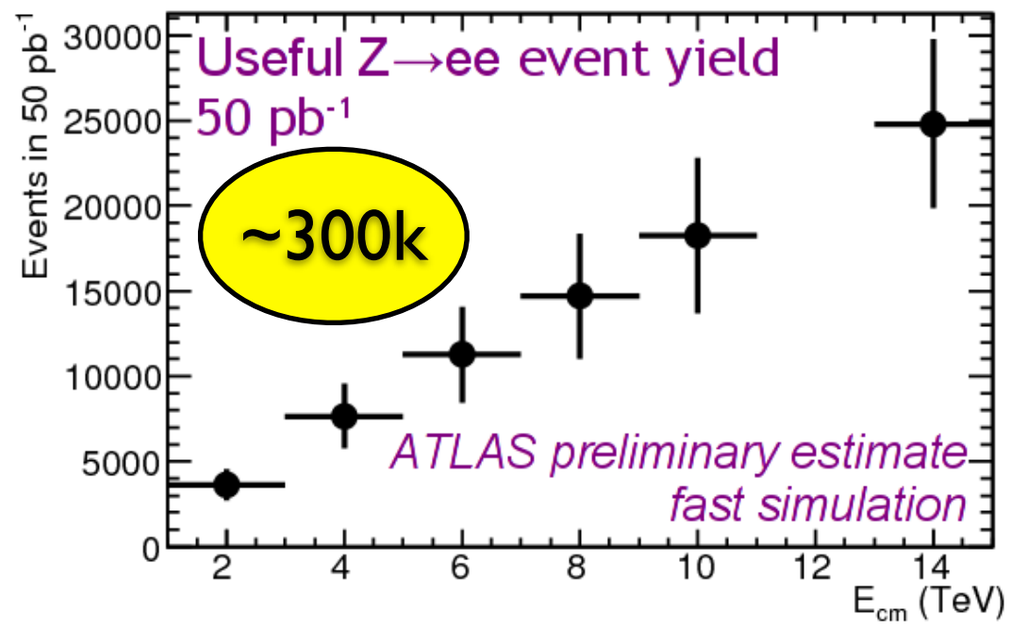
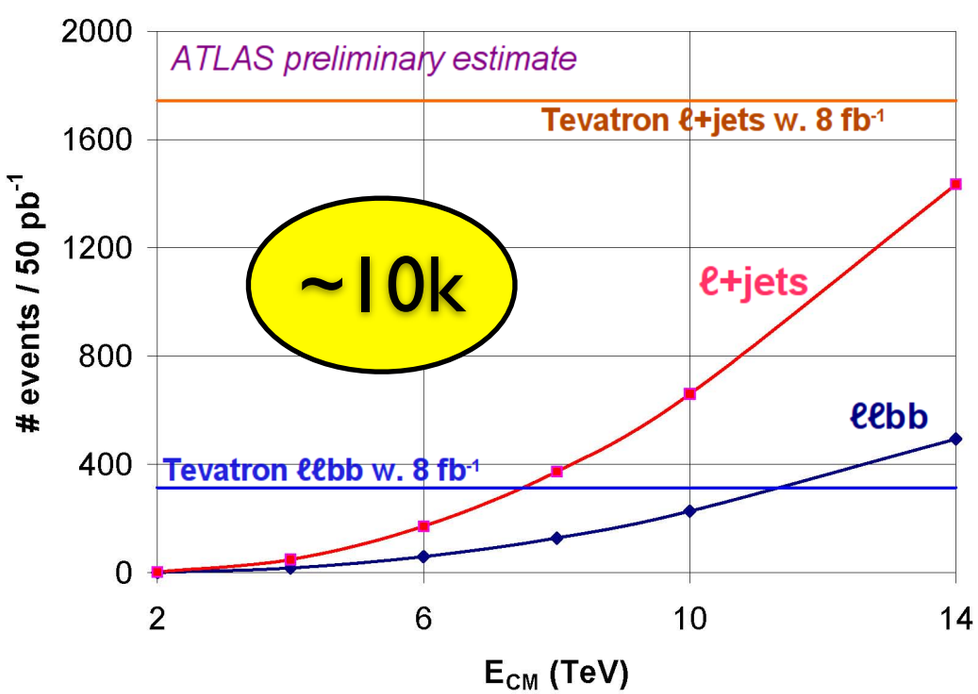
Summer 2010	End of 2010	Fall 2011
~ 1 pb^{-1}	~ 100 pb^{-1}	~ 1000 pb^{-1} = 1 fb^{-1}

- Resonances are great! → Calibrate lepton/photon energy and momentum scales.
  - $Z \to ee/\mu\mu/\tau\tau$; $J/\psi \to ee/\mu\mu$; $\pi^0 \to \gamma\gamma$

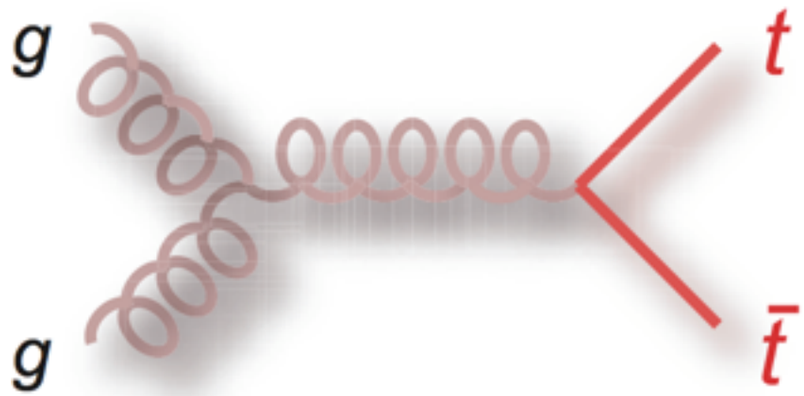


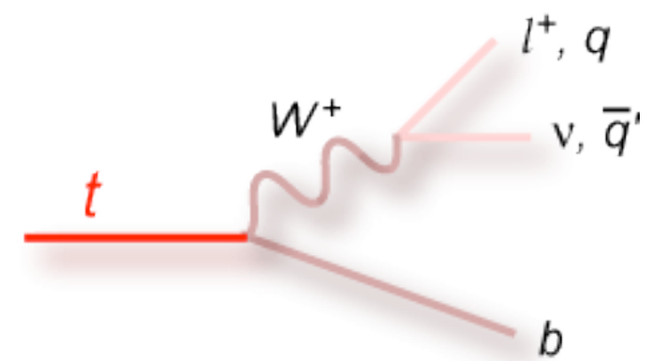


- $t \to Wb$ ($W \to jj$) , dijets, and γ+jets → JES scale.
- $t \to Wb$ (top mass helps b-jet calibration)
- W and top events → missing E_T modeling

Early Top Quark Program @ LHC

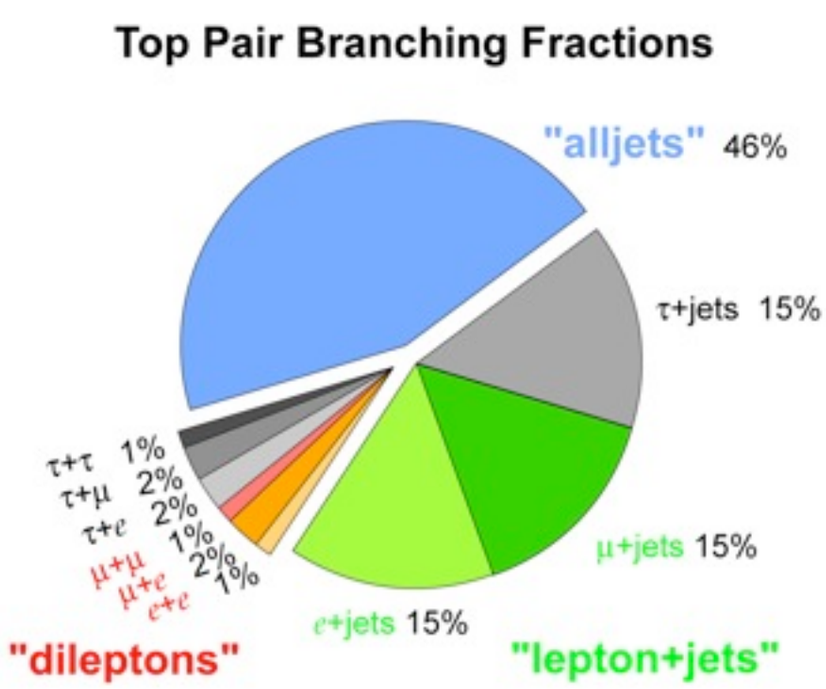
- LHC called a "top factory": $X_{LHC} << X_{Tevatron}$





tops don't hadronize and decay ~100% to Wb

- Analyses organized by W decays:



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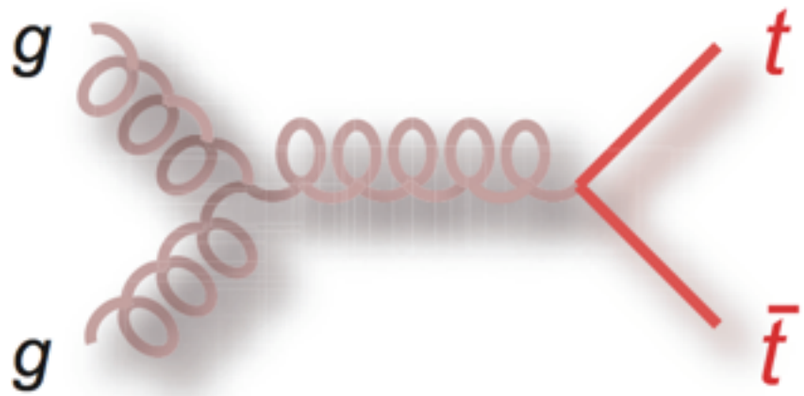
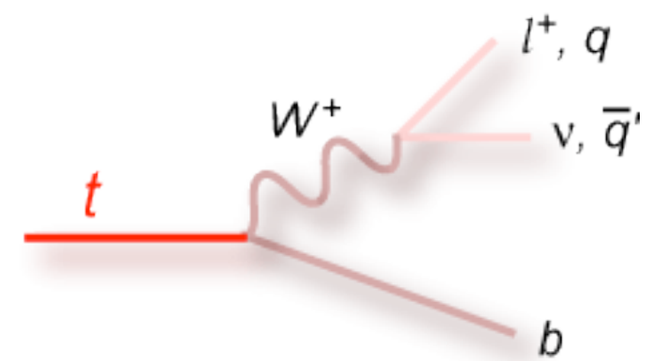
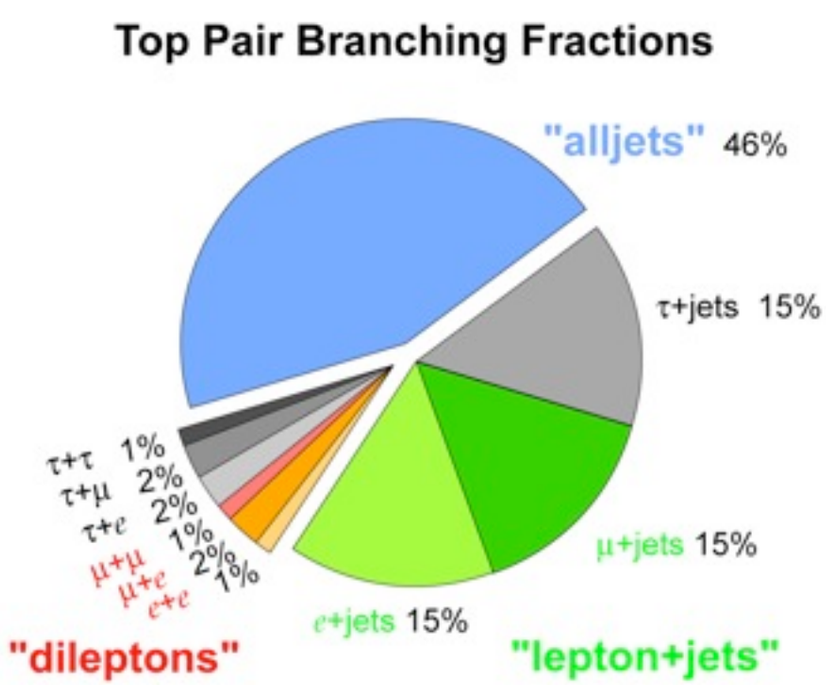




tops don't hadronize and decay ~100% to Wb

- Top already seen with 10 pb^{-1} in dilepton channels



Channel	N(Signal)	N(background)
e - μ	14	2.5
$e - e$	4.3	1.1
μ – μ	6.6	1.9
Total	**25**	**5.5**

ATL-PHYS-PUB-2009-086 + scaling to 10 pb^{-1} @ 7 TeV.

Early Top Quark Program @ LHC

the ATLAS Experiment

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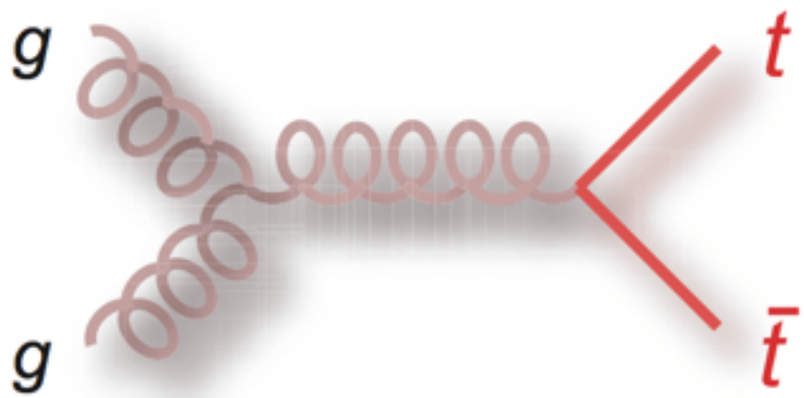
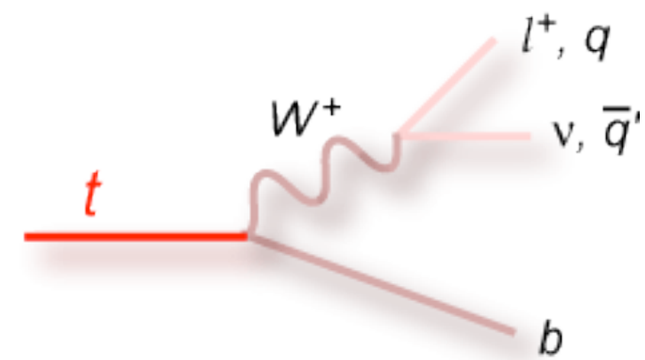
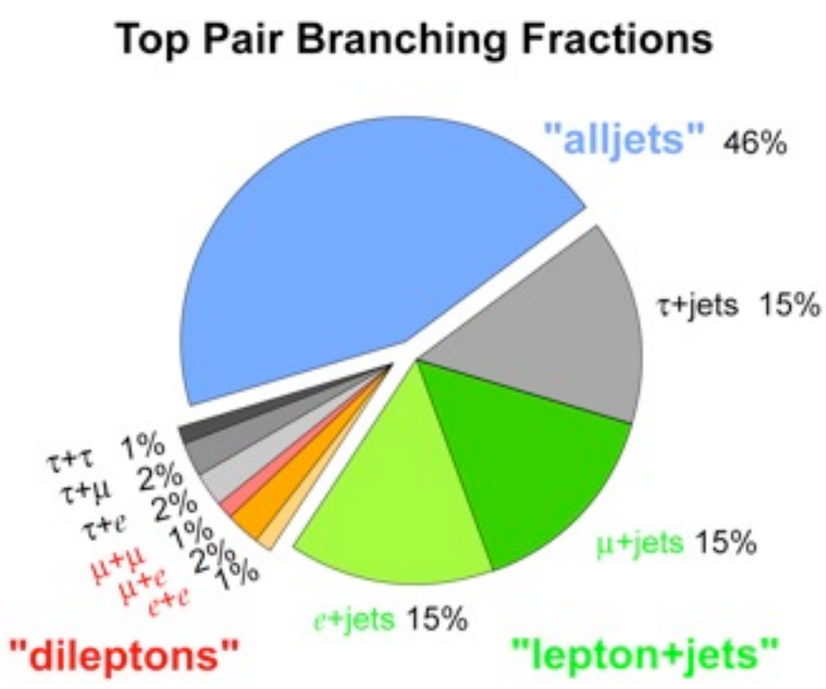
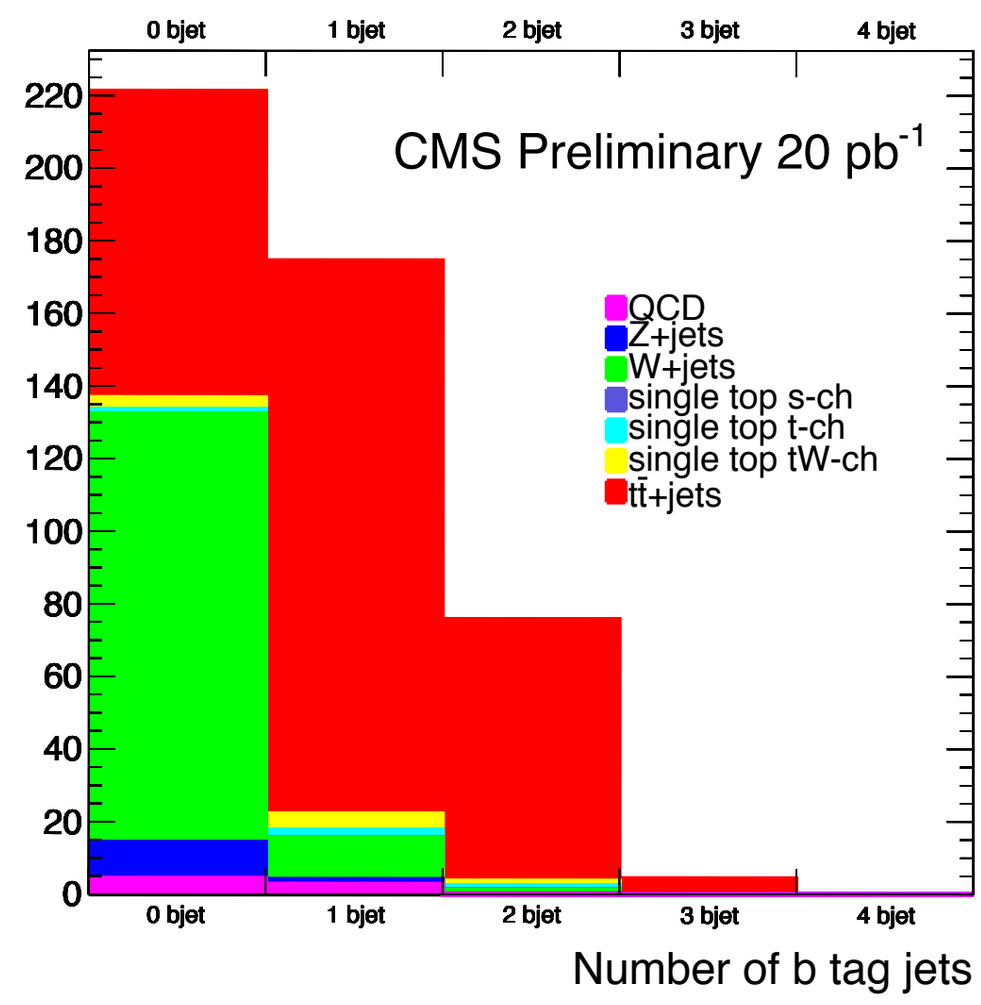




tops don't hadronize and decay ~100% to Wb

- Soon followed by lepton+jets channel with 20-50 pb^{-1}.





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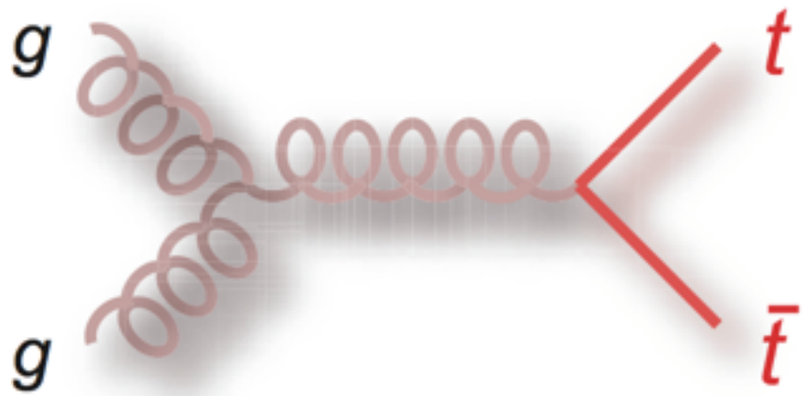
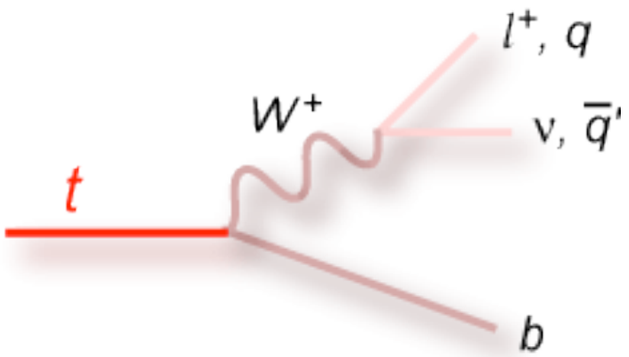
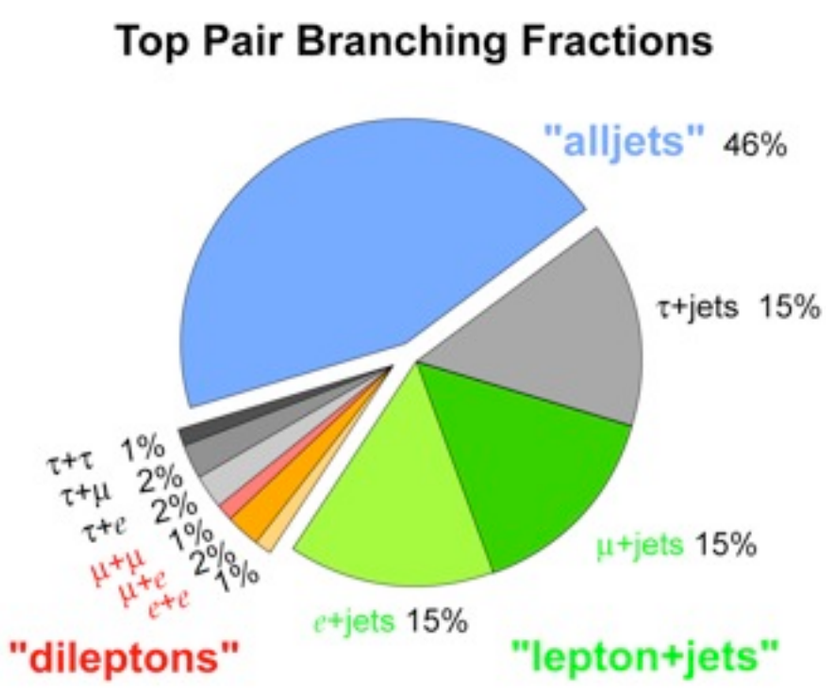
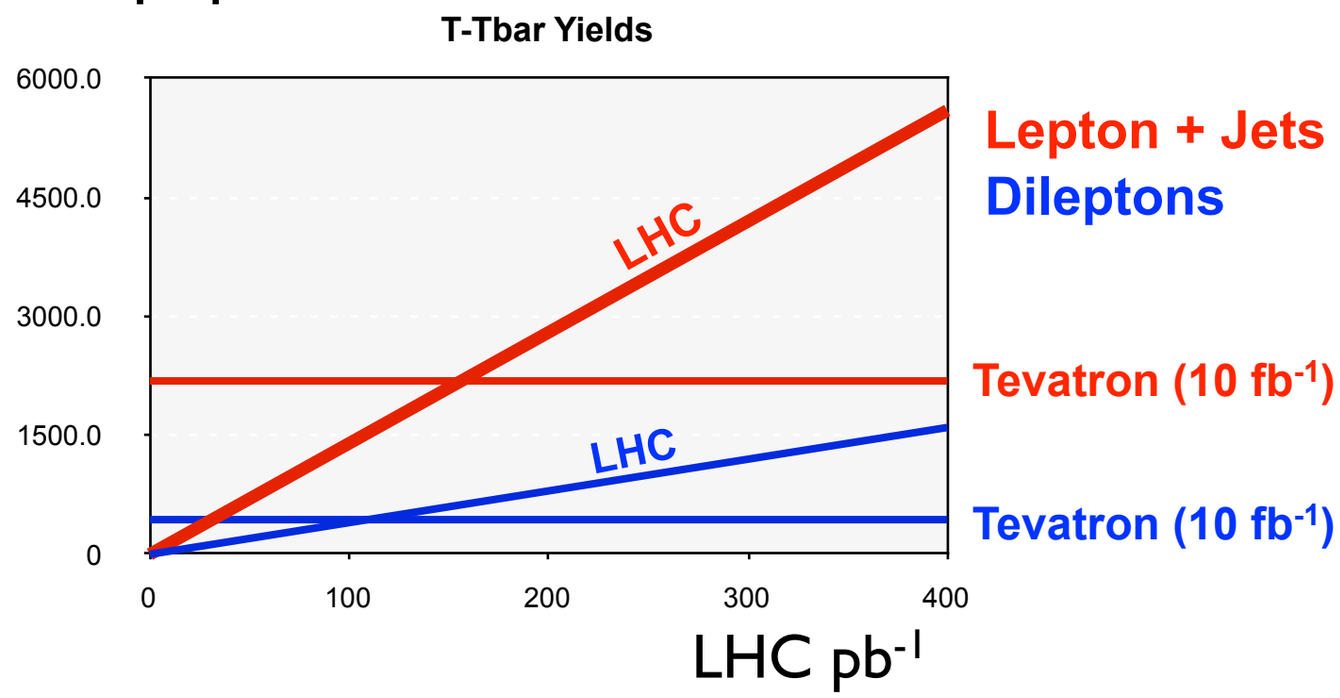




