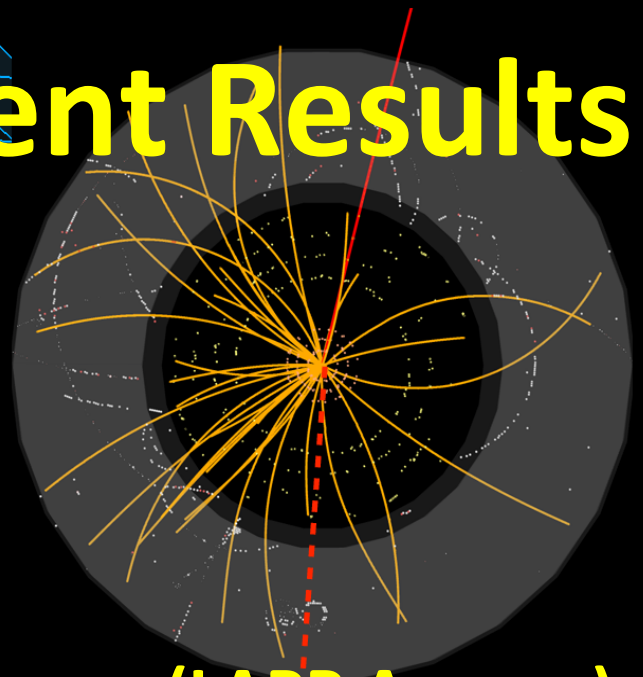
Status of the ATLAS Experiment and Recent Results

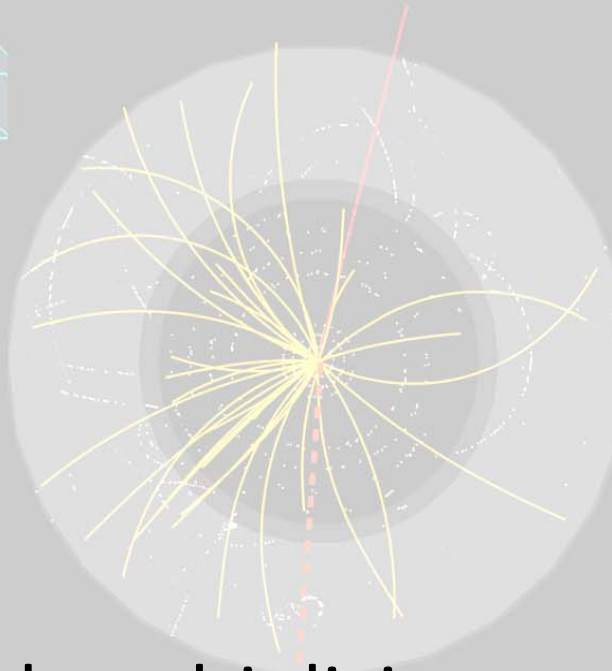


Nicolas Berger (LAPP Annecy)
for the ATLAS Collaboration