tops don't hadronize and decay ~100% to Wb

- Early next year LHC will have more top quarks than the Tevatron

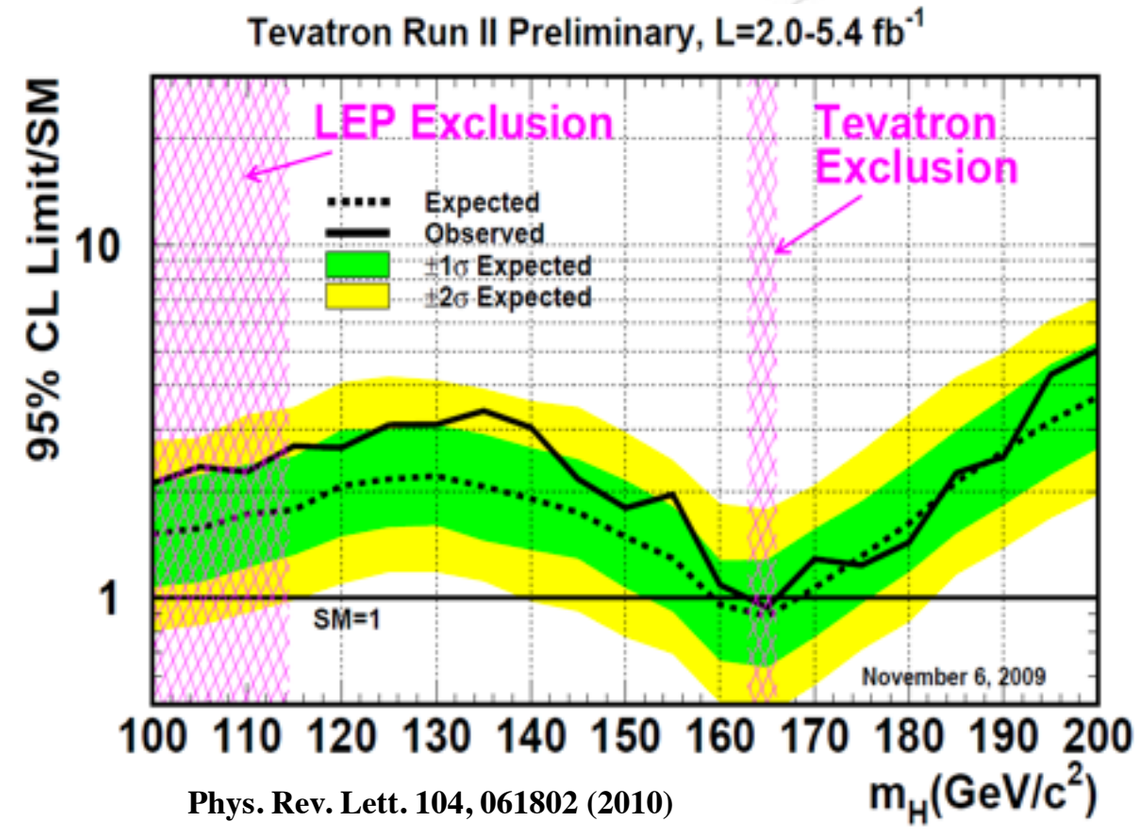




By end of year LHC will approach current Tevatron top quark yields

Higgs In 2010/2011

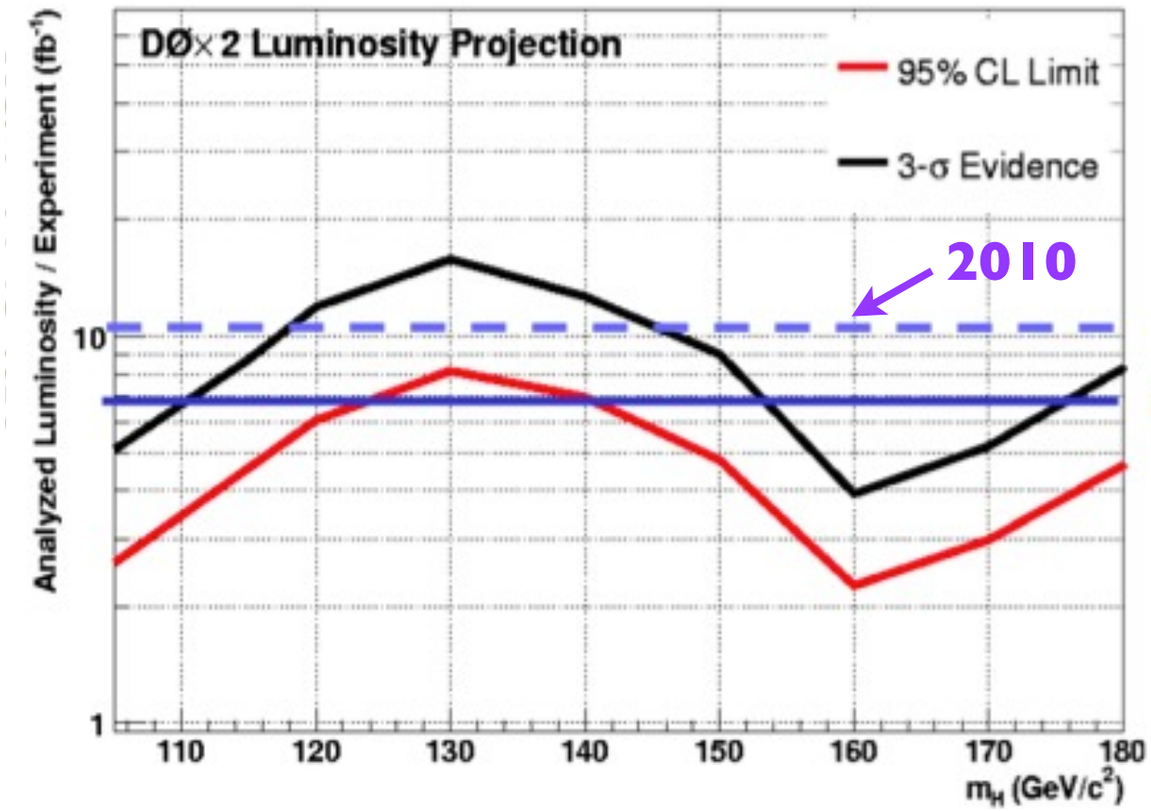
- Tevatron already excluding Higgs!



Phys. Rev. Lett. 104, 061802 (2010)

Higgs In 2010/2011

- Tevatron already excluding Higgs!
- Can expect 2x more data and several analysis improvements in the next few years.
- Anything left for the LHC?



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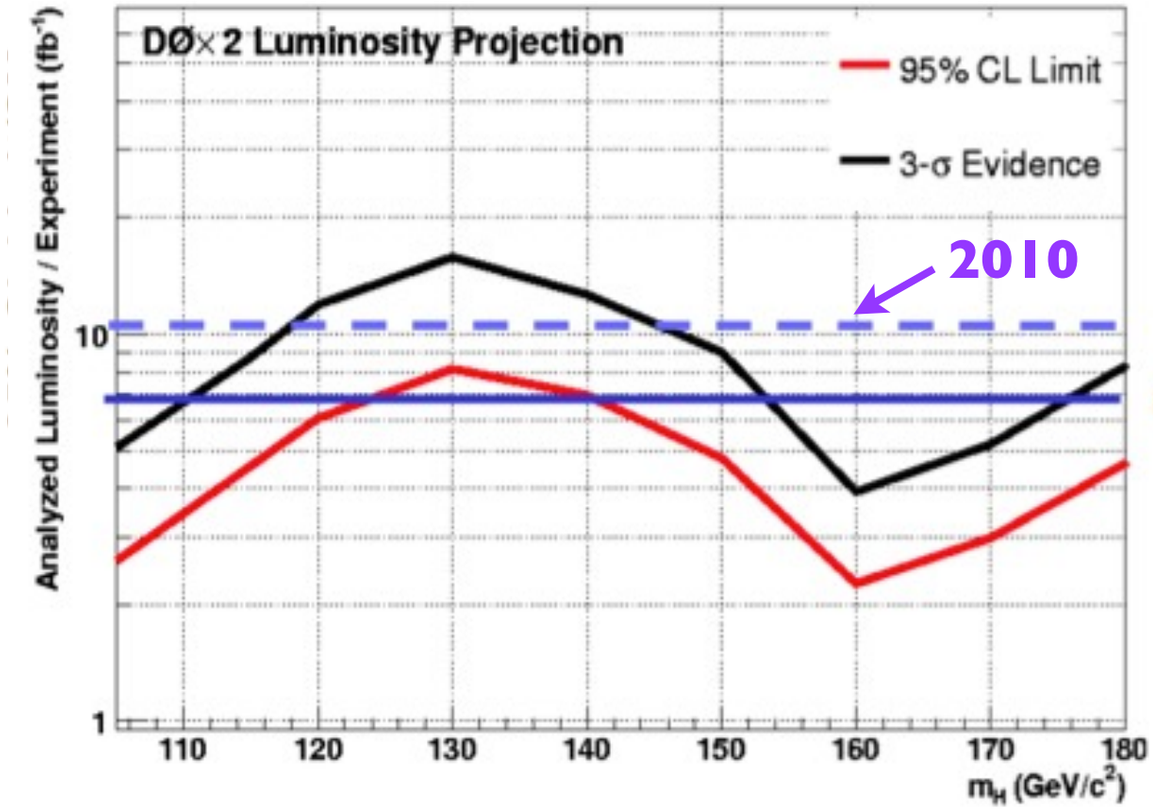

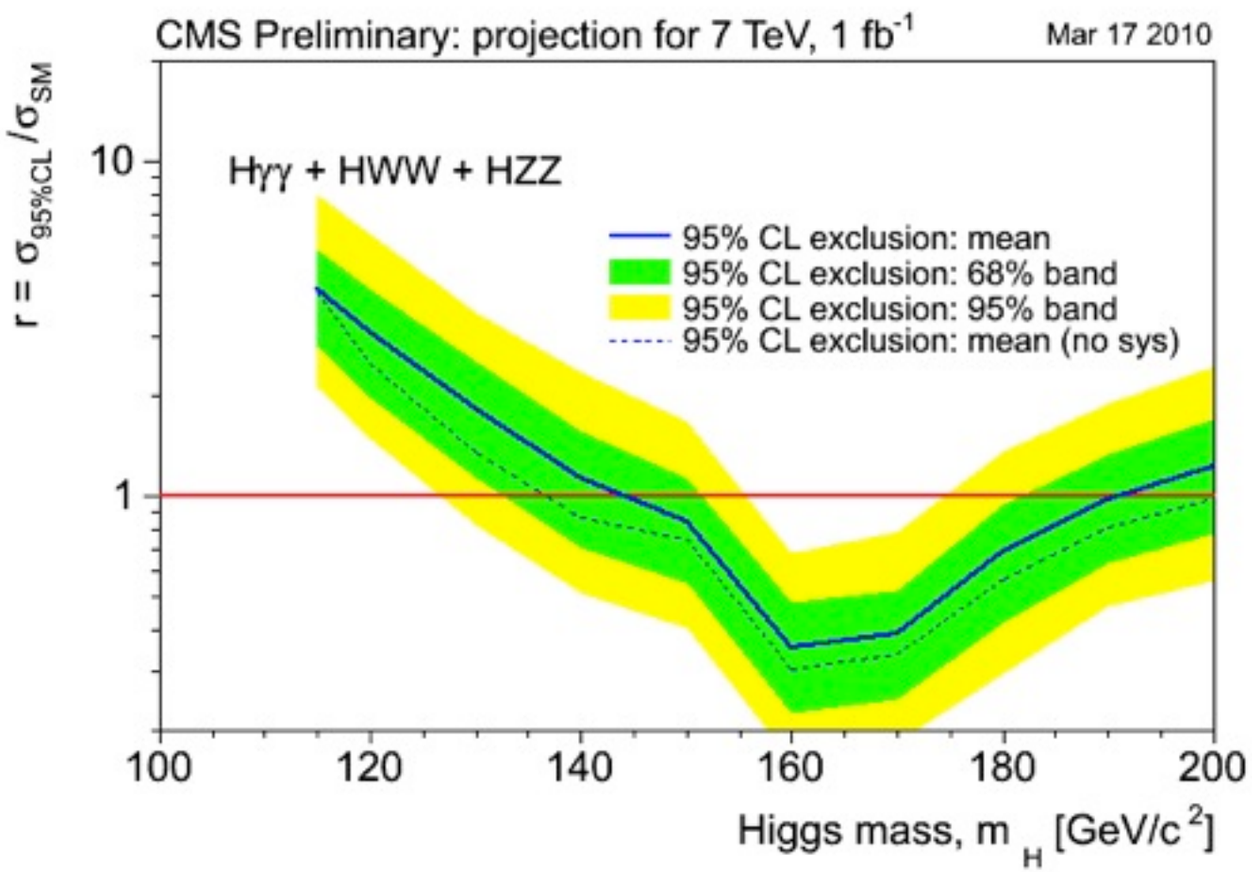

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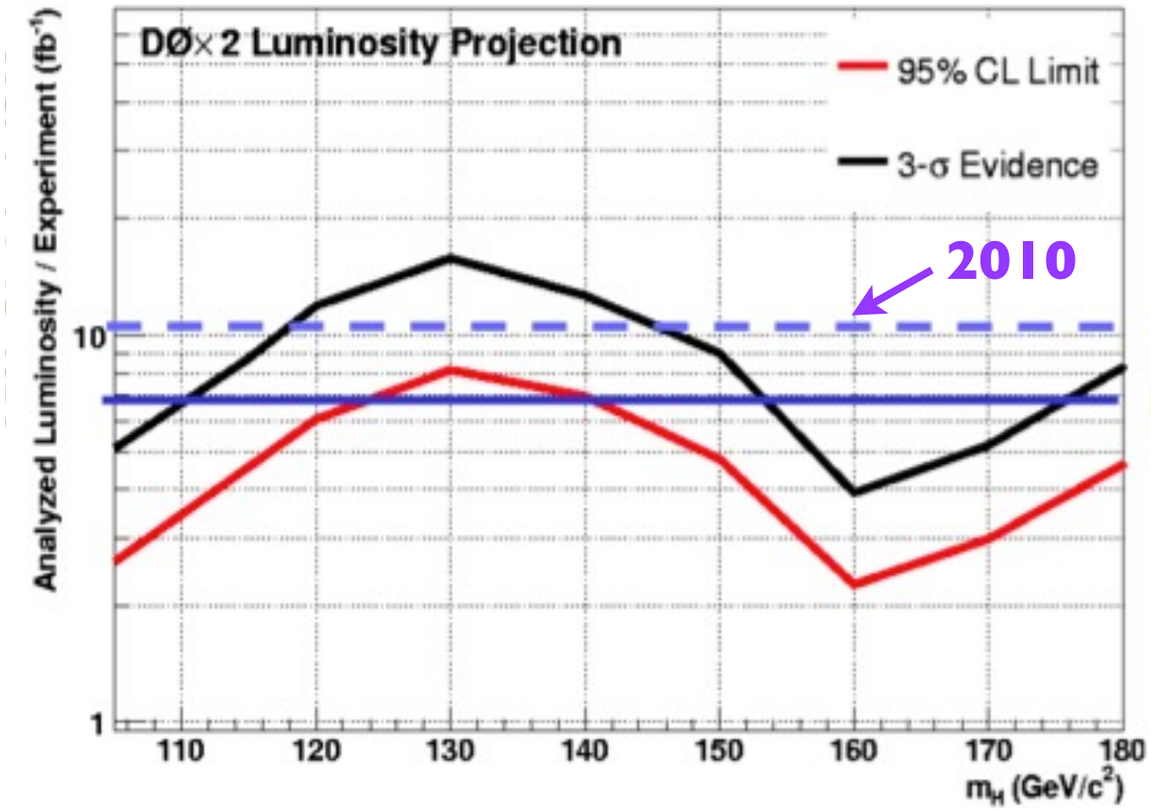
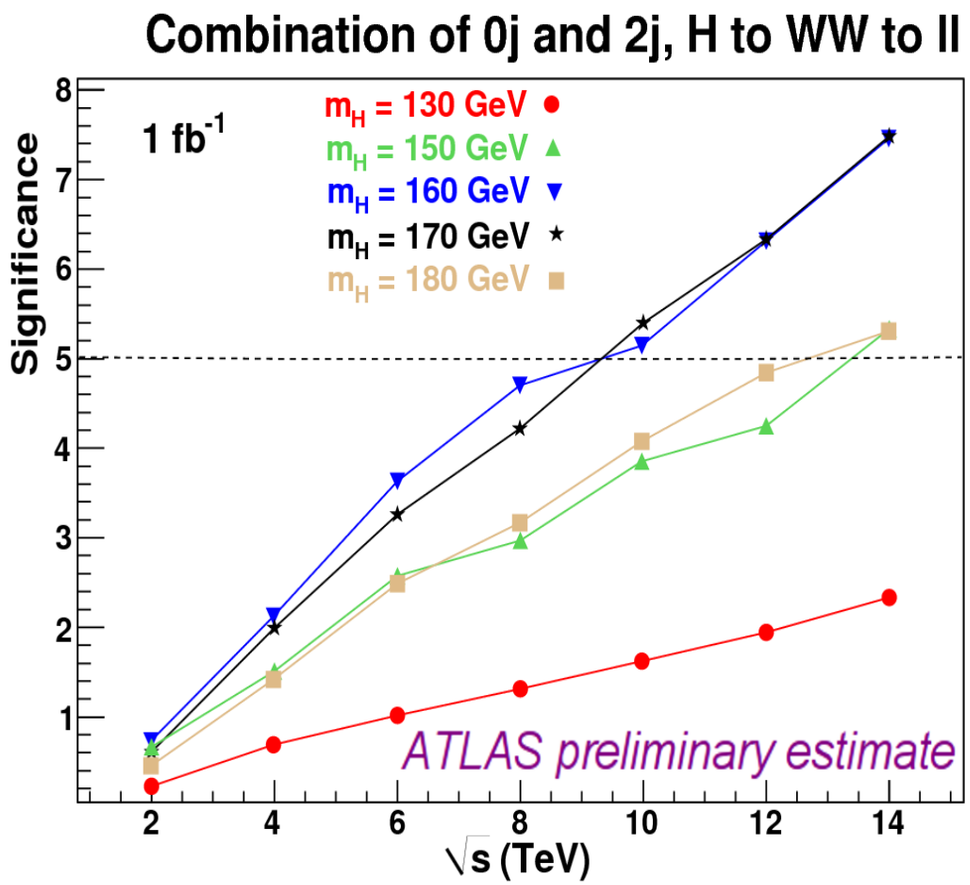




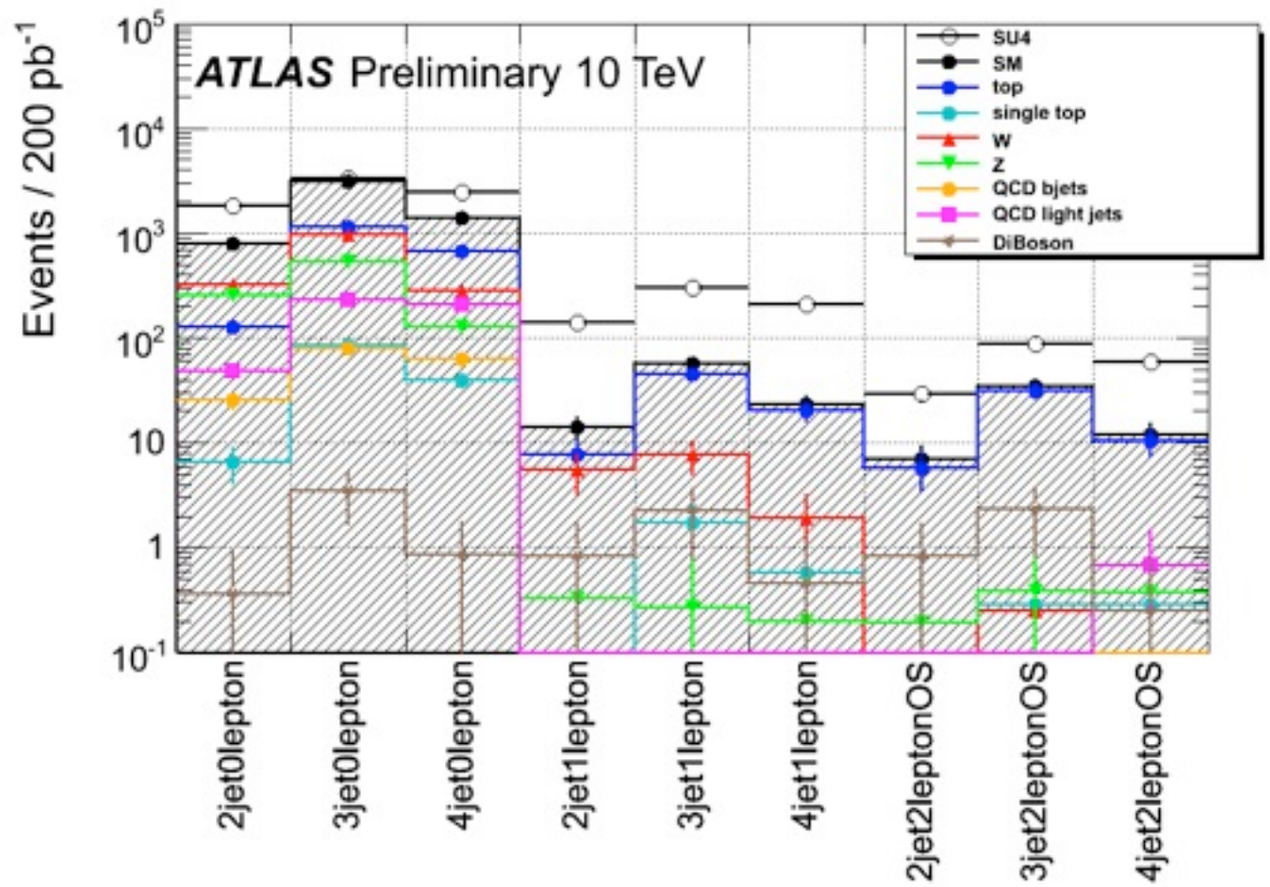
- 1 experiment with 1 fb^{-1} can also exclude Higgs if $140 < M_H < 200$
- Expect to see hints of Higgs with 1 fb-1 is mass is [150,180]
- 5σ discovery or full exclusion over entire mass range will require more data.

SUSY In 2010/2011

- SUSY can lead to signals in many channels.

Example: 200 pb^{-1} @10 TeV (~ 700 pb^{-1} @ 7 TeV)

- Most SUSY searches have top pair production as largest background.
- Controlling systematics (e.g. top) important for these searches.



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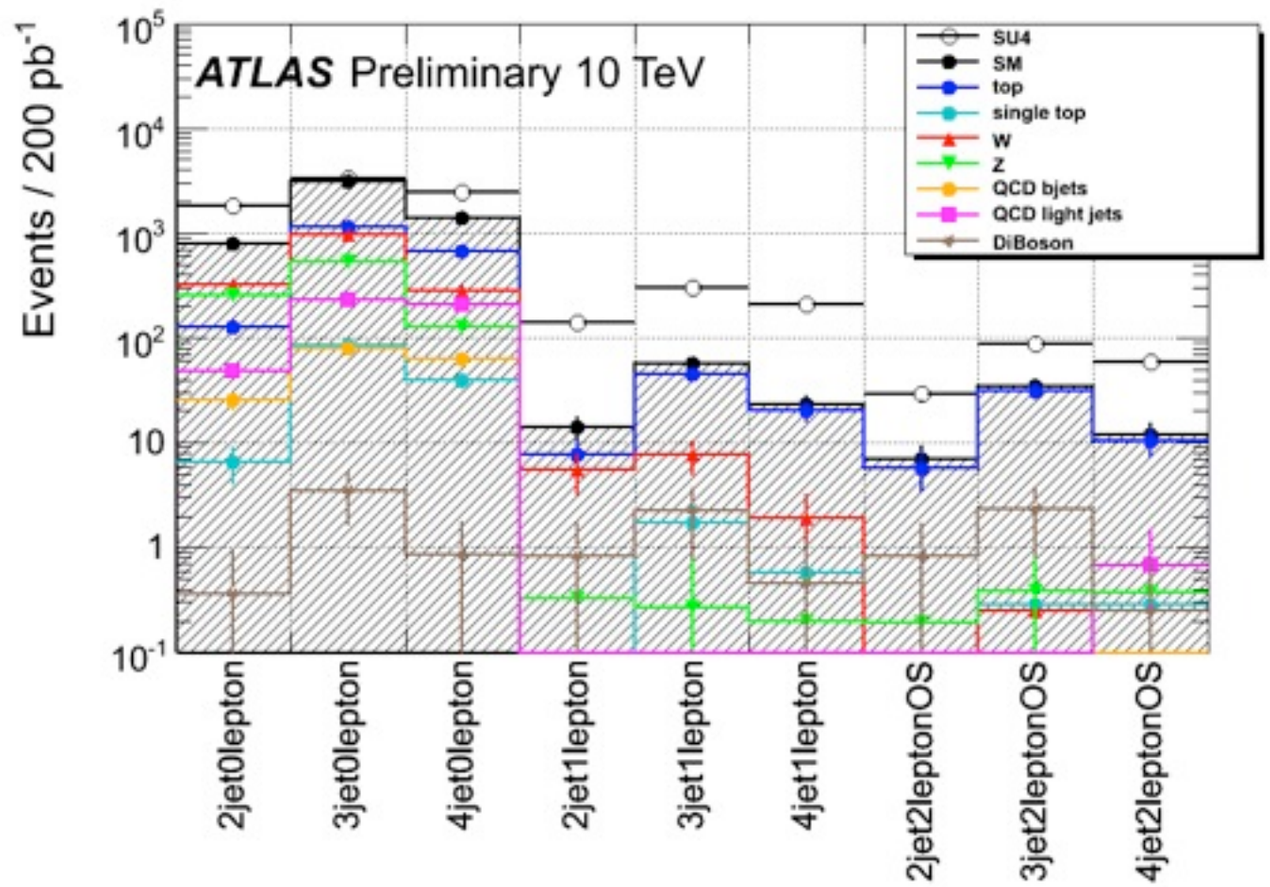

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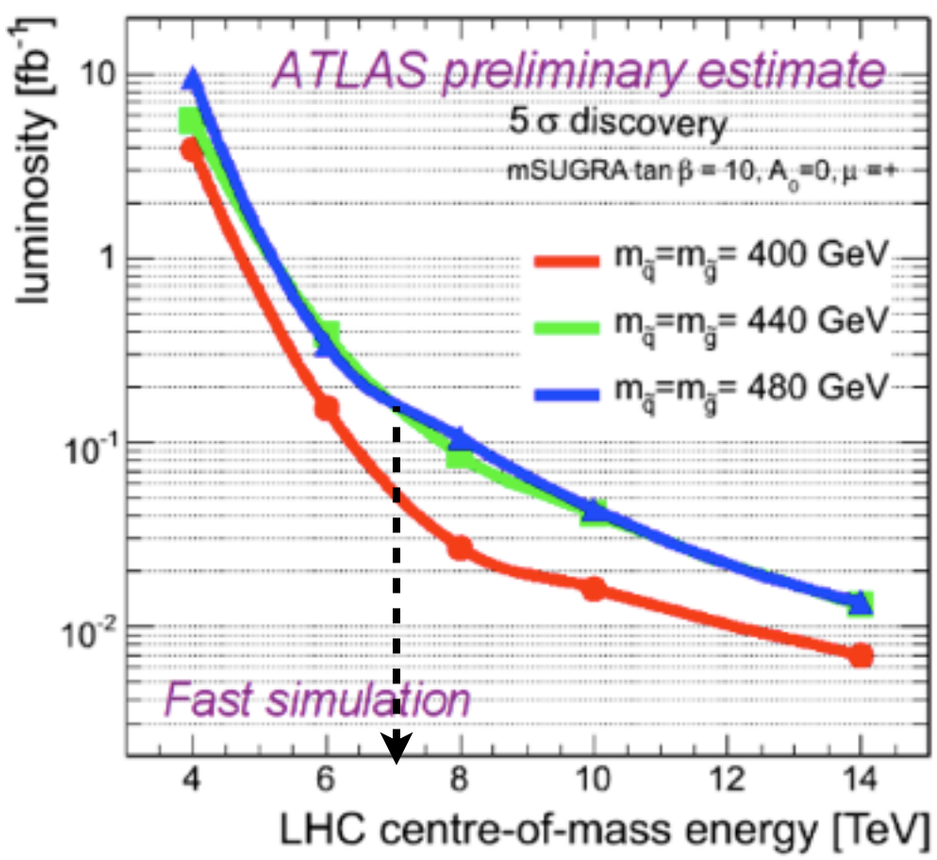

- Extend Tevatron squark/gluino limits with O(100 pb^{-1}).
- Ongoing work to present results in more model-independent approach.
- Increasing $\sqrt{s}$ really helps this search.

What Else Can We Find?

the ATLAS Experiment

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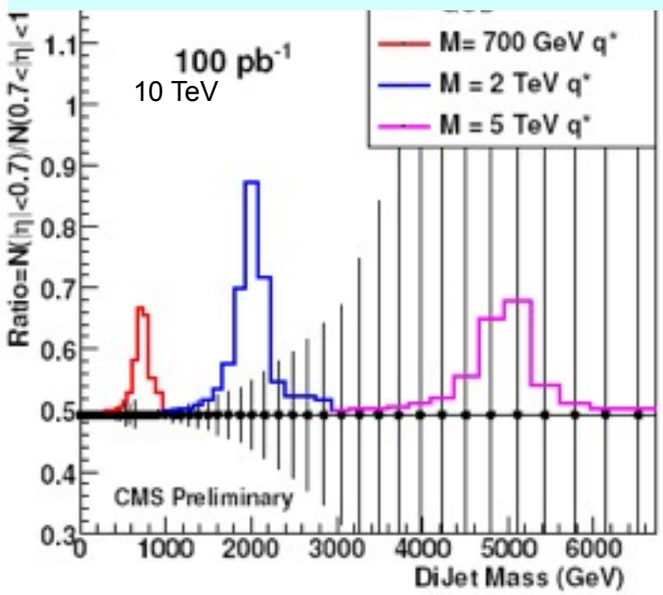
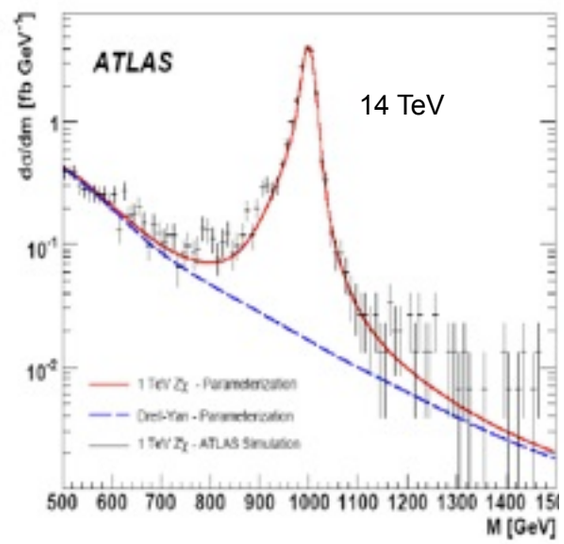
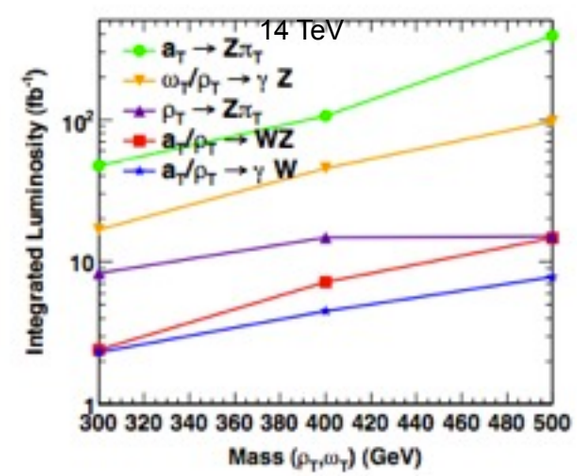
Contact Interaction /Excited Quarks?



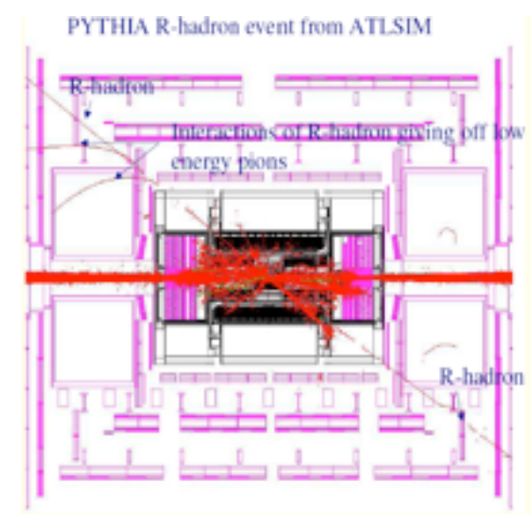
New Gauge Bosons?



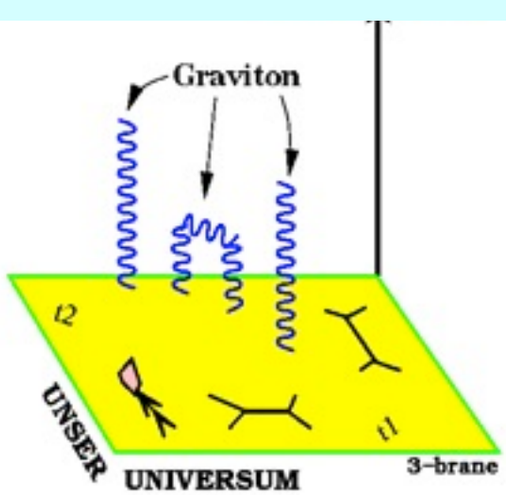
Technicolor?



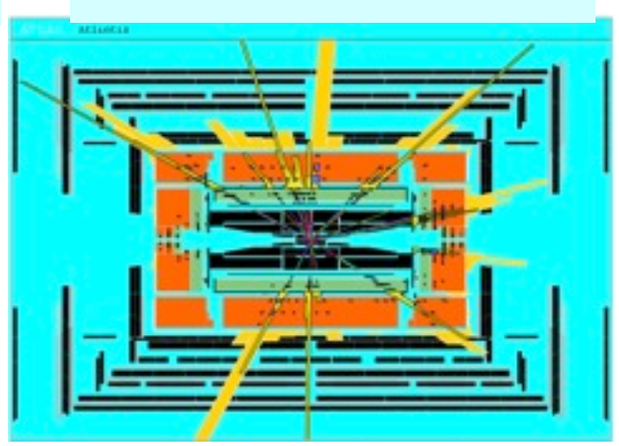
Split Susy?



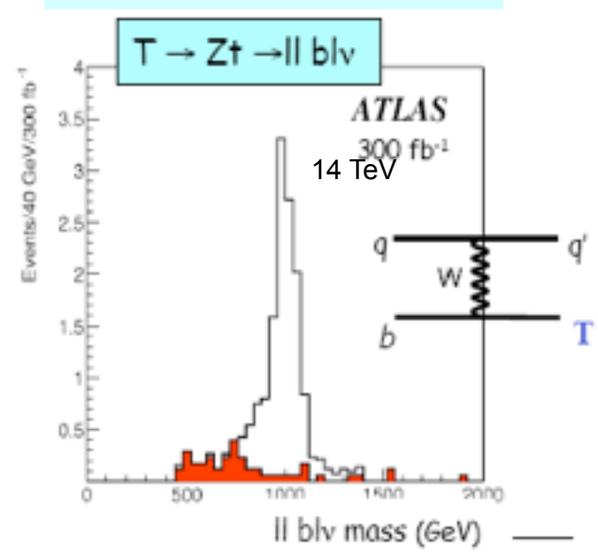
Extra Dimensions?



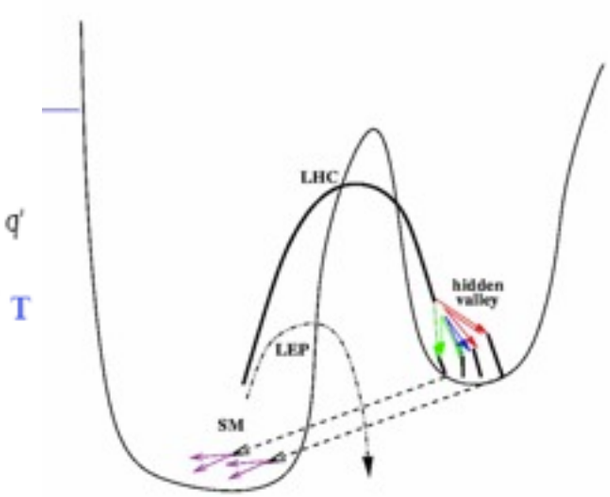
Black Holes???



Little Higgs?



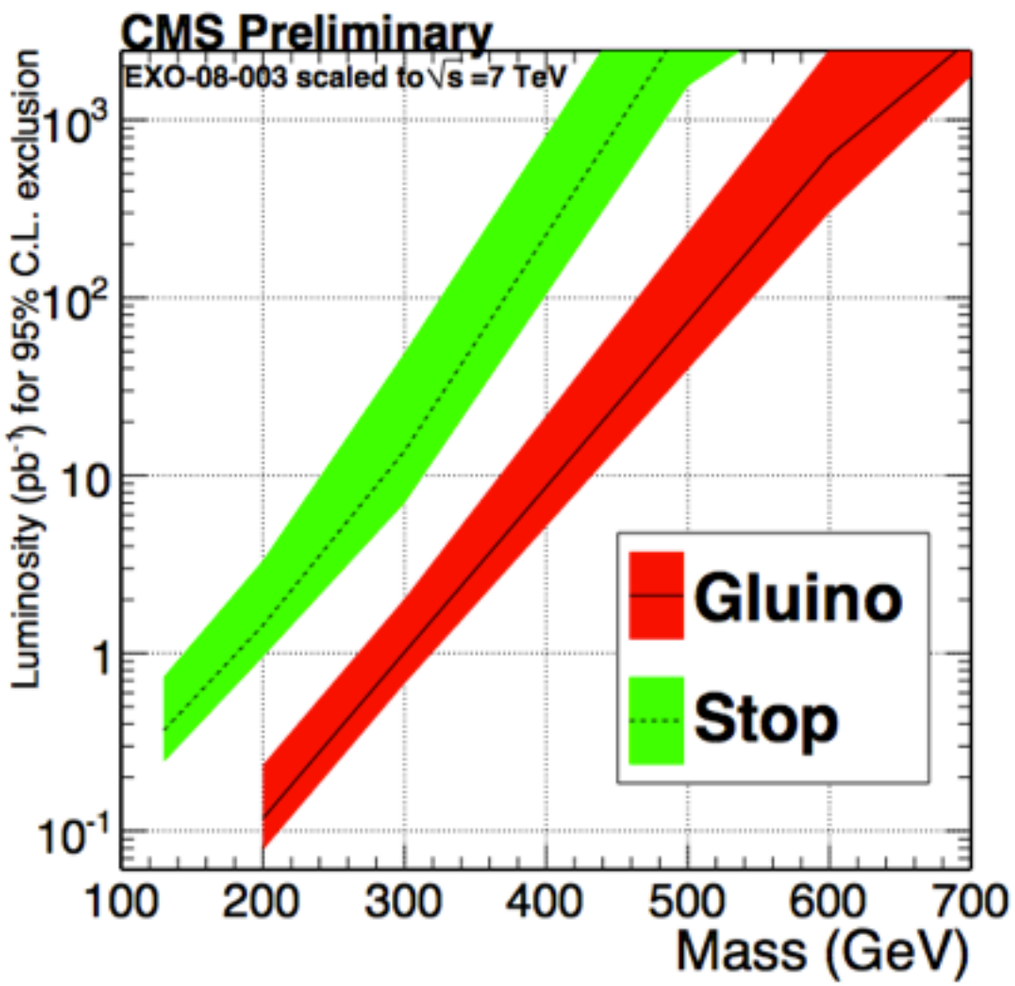
Hidden Valley??



Taken from O. Buchmüller (5/05/2010)

Exotics Reach with Early Data

- Heavy slow charged particle can be found with 1 pb^{-1}. using dE/dx from tracker.



CMS PAS EXO-08-003, scaled to 7 TeV

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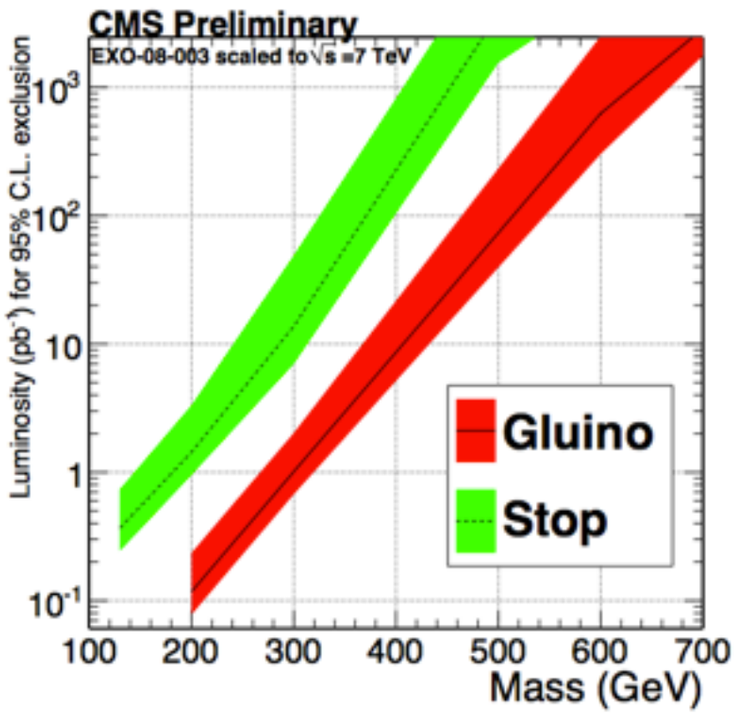
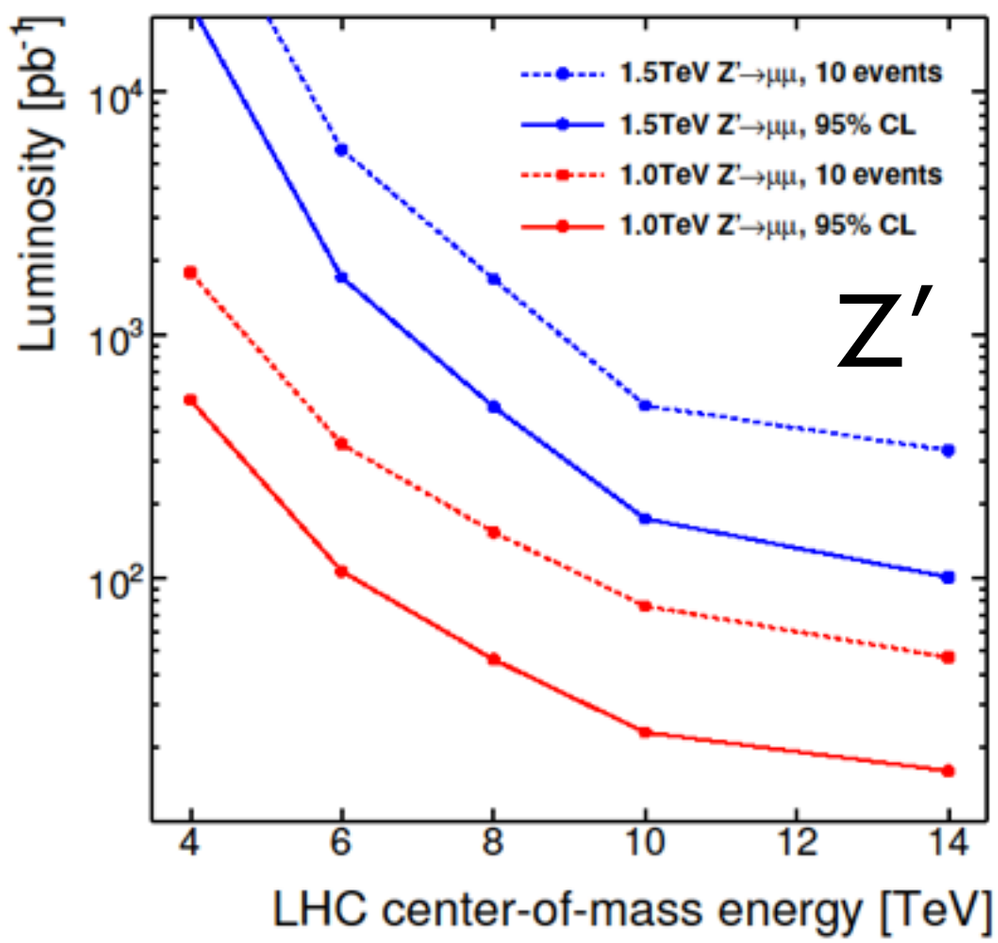


CMS PAS EXO-08-003, scaled to 7 TeV

- Z' (neutral resonance) shows up in many models → limits highly model dependent.
- Extend Tevatron limits ($M_{Z'}$ < 1 TeV) with 100 pb^{-1}.



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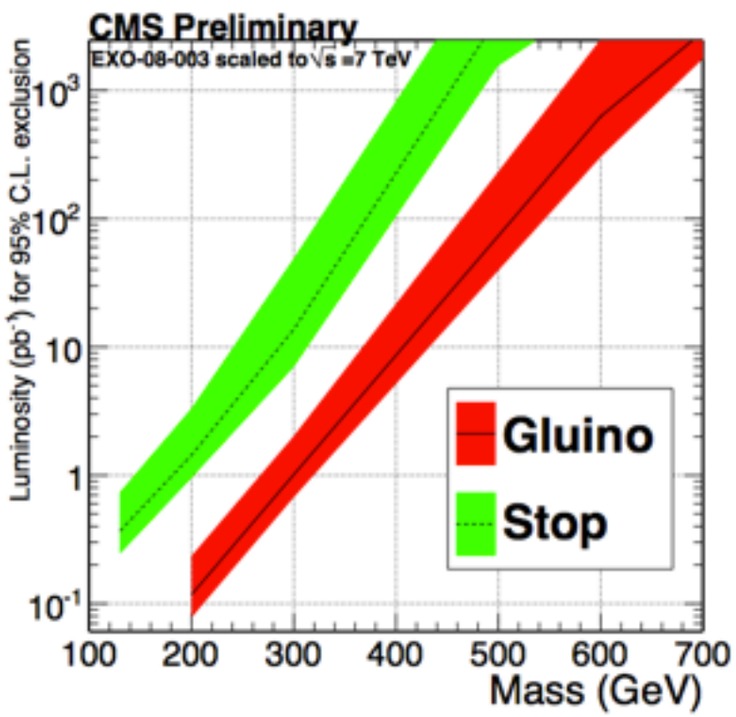

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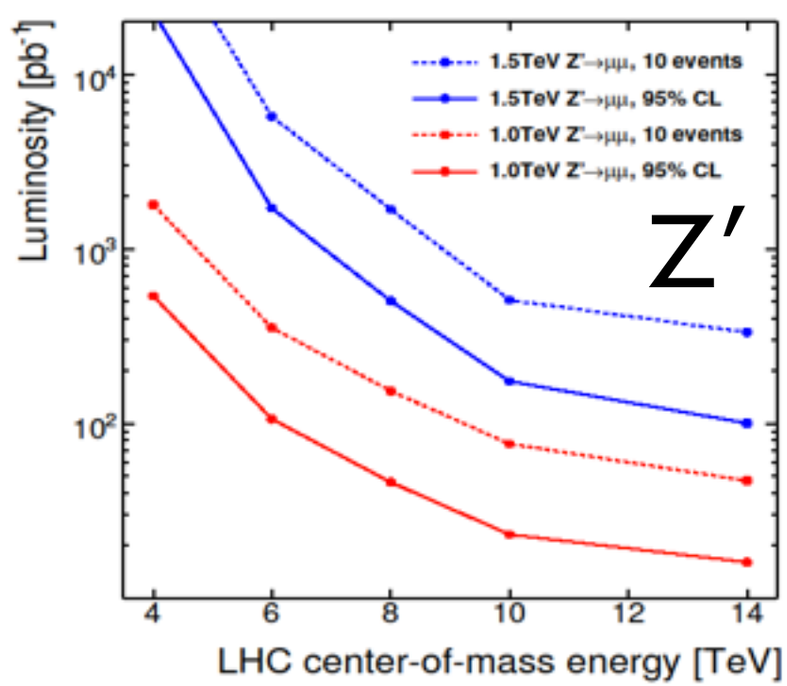

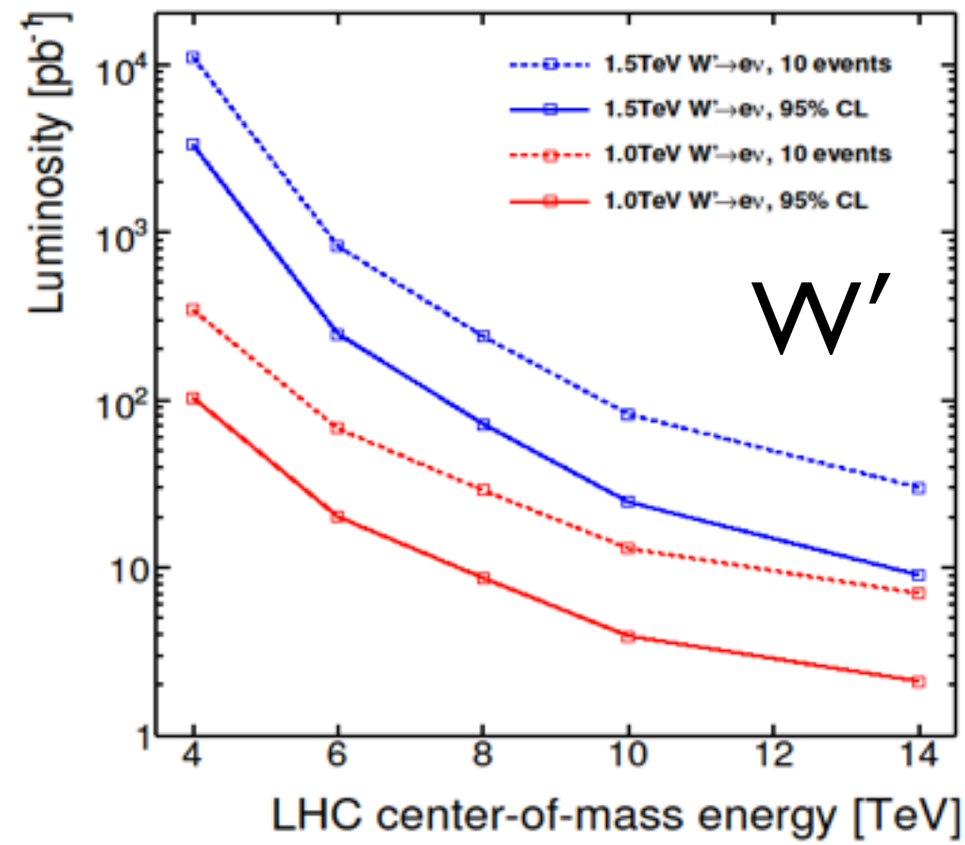

- W' (charged resonance) also shows up in many models.
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Current LHC Run Schedule

- Current 7 TeV run will last until Fall 2011 → Collect ~ 1 fb^{-1}.
  - Surpass Tevatron in top quark yield.
  - Sensitive to low mass SUSY
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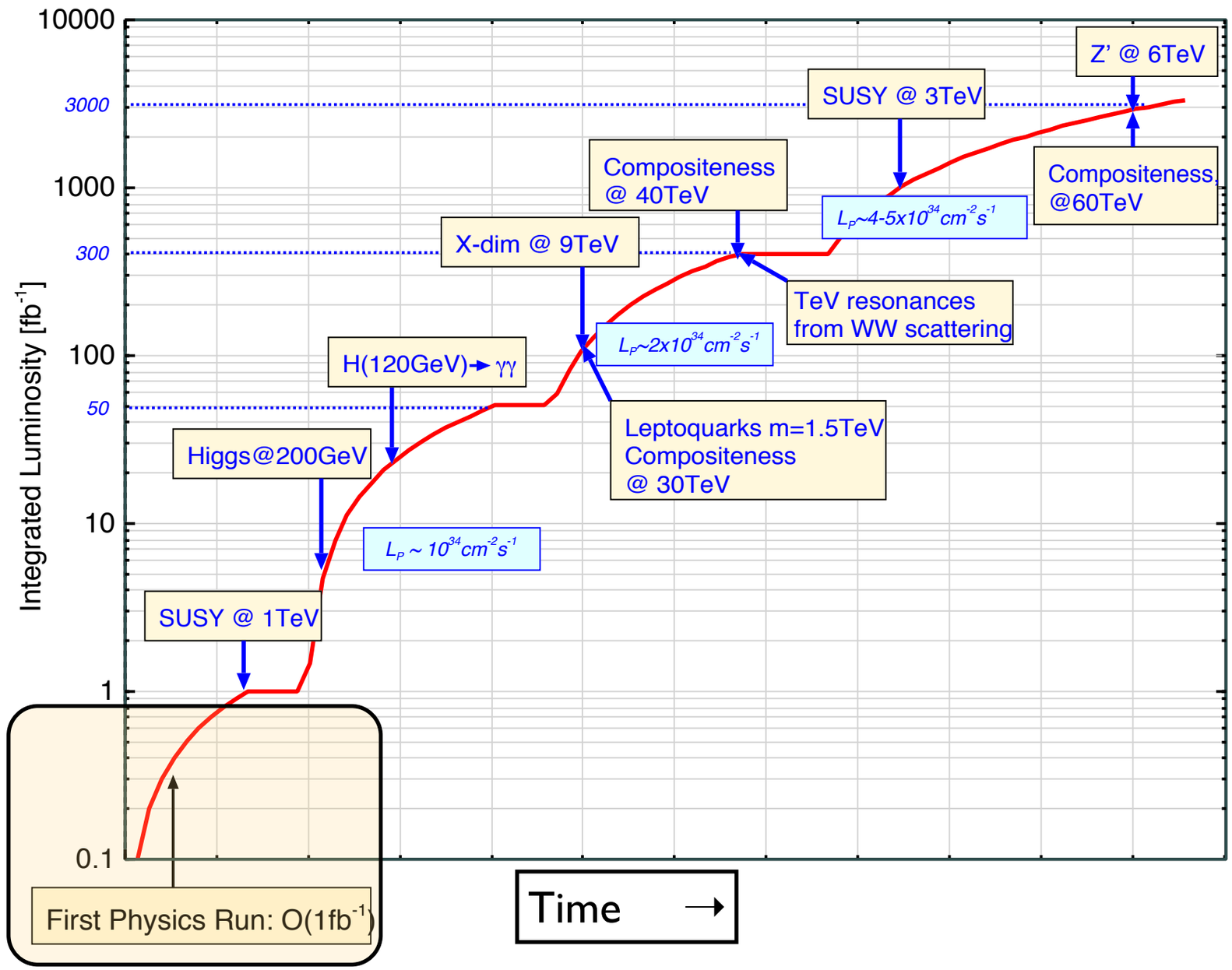

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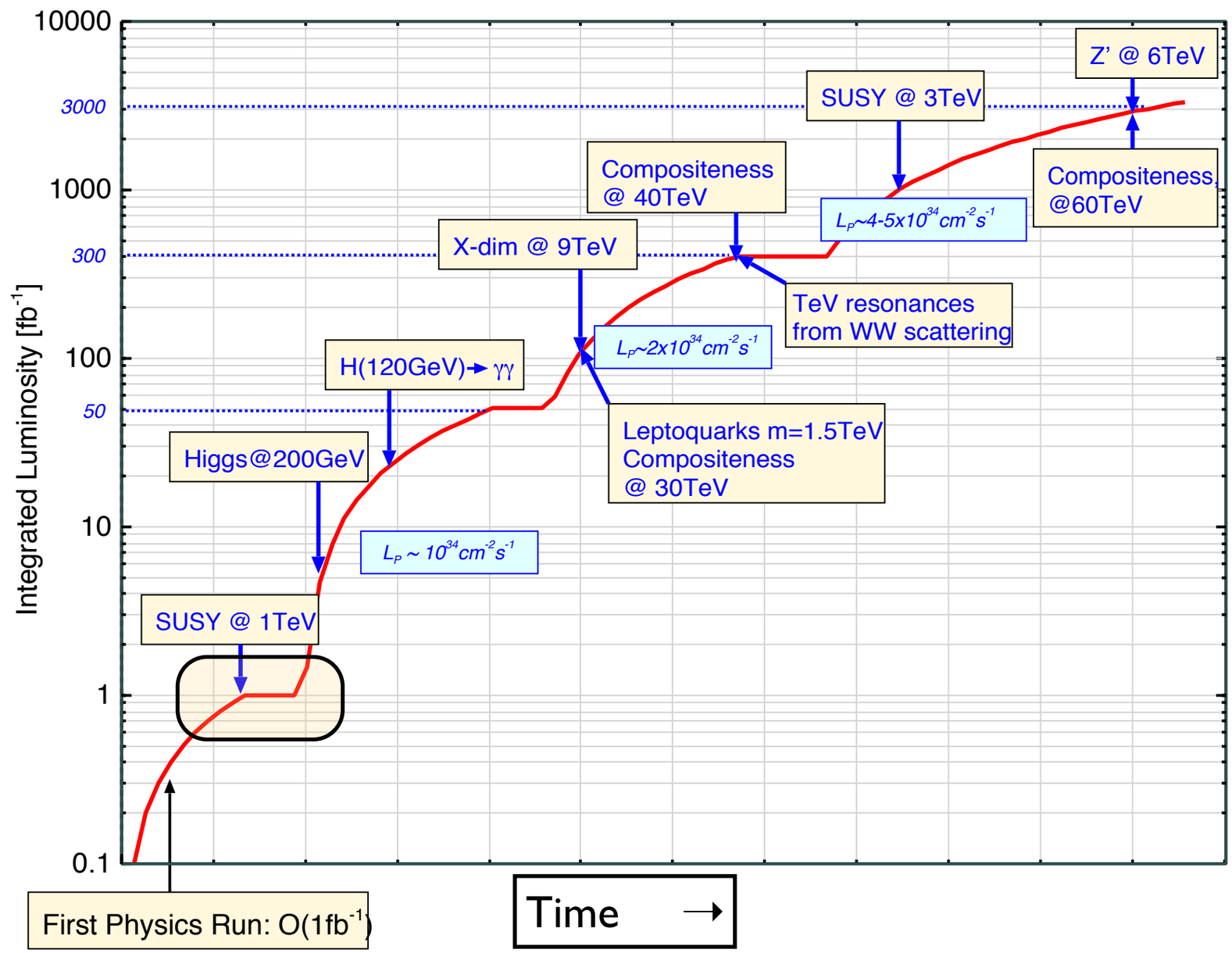

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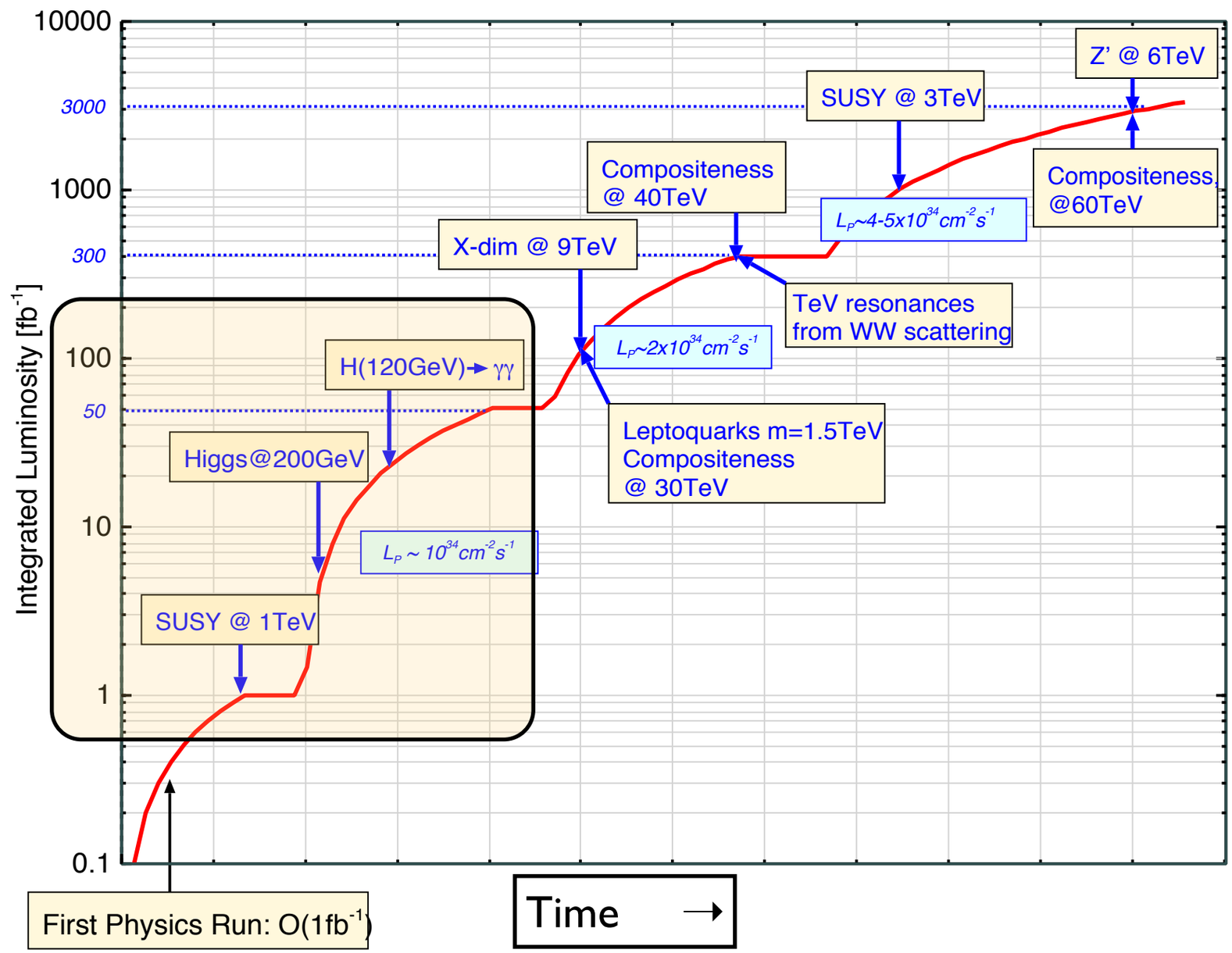
- Starting in 2013 we will run at $\sqrt{s}$ = 13 TeV with increased $\mathcal{L} \sim 10^{34}$ [$cm^{-2}\,s^{-1}$]
  - 5σ sensitivity to the Higgs w/ O(10 fb^{-1}).
  - 2-3 TeV dilepton resonances.



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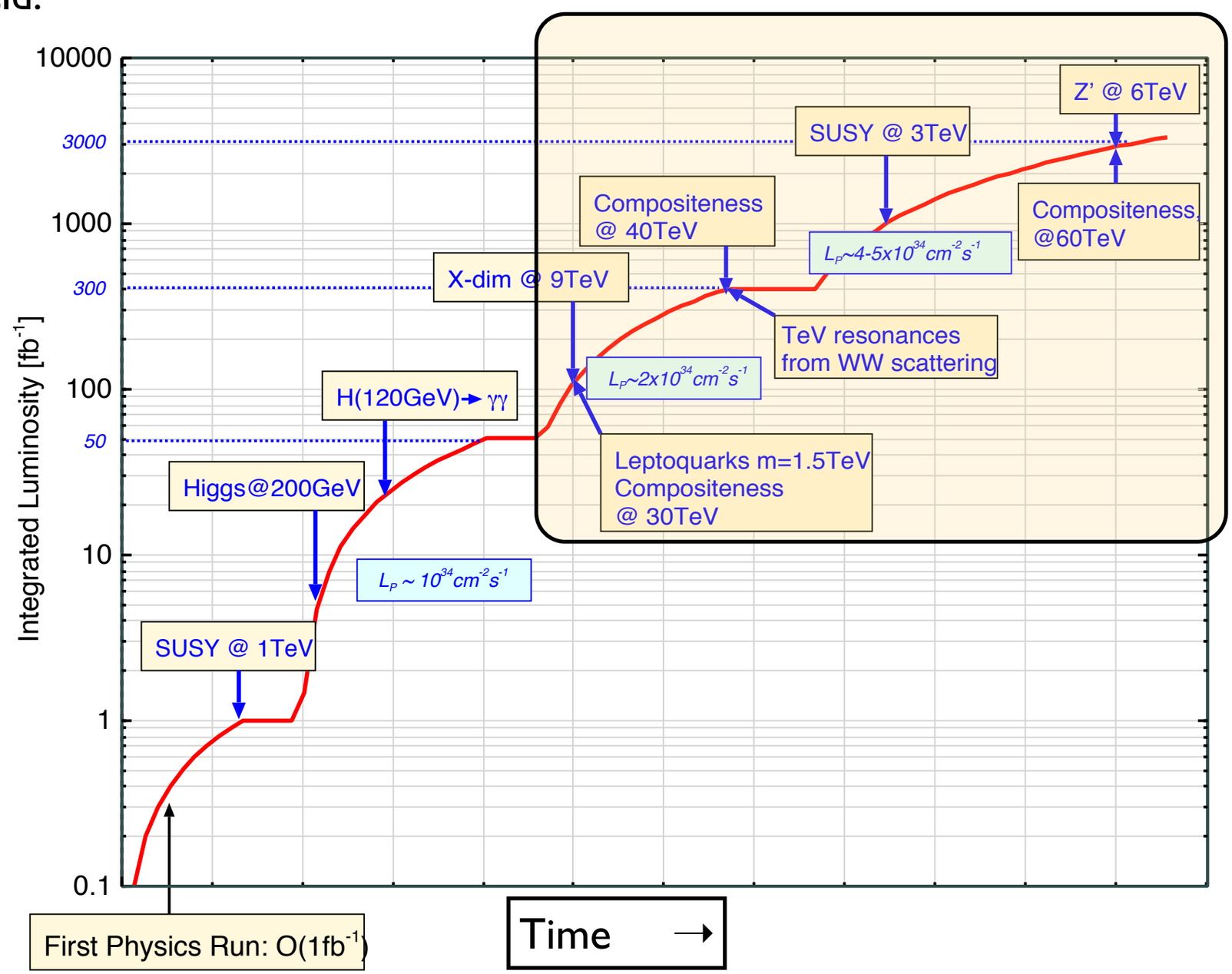
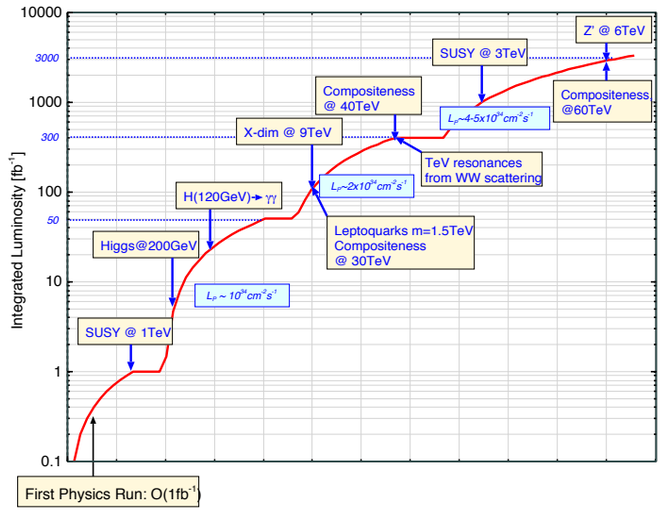


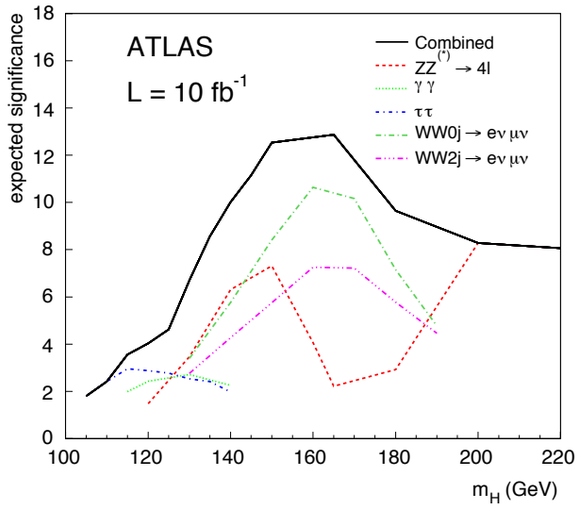
- With $\mathcal{L} \sim 10^{35}$ [$cm^{-2}\,s^{-1}$] LHC upgrade full TeV physics program available.
  - Strong $W_LW_L \rightarrow W_LW_L$ scattering, 2-3 TeV SUSY, Λ =50 TeV compositeness.

Summary & Outlook

- The LHC is increasing instantaneous luminosity every week
  - We expect to run at 7 TeV for the next year and collect 1 fb^{-1}.
  - A 1+ year shutdown will follow for LHC work and come back in 2013 with 13 TeV collisions.



- By the end of 2011 we will know if there is a high mass Higgs.
  - If SUSY just happens to be beyond Tevatron reach, we should see it.
- With 10-20 fb^{-1} we expect to make a definitive statement on the SM Higgs.



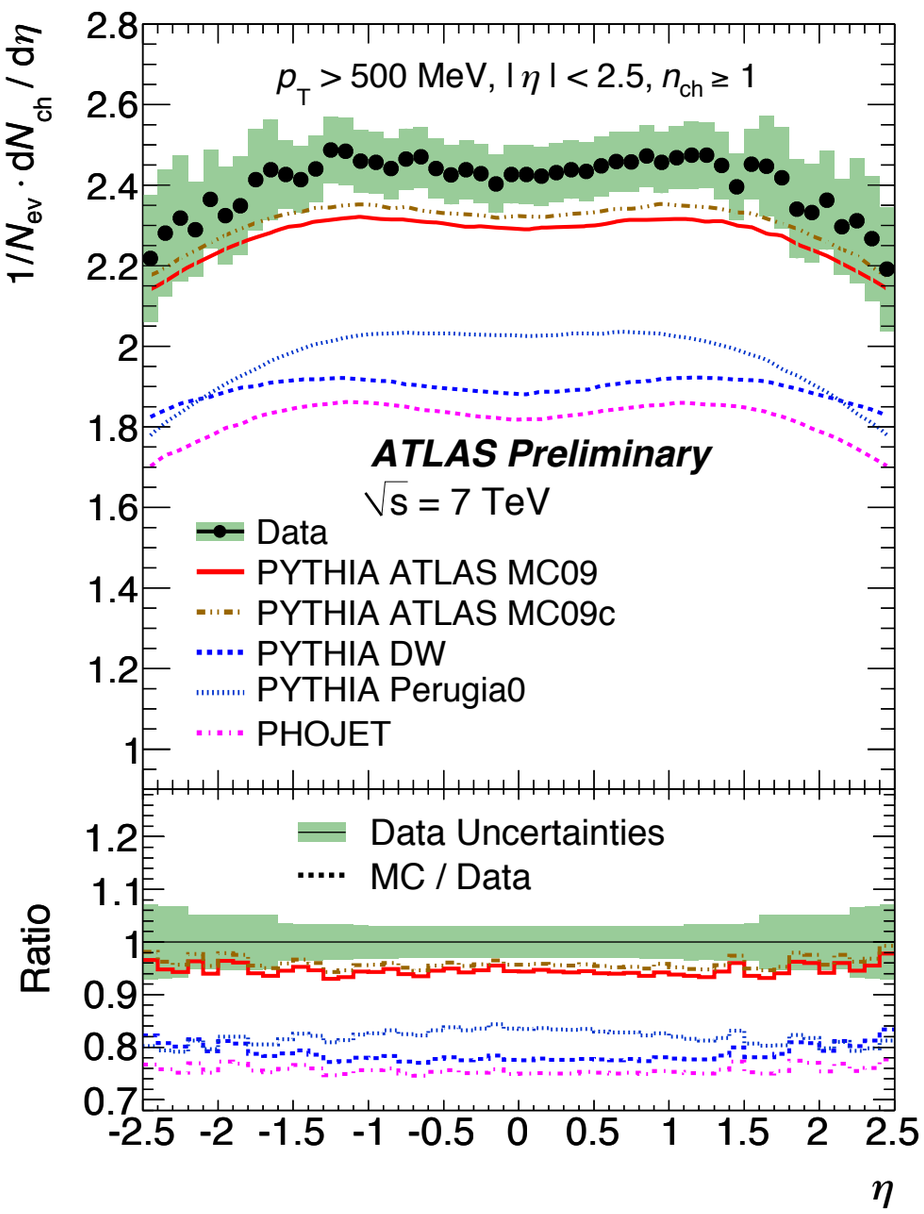
- Very exciting results might be just around the corner... Stay tuned!

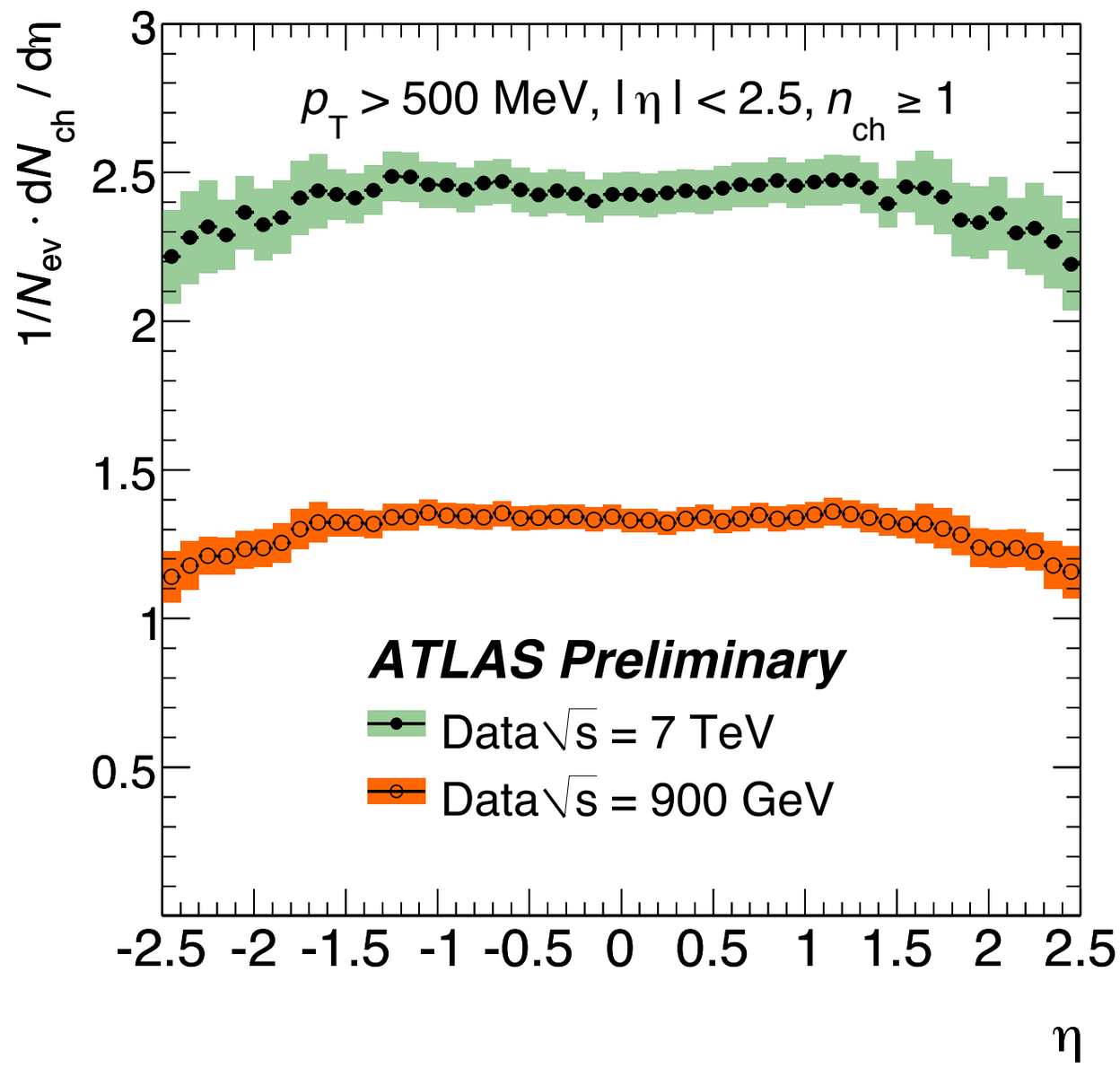
Back Up

Charged Particle Multiplicity @ 7 TeV

- Select tracks with pT > 500 MeV in events with exactly one vertex and MTBS A/C coincident hits.
- Several ways to present results:

Simulation produces too few particles w/ up to 50% disagreement in pT spectrum.

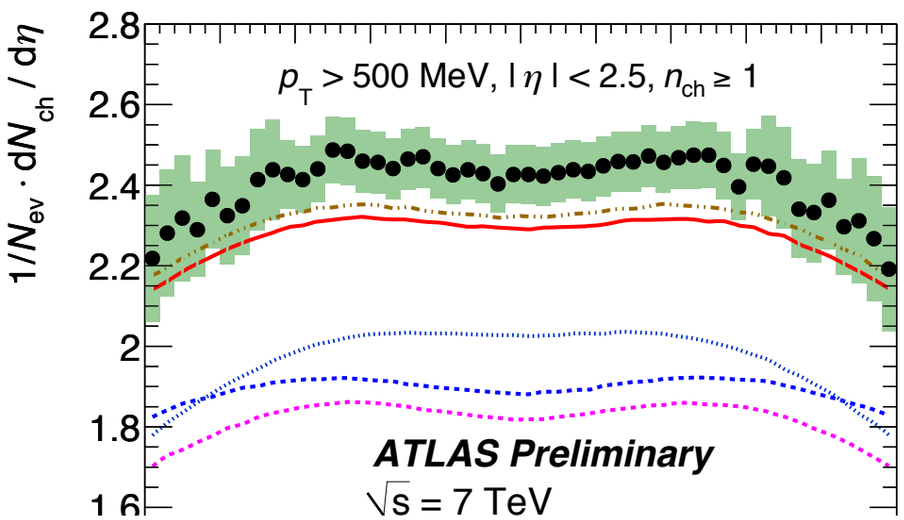


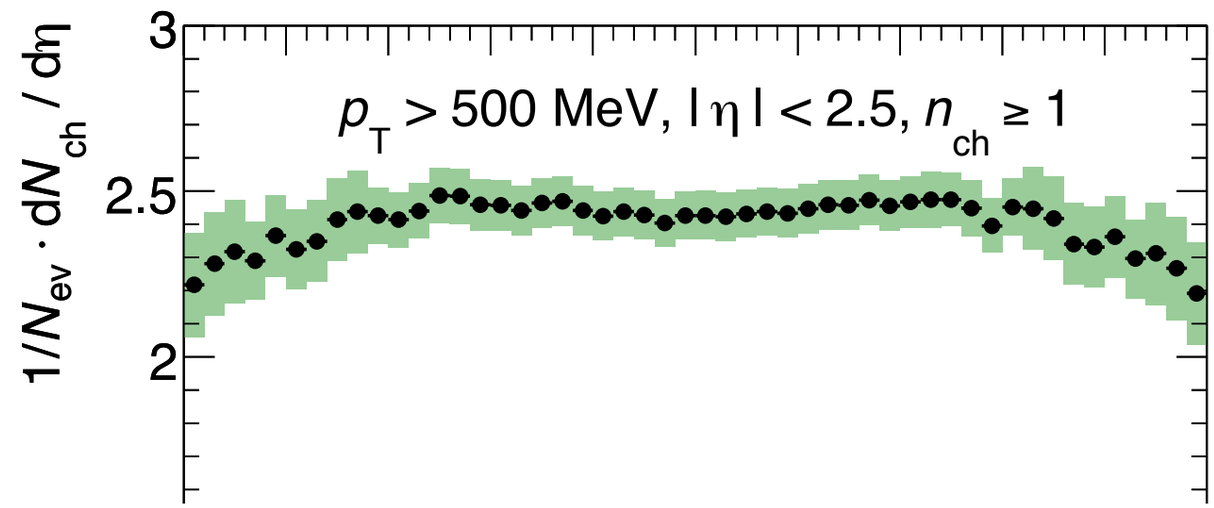


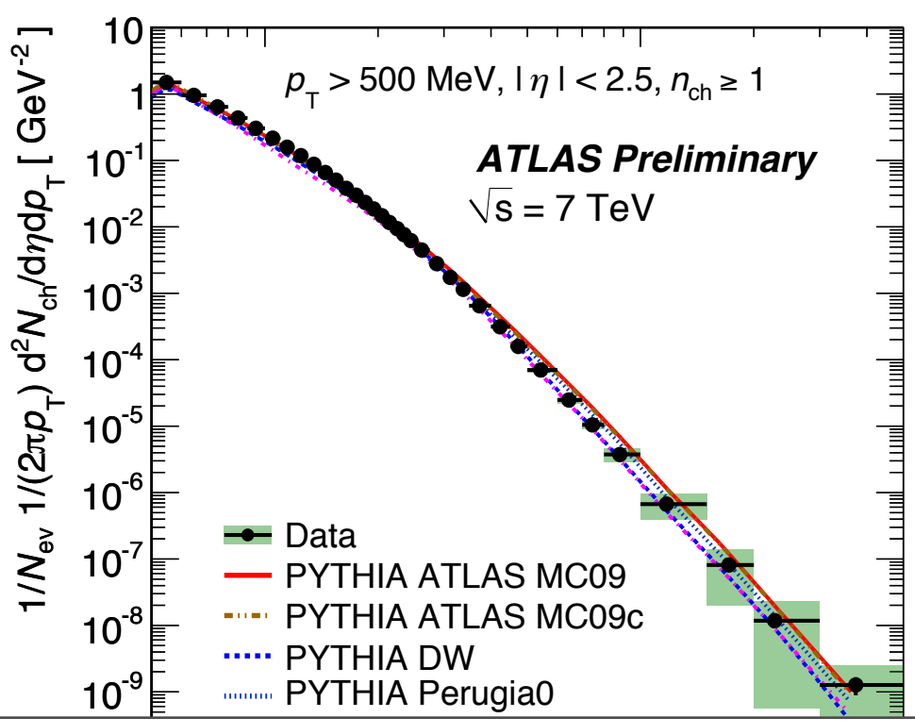
Charged Particle Multiplicity @ 7 TeV

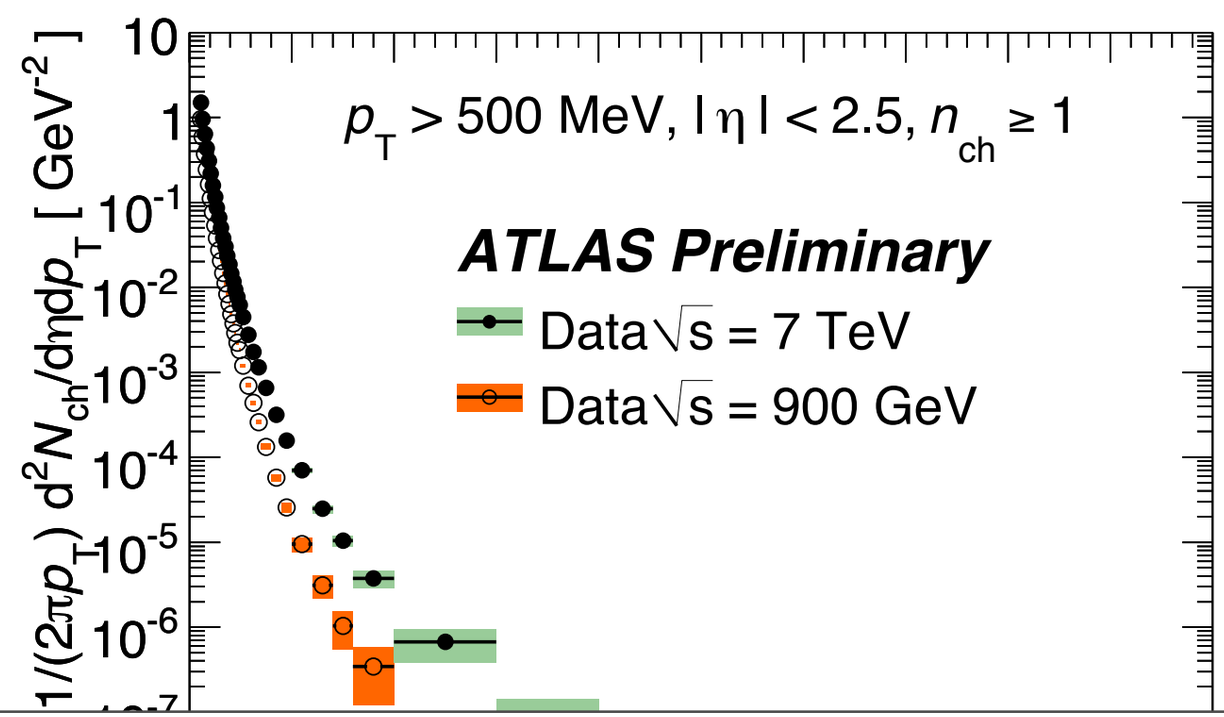
- Select tracks with pT > 500 MeV in events with exactly one vertex and MTBS A/C coincident hits.
- Several ways to present results:

Simulation produces too few particles w/ up to 50% disagreement in pT spectrum.

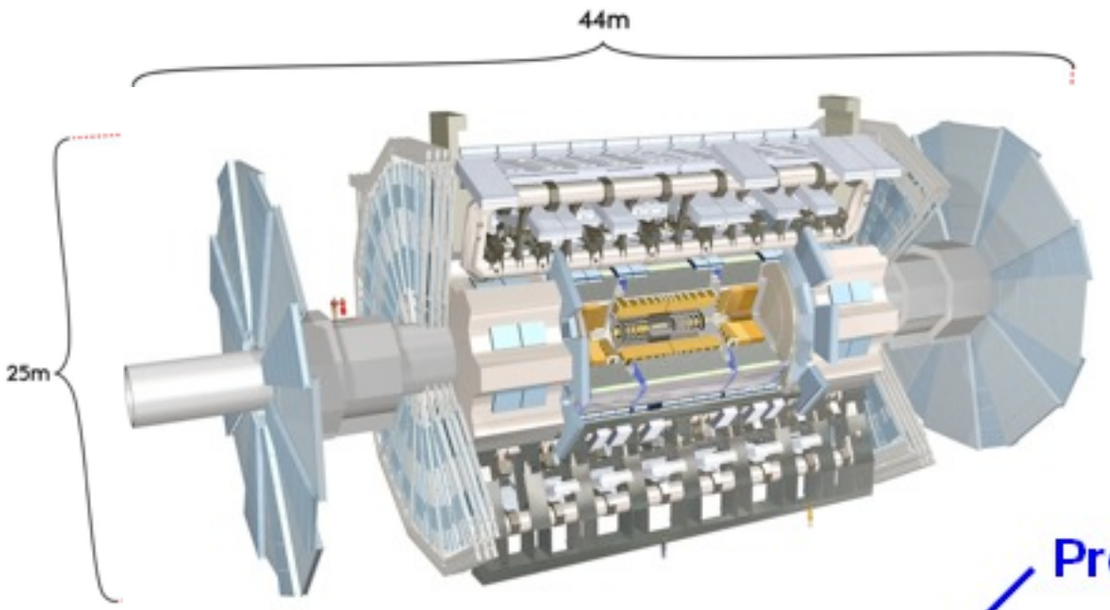




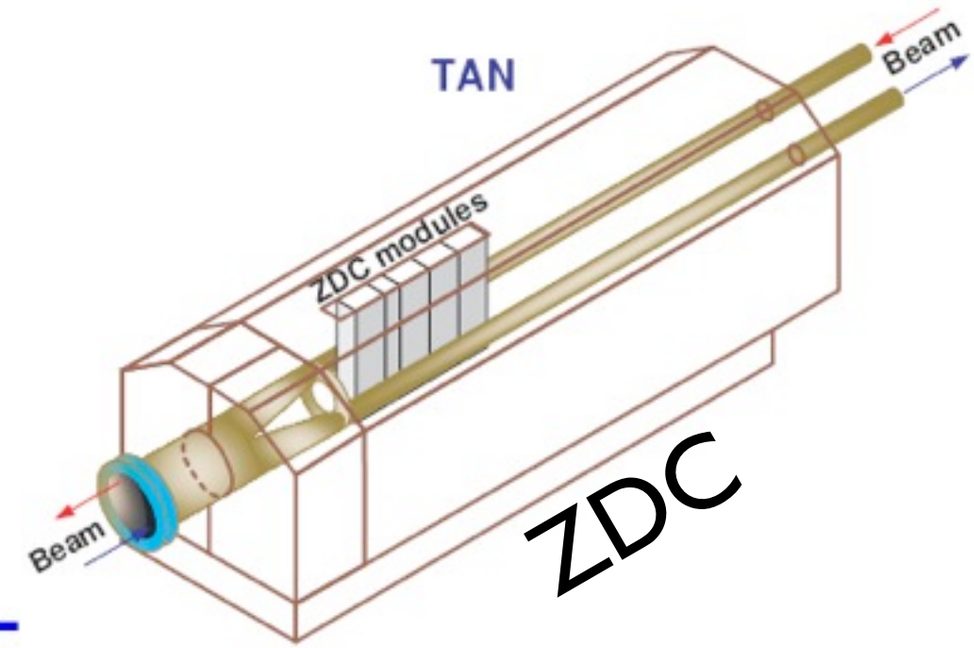


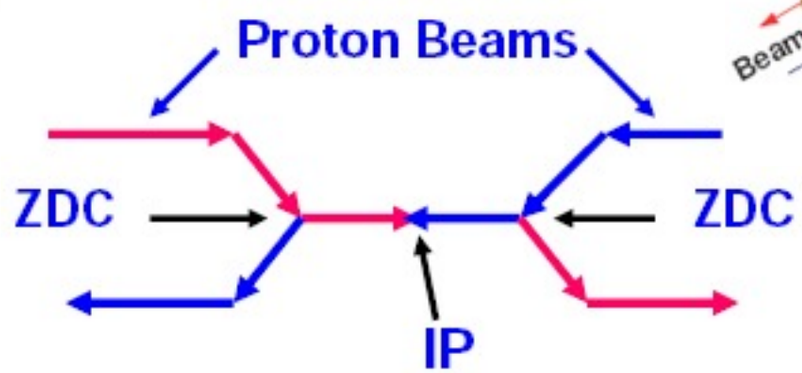


ATLAS Forward Detectors



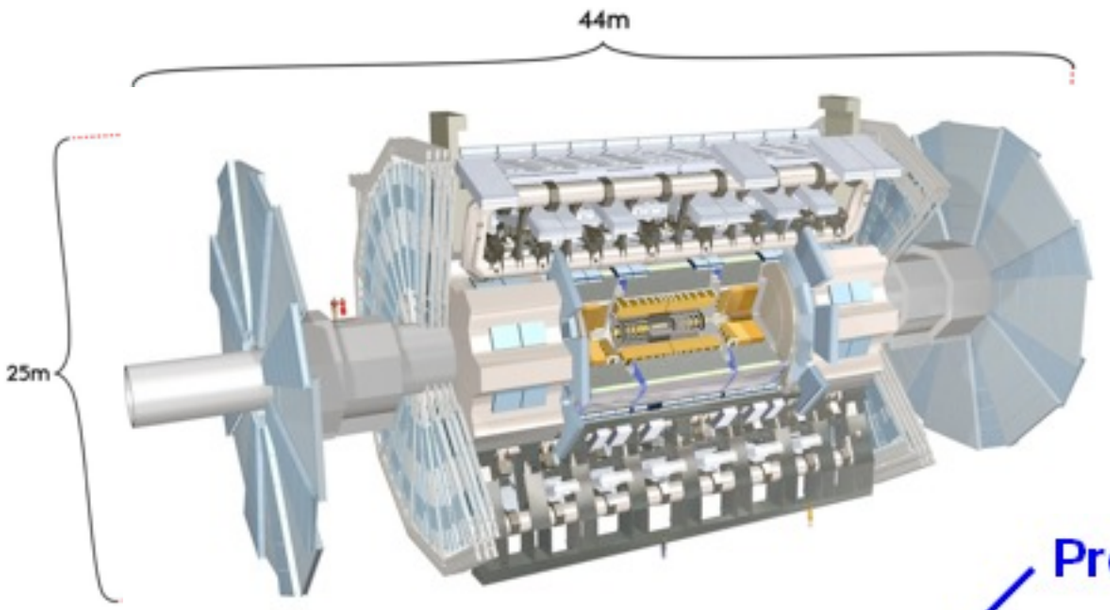
± 140 m



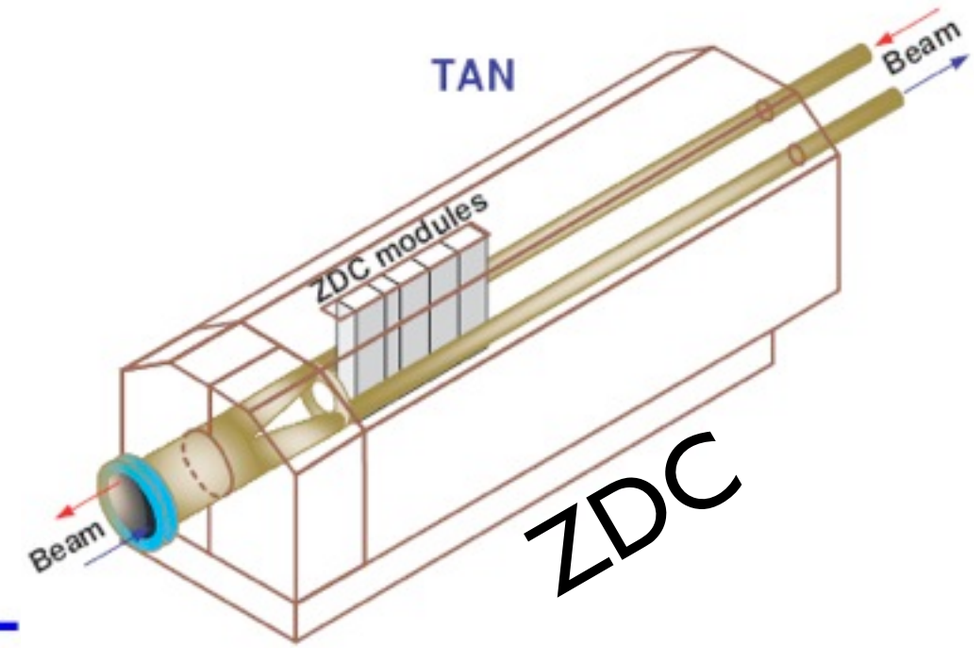


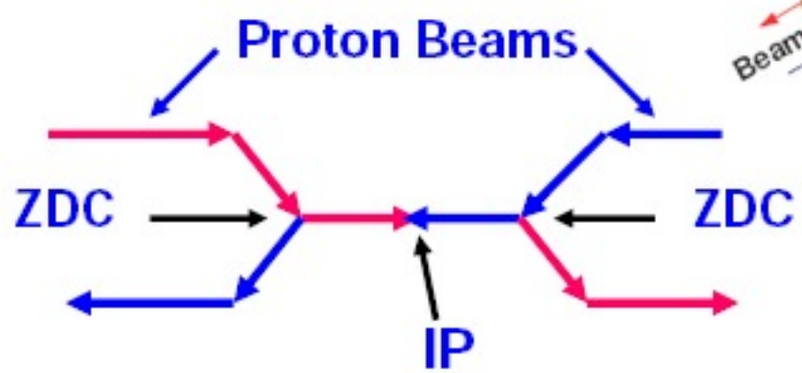
- Zero degree calorimeter (ZDC) provides precise energy and position measurements for $|\eta| > 8,3$
  - Can measure centrality of Pb+Pb collisions

ATLAS Forward Detectors

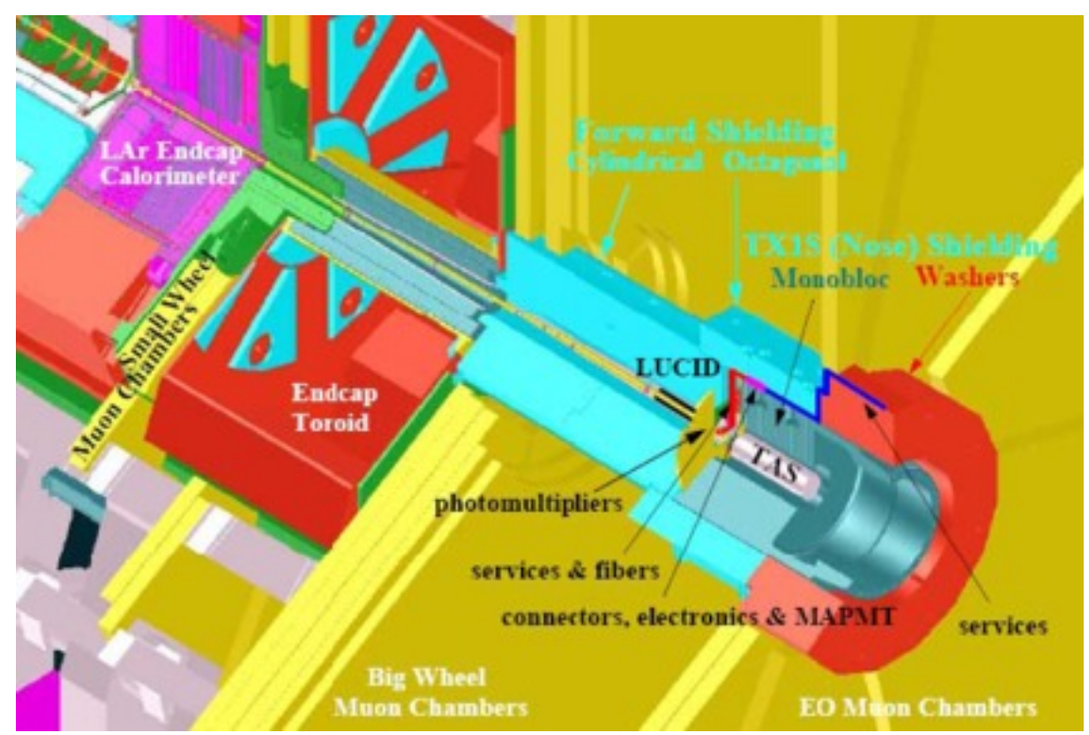


± 140 m

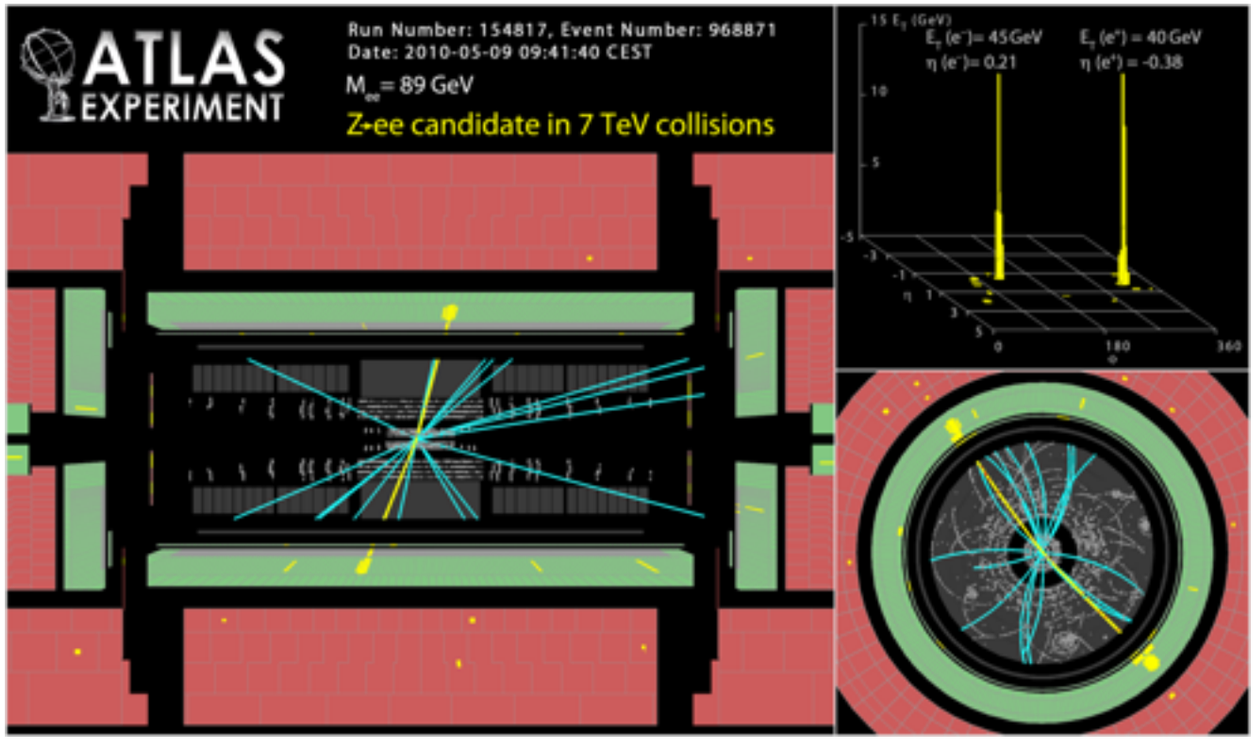


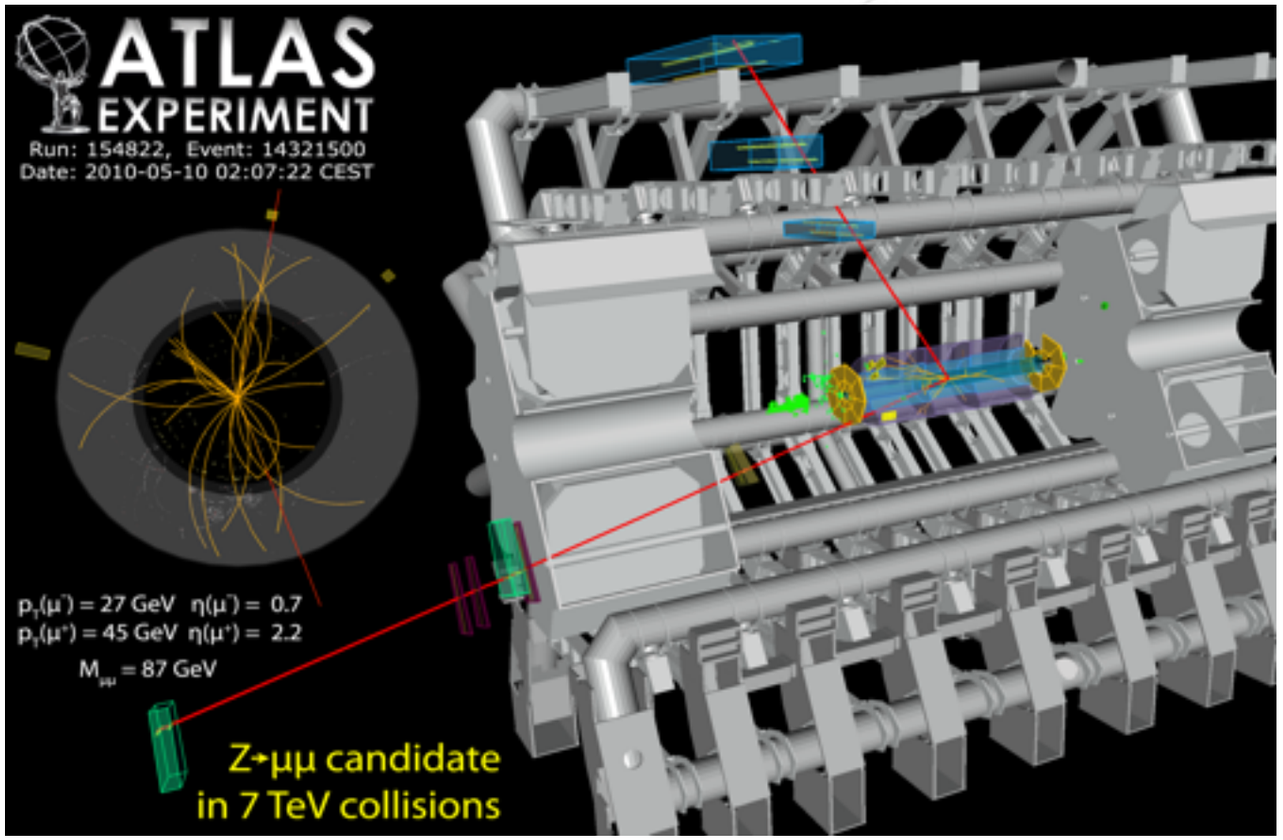


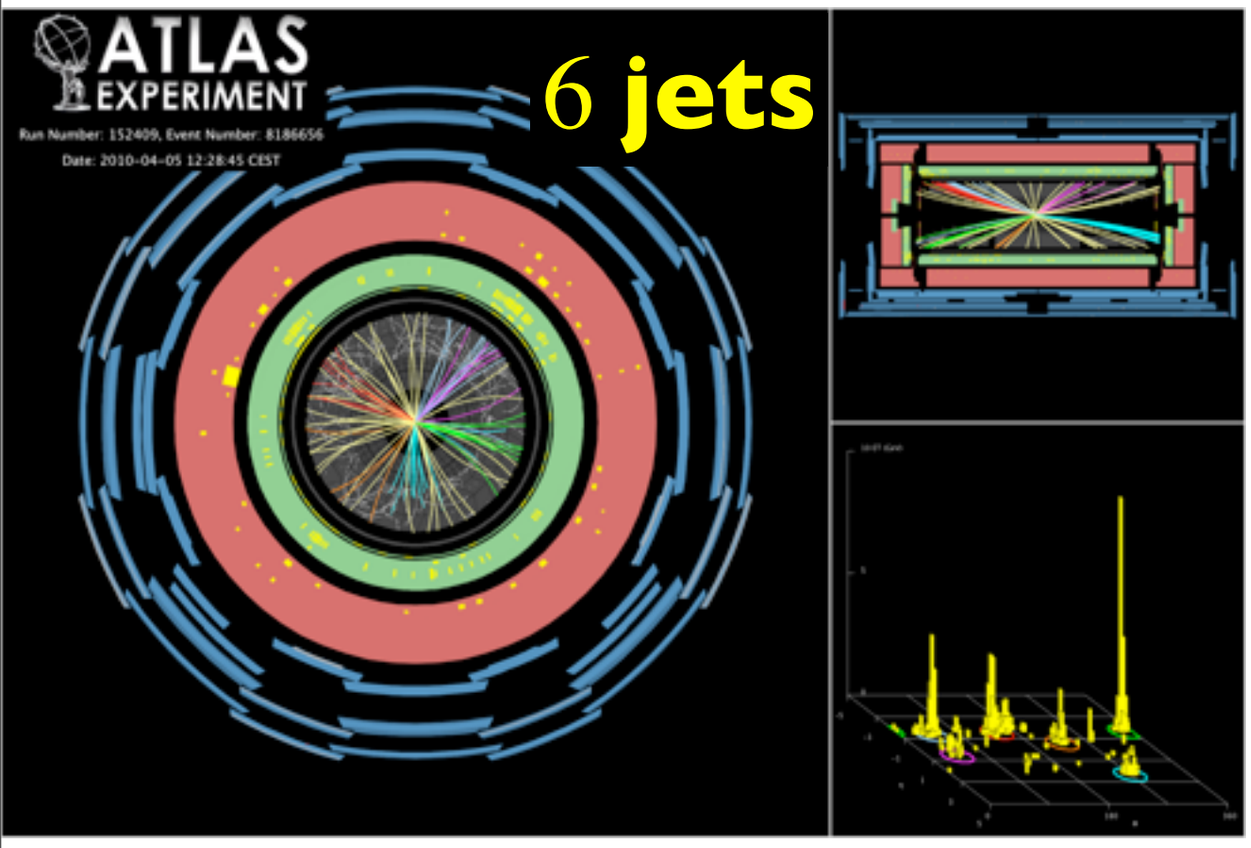
- Zero degree calorimeter (ZDC) provides precise energy and position measurements for |η| > 8,3
  - Can measure centrality of Pb+Pb collisions
- LUCID is a ring 20 Cherynkov light detectors designed to provide an online luminosity and beam conditions monitor. The detector sits at ± 17m from the IP.

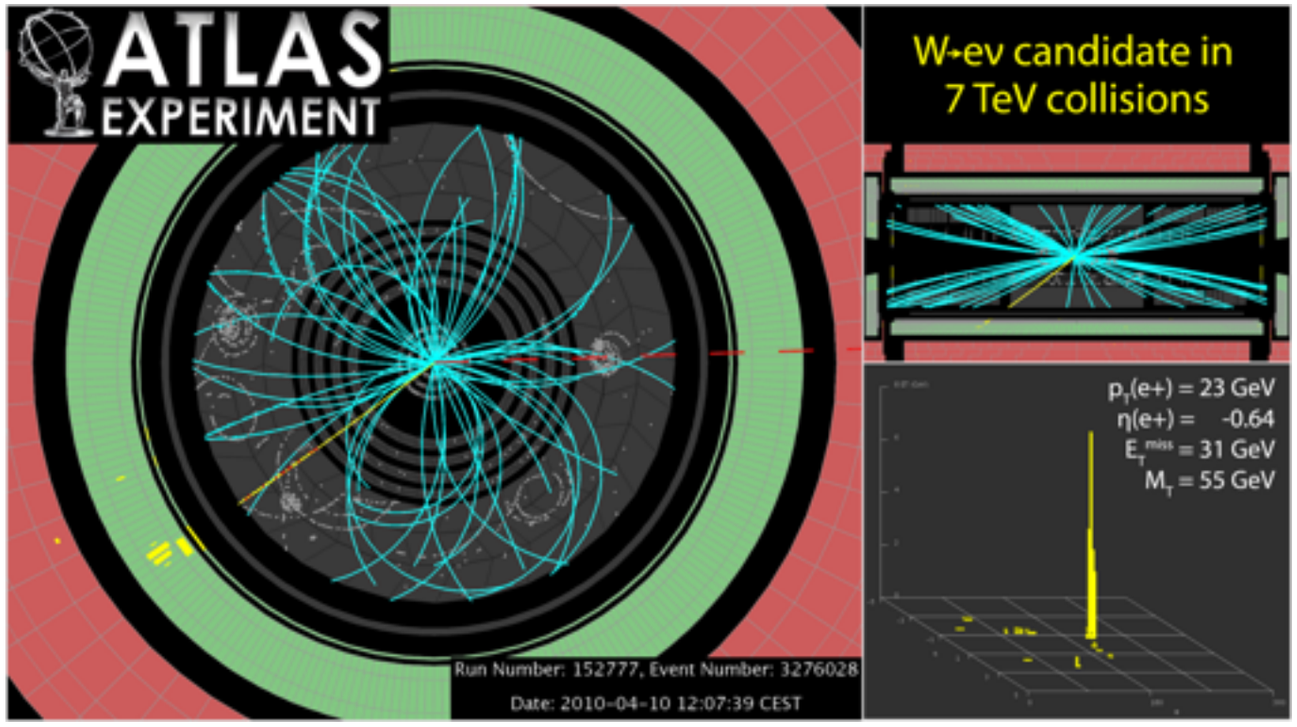


High P_T Program

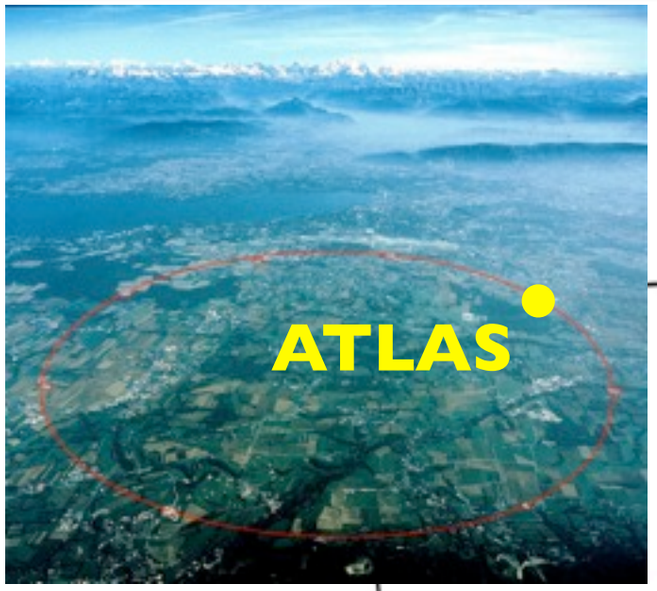


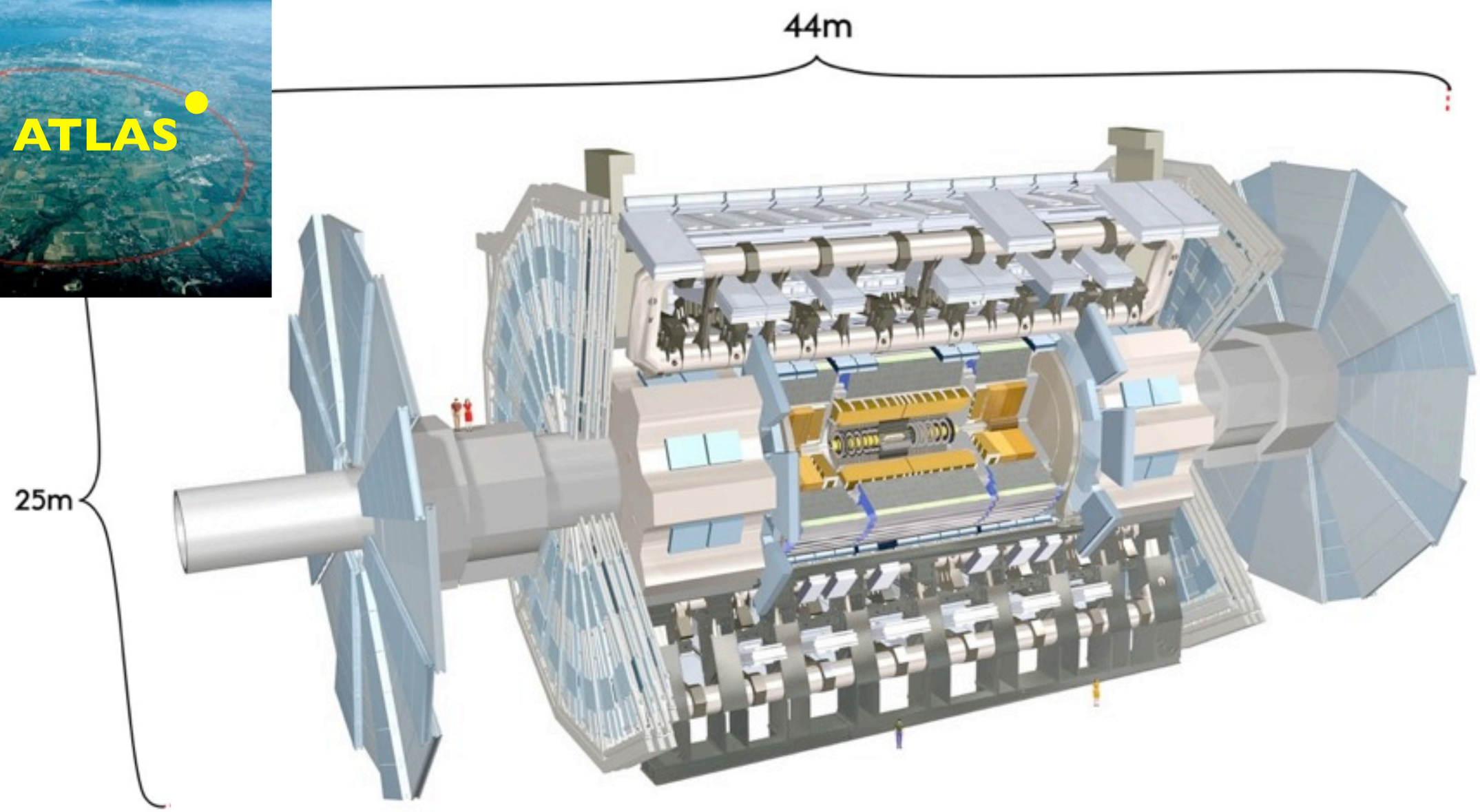






The ATLAS Detector

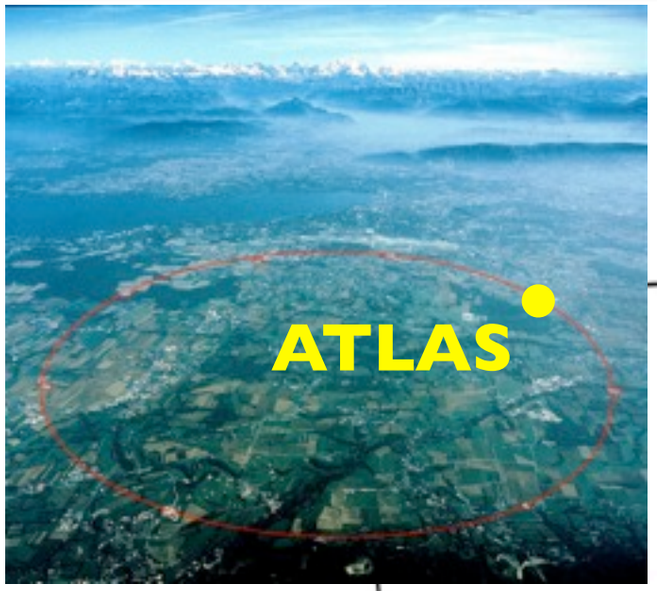


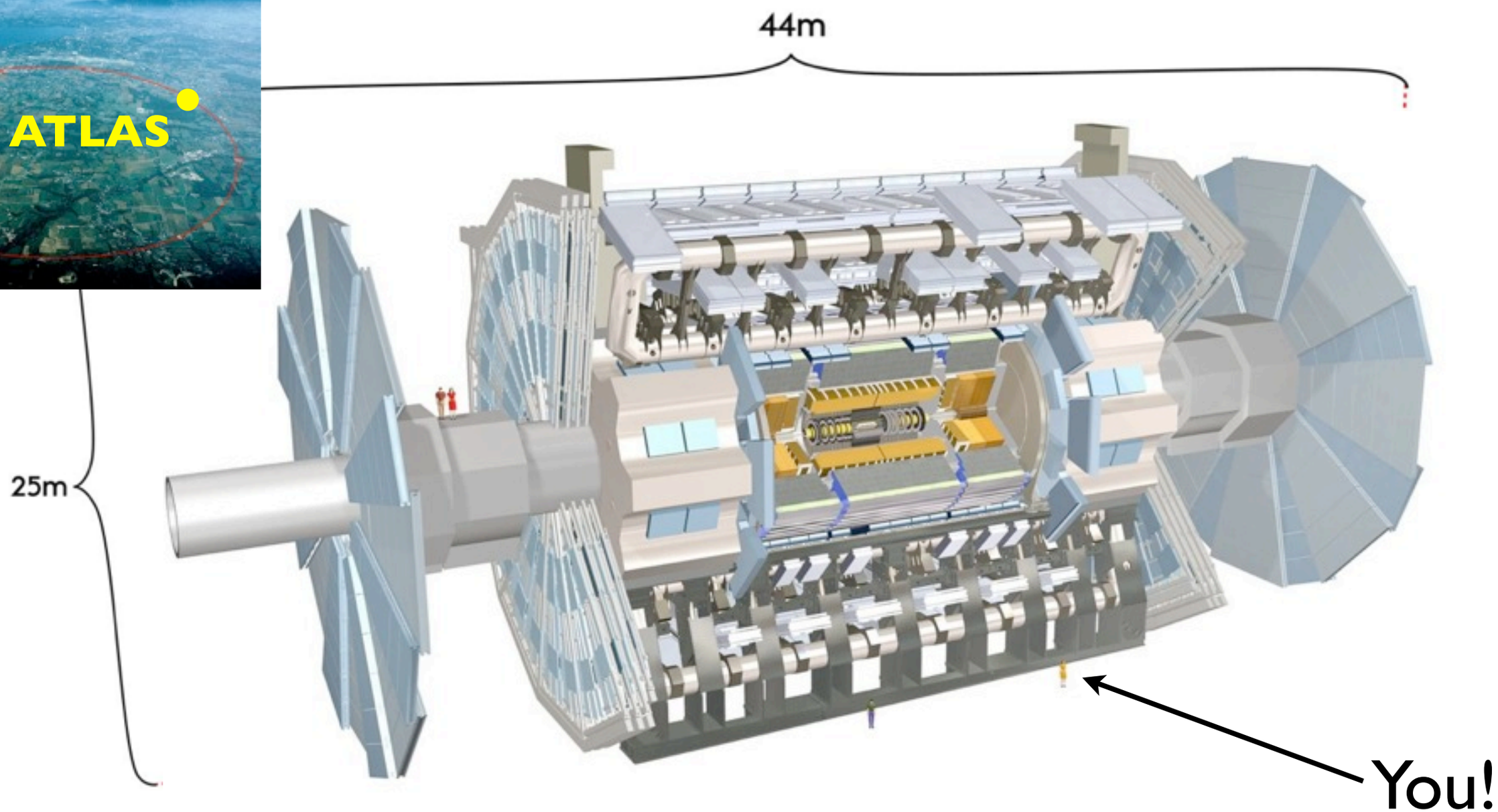


"Standard" HEP Detector

IP → Tracking Detector → Calorimeter → Muon System

The ATLAS Detector





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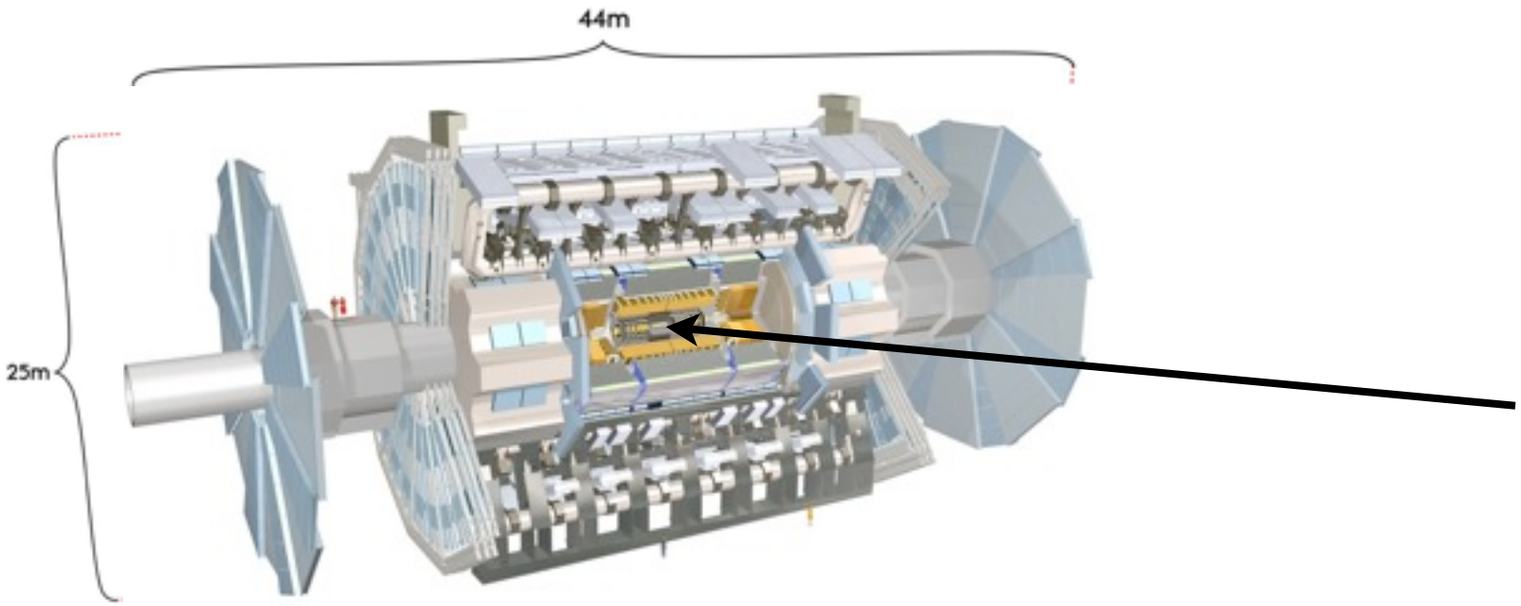
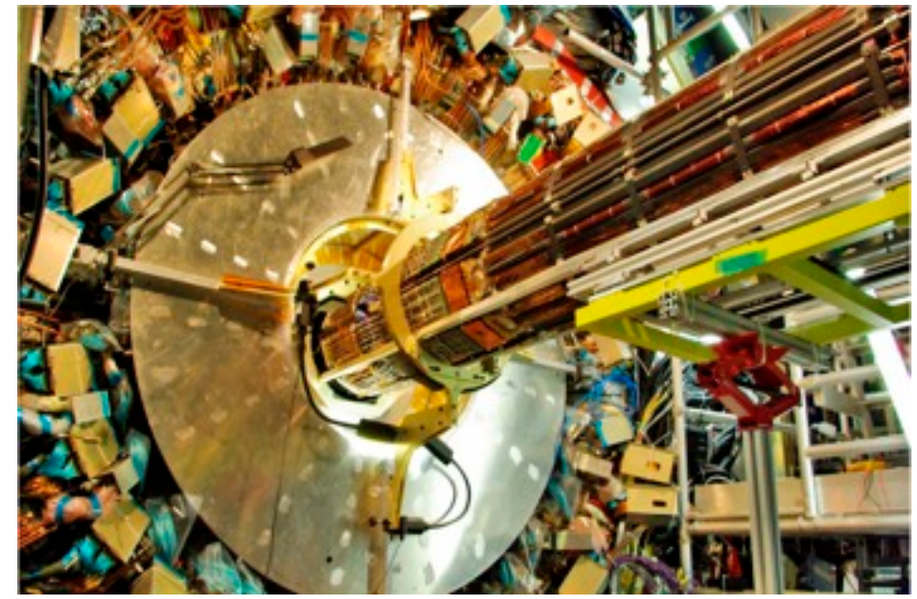
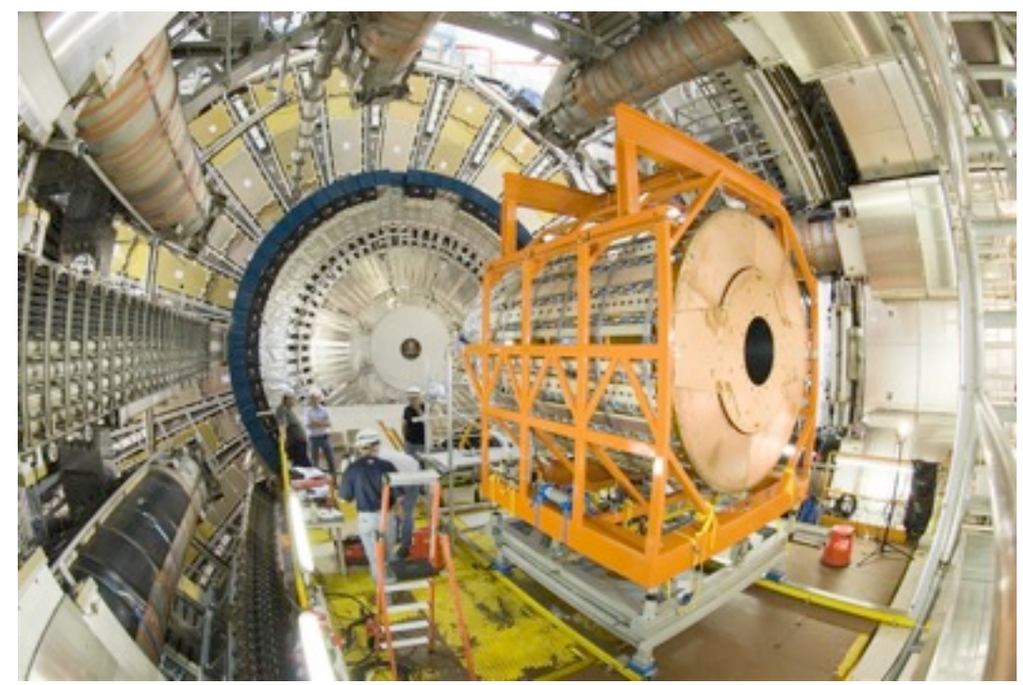




Tracking Detectors:

- Charged particle tracking out to $|\eta| < 2.5$
- 2T Solenoidal field surrounds 3 detectors:
  - Silicon pixels, strips (SCT), and transition radiation tracker (Xe, CO_2, O_2) (TRT)
- Specs:

$$\frac{\sigma_{p_T}}{p_T} = 0.05 p_T \oplus 1 \qquad IP^{xy}_{res} = 10\mu m$$



"Standard" HEP Detector

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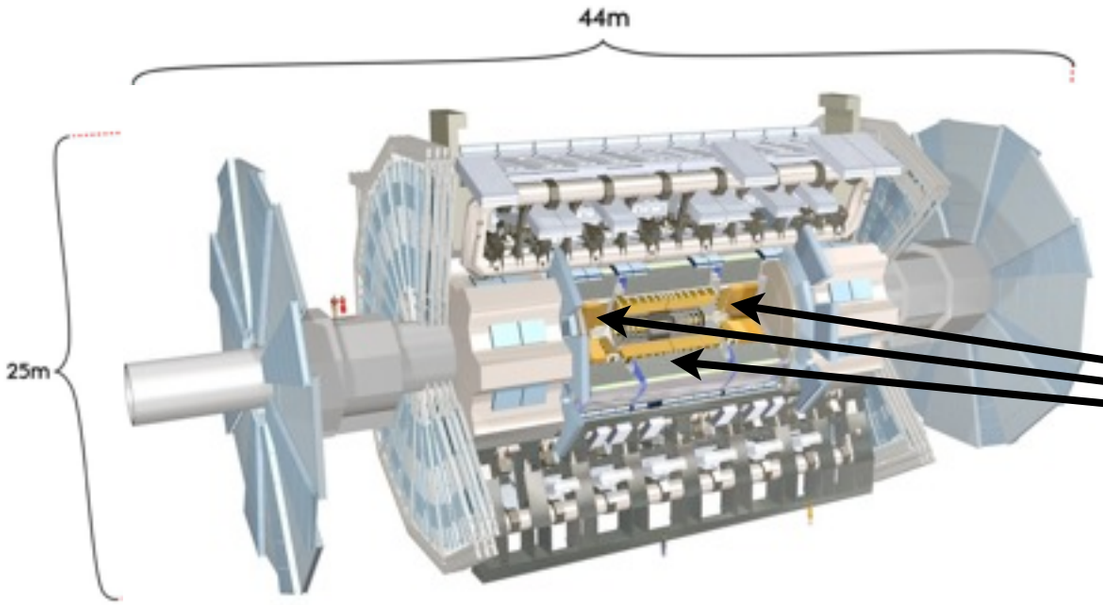
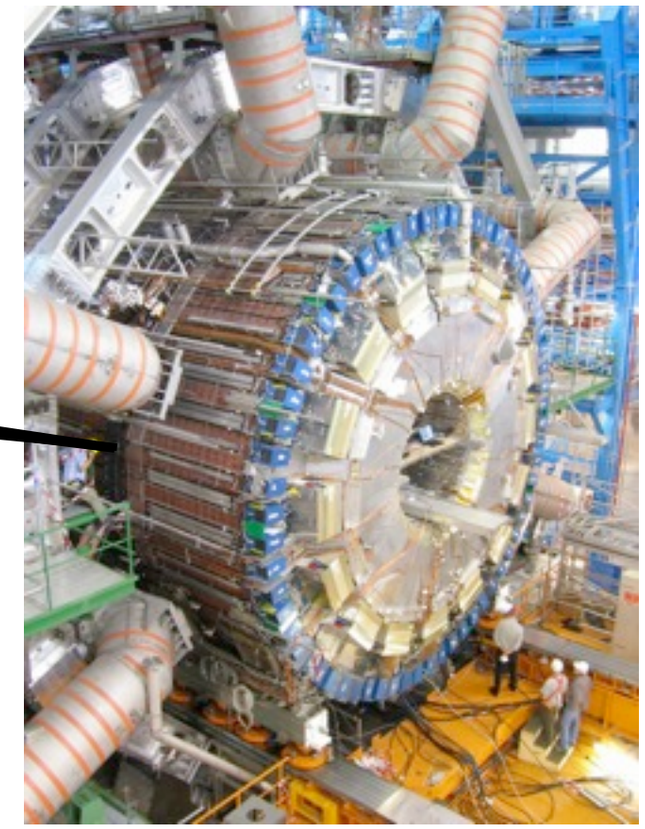
The ATLAS Detector

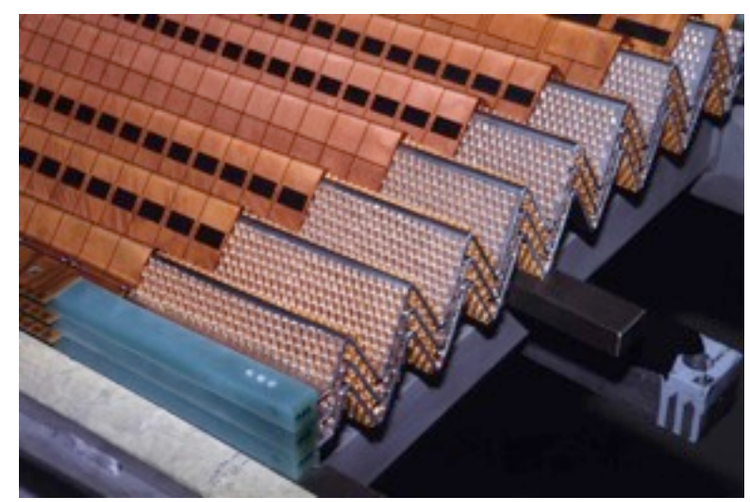




Calorimeters:

- EM & hadronic energy measurement out to $|\eta| < 4.9$
- Liquid Argon: Pb (barrel)/Cu (endcap) w/ accordion geom.
  - EM Barrel & endcaps $|\eta| < 3.1$.

$$\frac{\Delta E}{E} = \frac{10\%}{\sqrt{E}} \oplus 0.7\%$$



"Standard" HEP Detector

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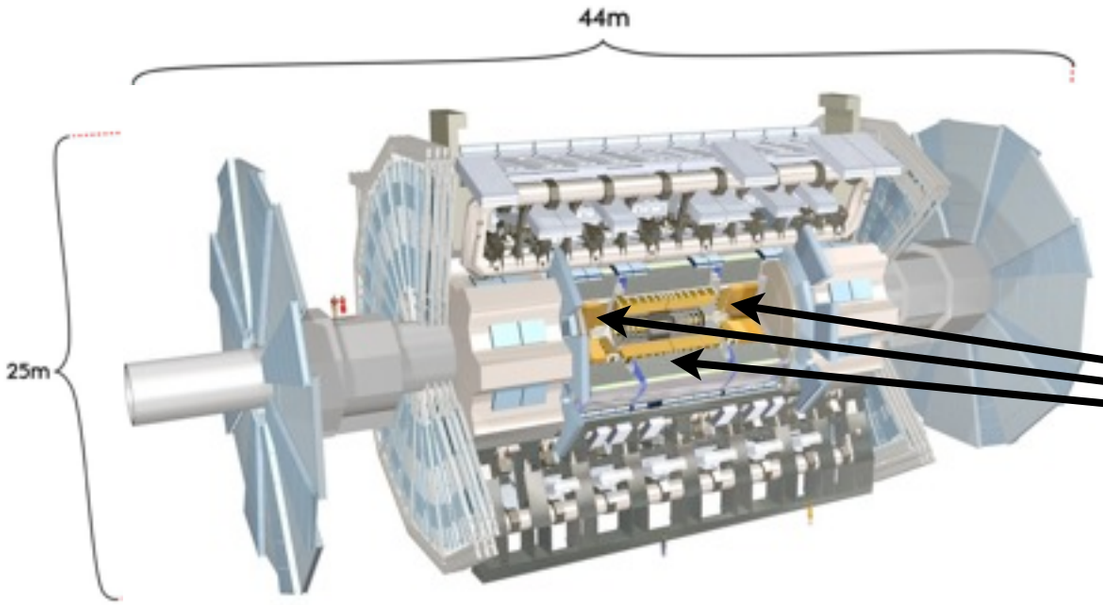
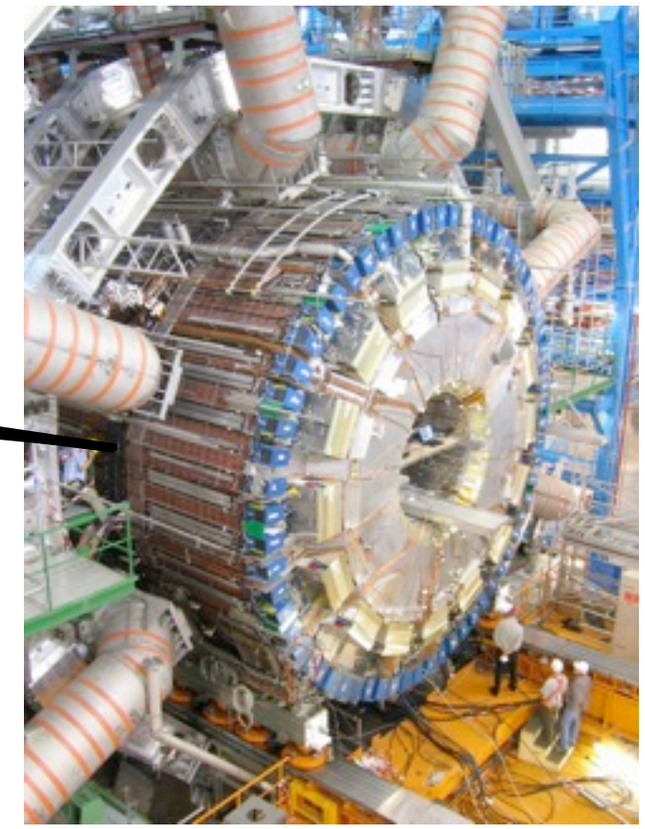
The ATLAS Detector





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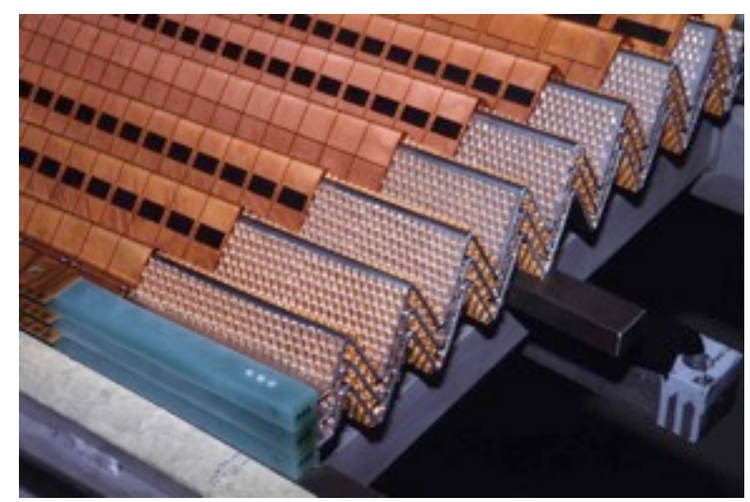
  - EM Barrel & endcaps $|\eta| < 3.1$.
  - Hadronic endcap (HEC) $|\eta| < 3.1$.

$$\frac{\Delta E}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$$



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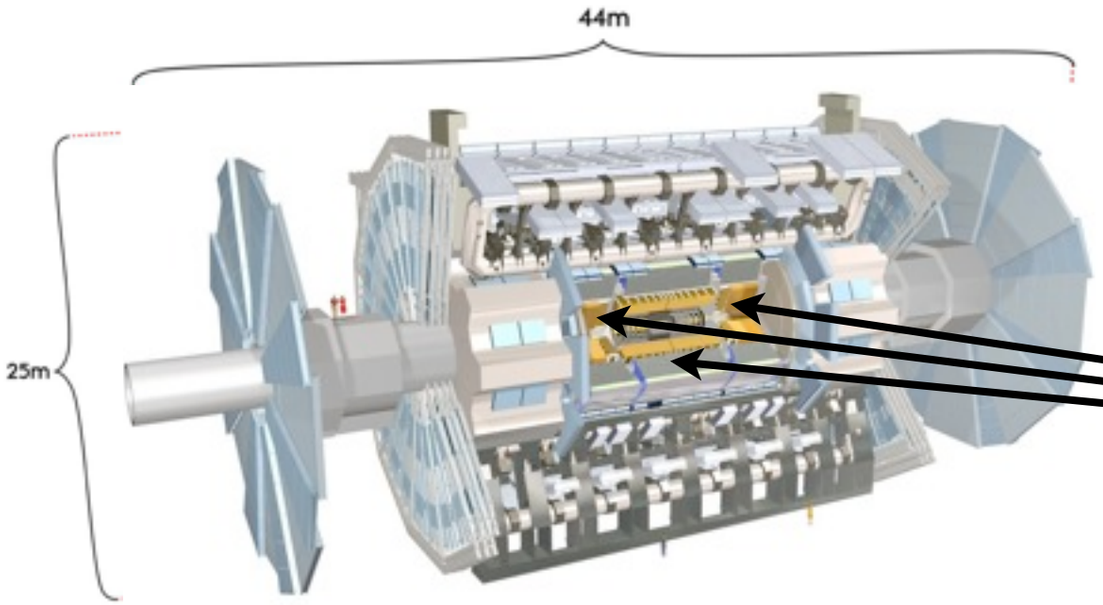

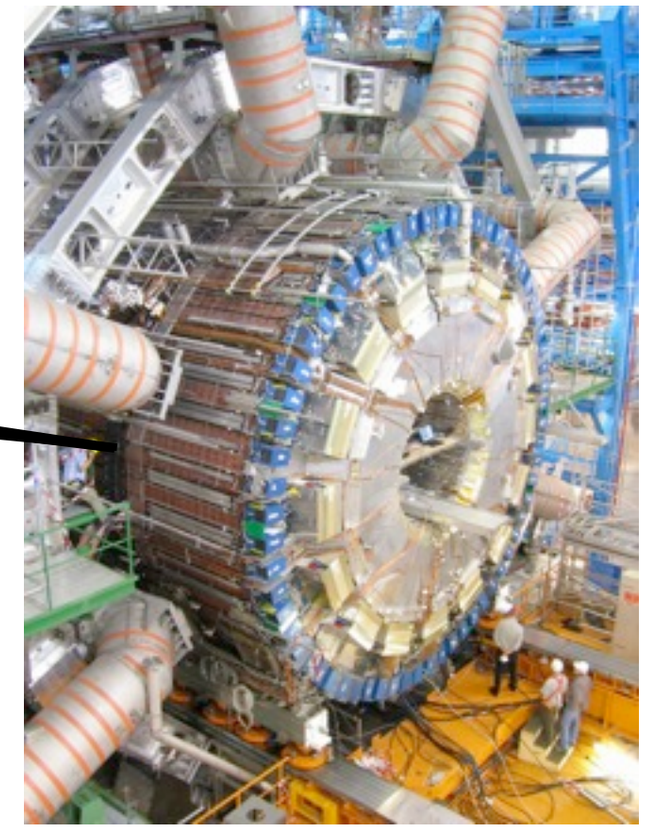

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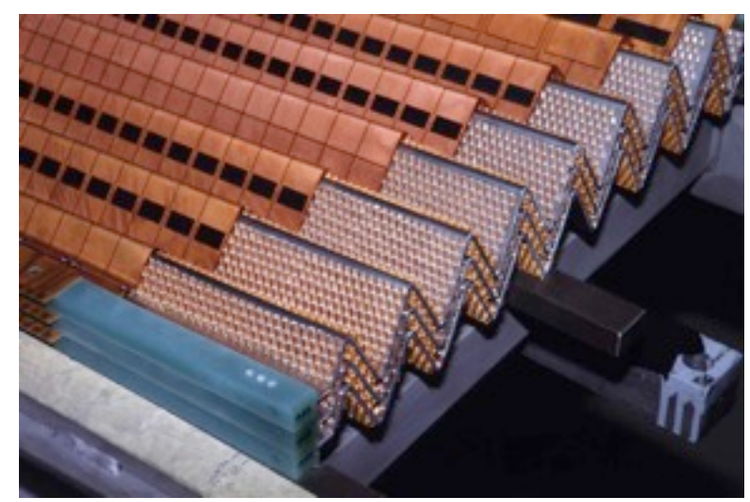
  - EM Barrel & endcaps $|\eta| < 3.1$.
  - Hadronic endcap (HEC) $|\eta| < 3.1$.
  - Forward Cal (FCAL) $3.1 < |\eta| < 4.9$.

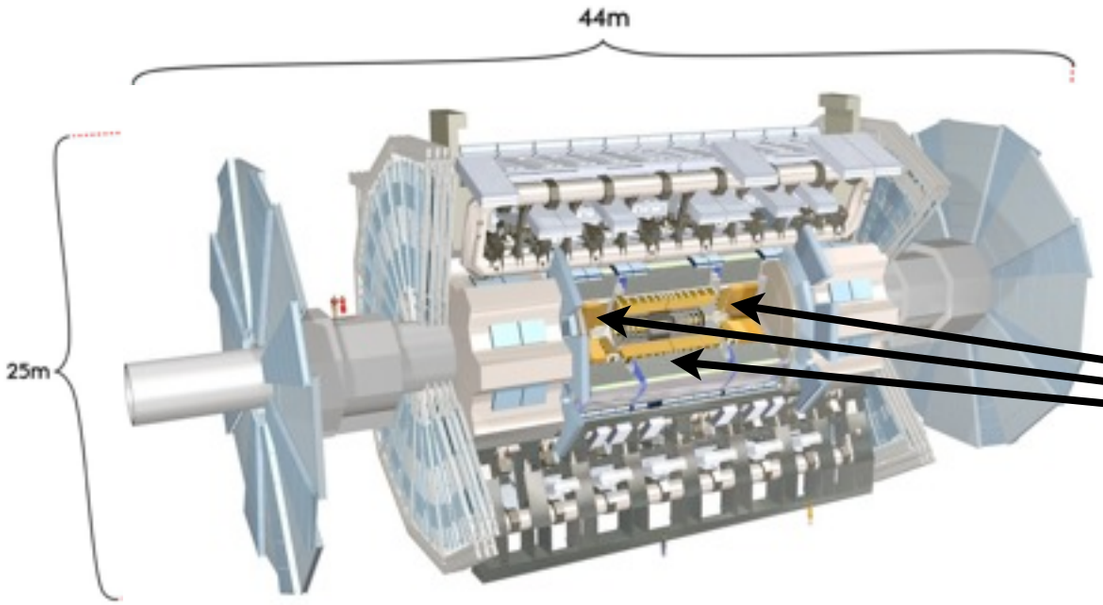
$$\frac{\Delta E}{E} = \frac{100\%}{\sqrt{E}} \oplus 10\%$$

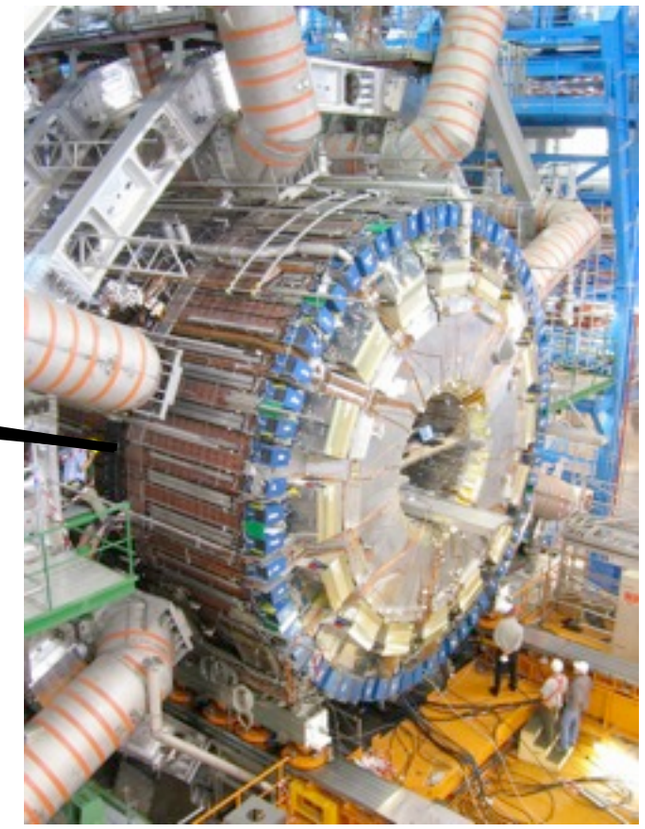


"Standard" HEP Detector

IP → Tracking Detector → Calorimeter → Muon System

The ATLAS Detector





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  - EM Barrel & endcaps $|\eta| < 3.1$.
  - Hadronic endcap (HEC) $|\eta| < 3.1$.
  - Forward Cal (FCAL) $3.1 < |\eta| < 4.9$.

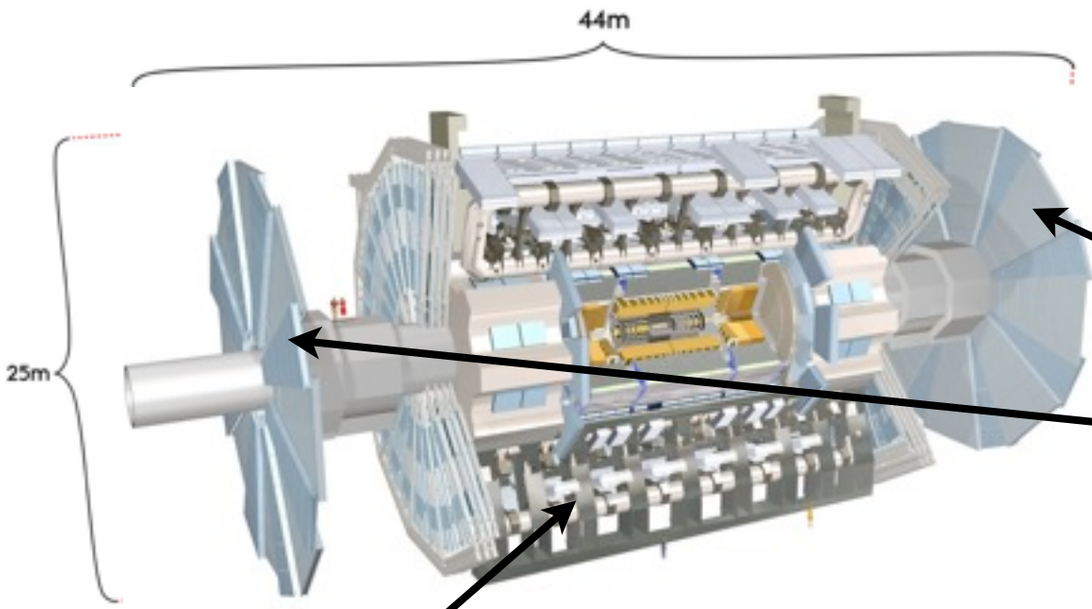
$$\frac{\Delta E}{E} = \frac{100\%}{\sqrt{E}} \oplus 10\%$$

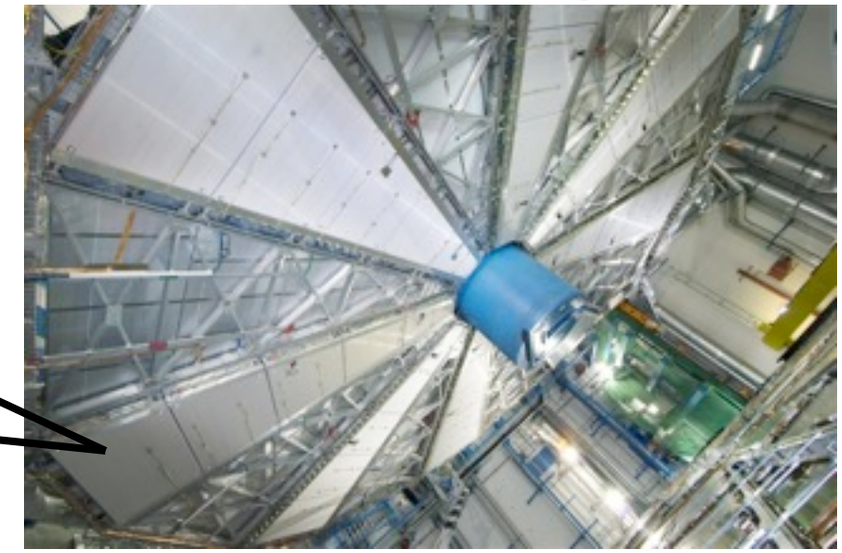
- Scintillating tiles w/ steel absorber as hadronic cal.

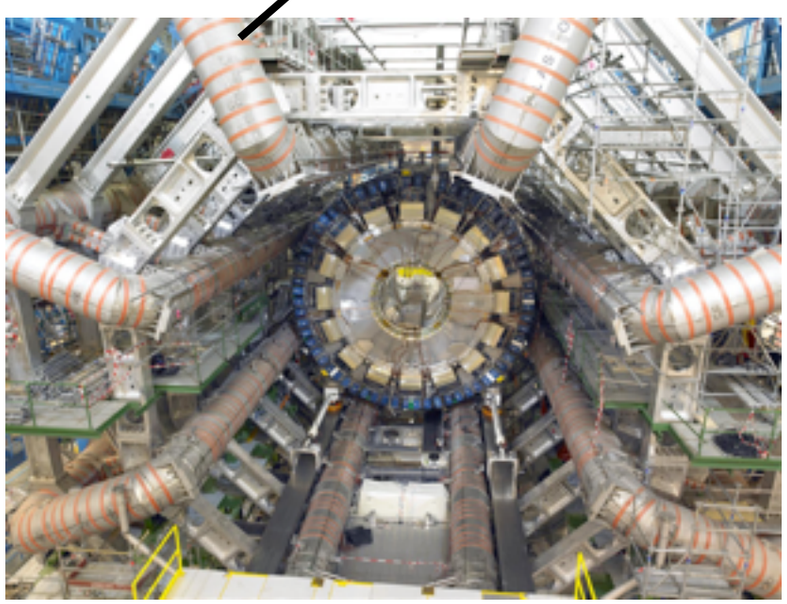
"Standard" HEP Detector

IP → Tracking Detector → Calorimeter → Muon System

The ATLAS Detector







Muon System:

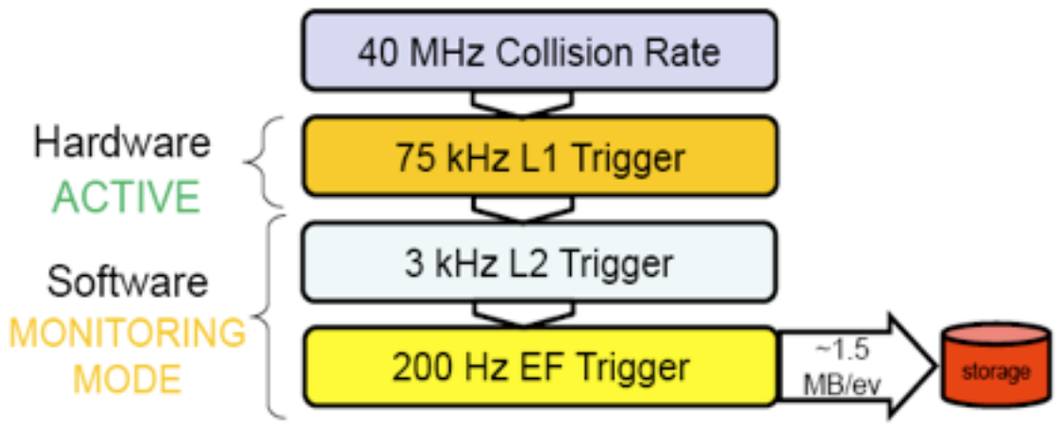
- Muon ID and independent muon momentum (air-code toroid magnets provide **B** field)
  - Monitored drift chambers (MDT) and Cathode strip chambers (CSC) → precise position
  - Thin gap chambers (TGC) and Resistive-plate chambers (RGC) → fast triggering
- Specs: $\frac{\sigma_{p_T}}{p_T} \sim 2(10)\%\ w/p_T = 10(1000)\ \mathrm{GeV}$

"Standard" HEP Detector

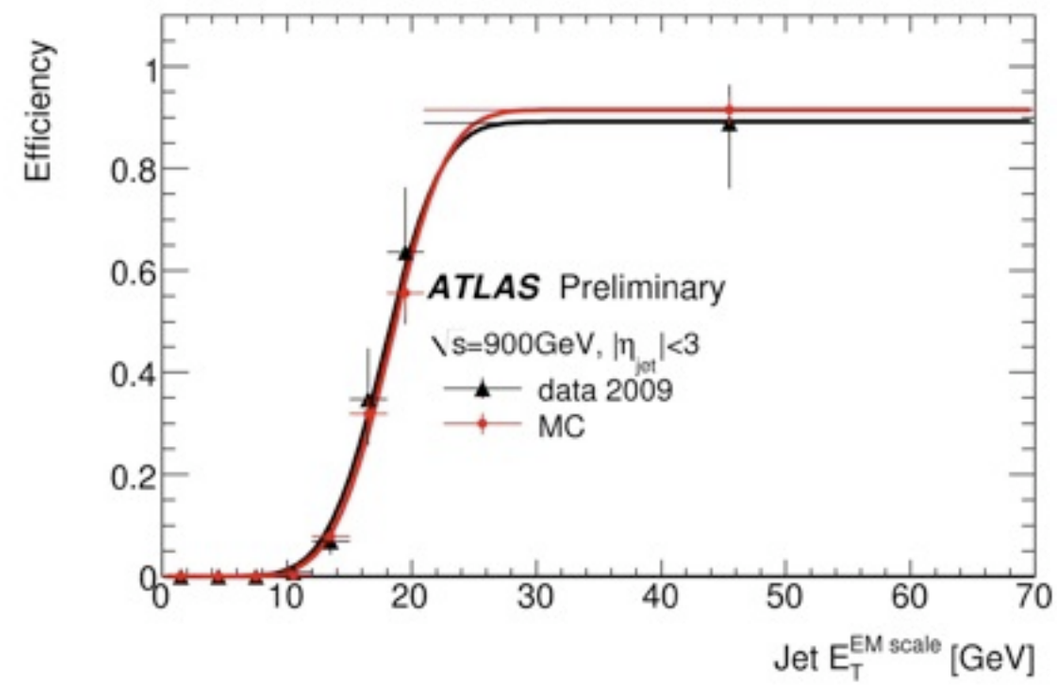
IP → Tracking Detector → Calorimeter → Muon System

Detector Performance: Tracking

- Small sampling of the 900 and 7 TeV detector performance results.



L1 Jet E_T > 10 GeV trigger efficiency



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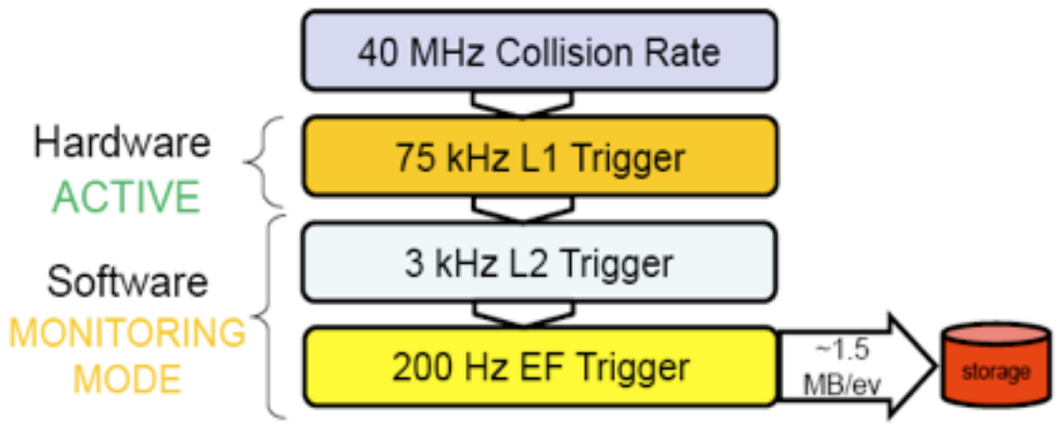

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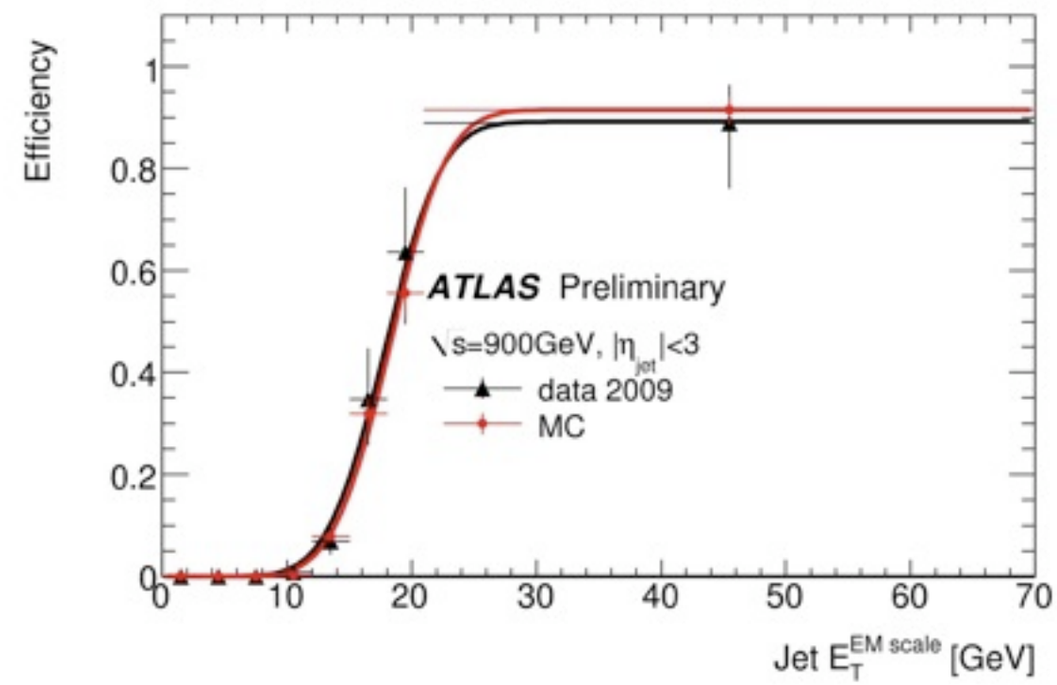
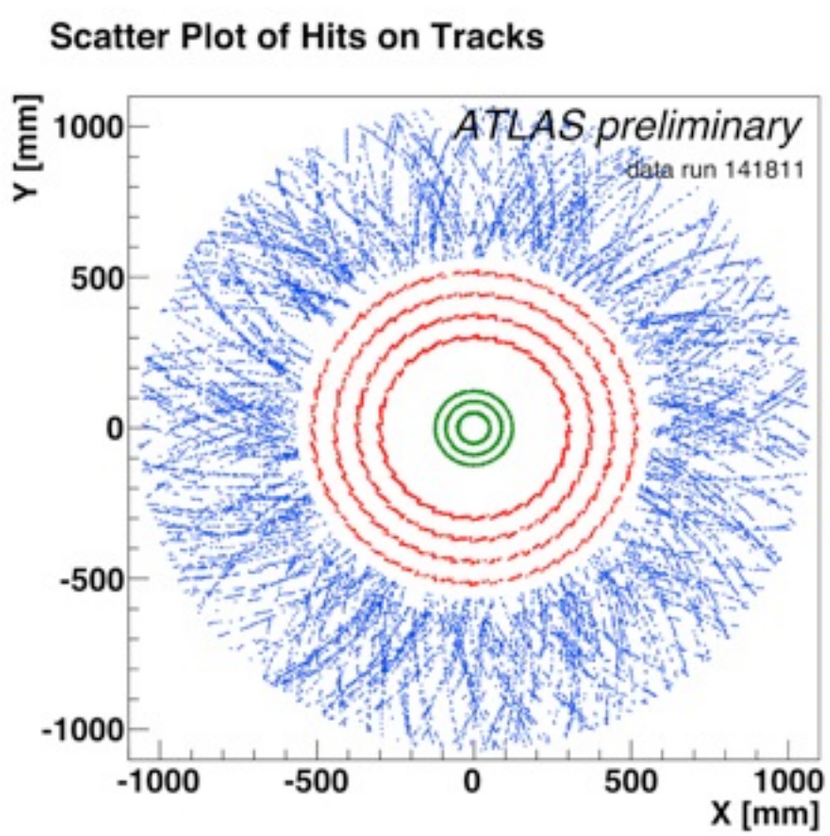
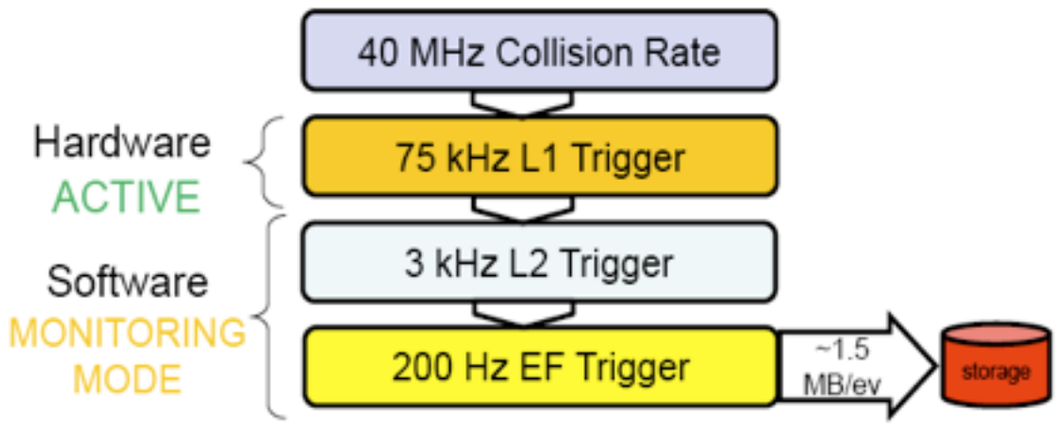
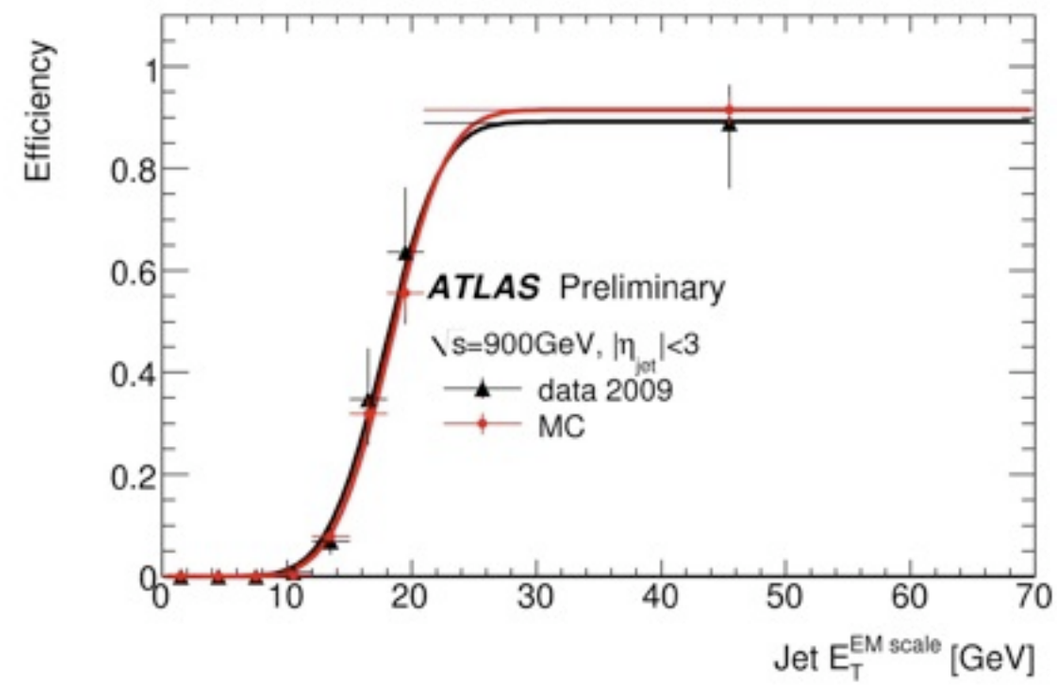
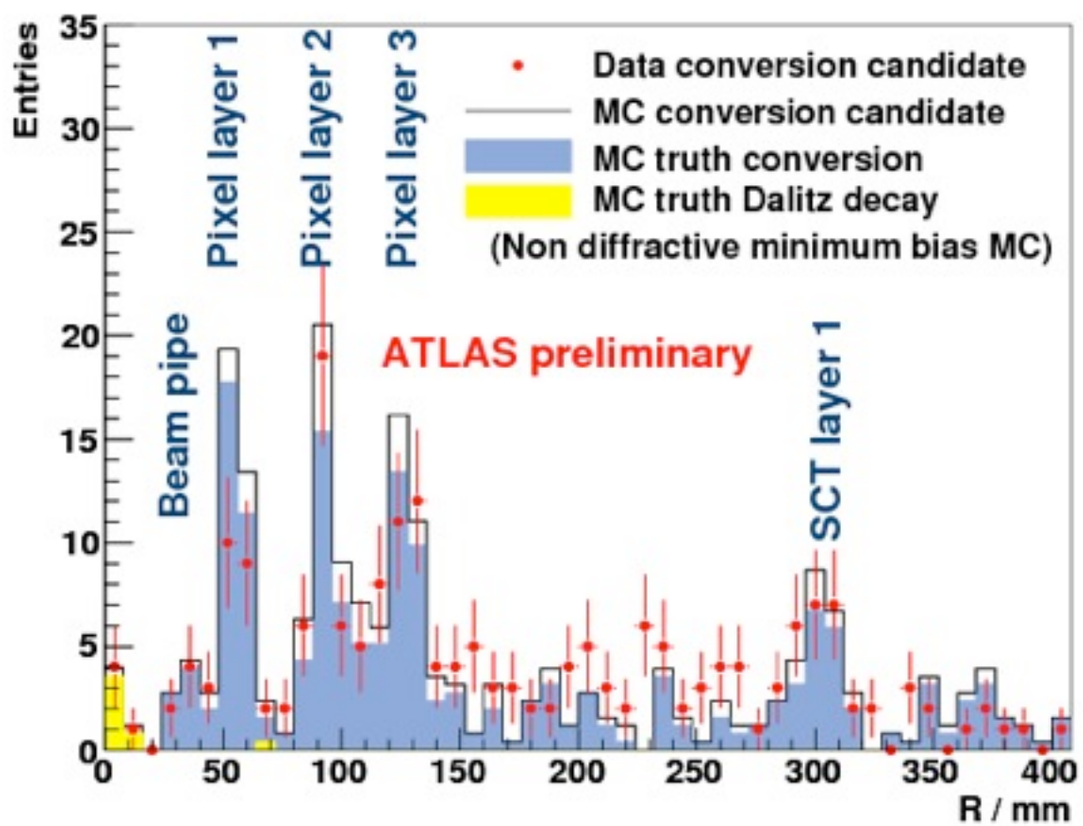
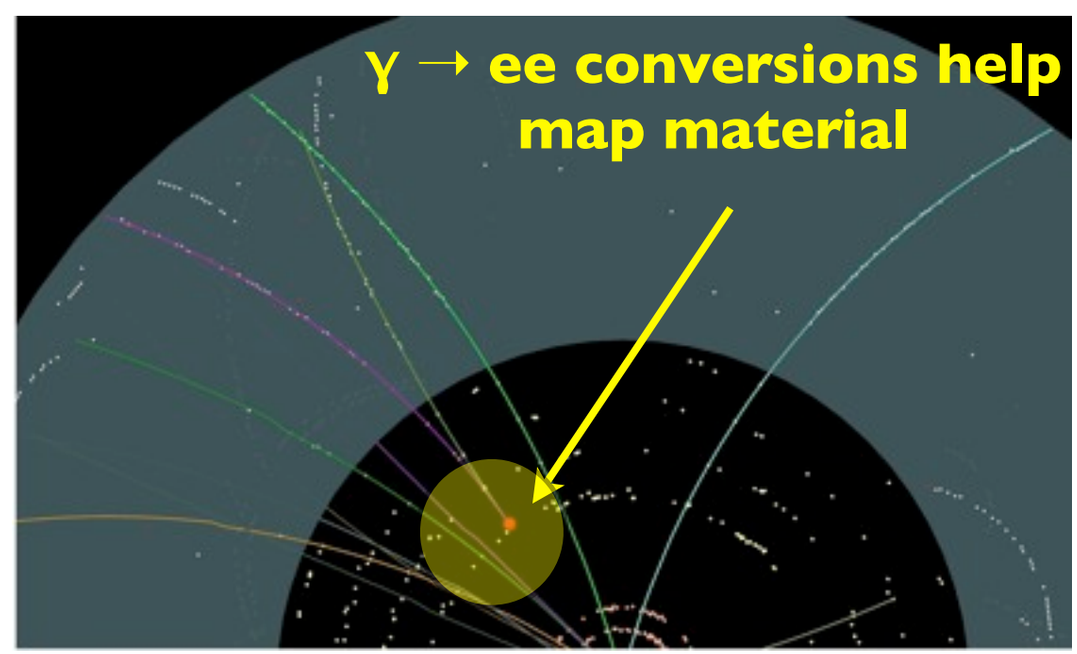




- Hits in the inner detector. **Pixel** and **SCT** layers clearly present as are **TRT** tracks.

Detector Performance: Tracking

- Small sampling of the 900 and 7 TeV detector performance results.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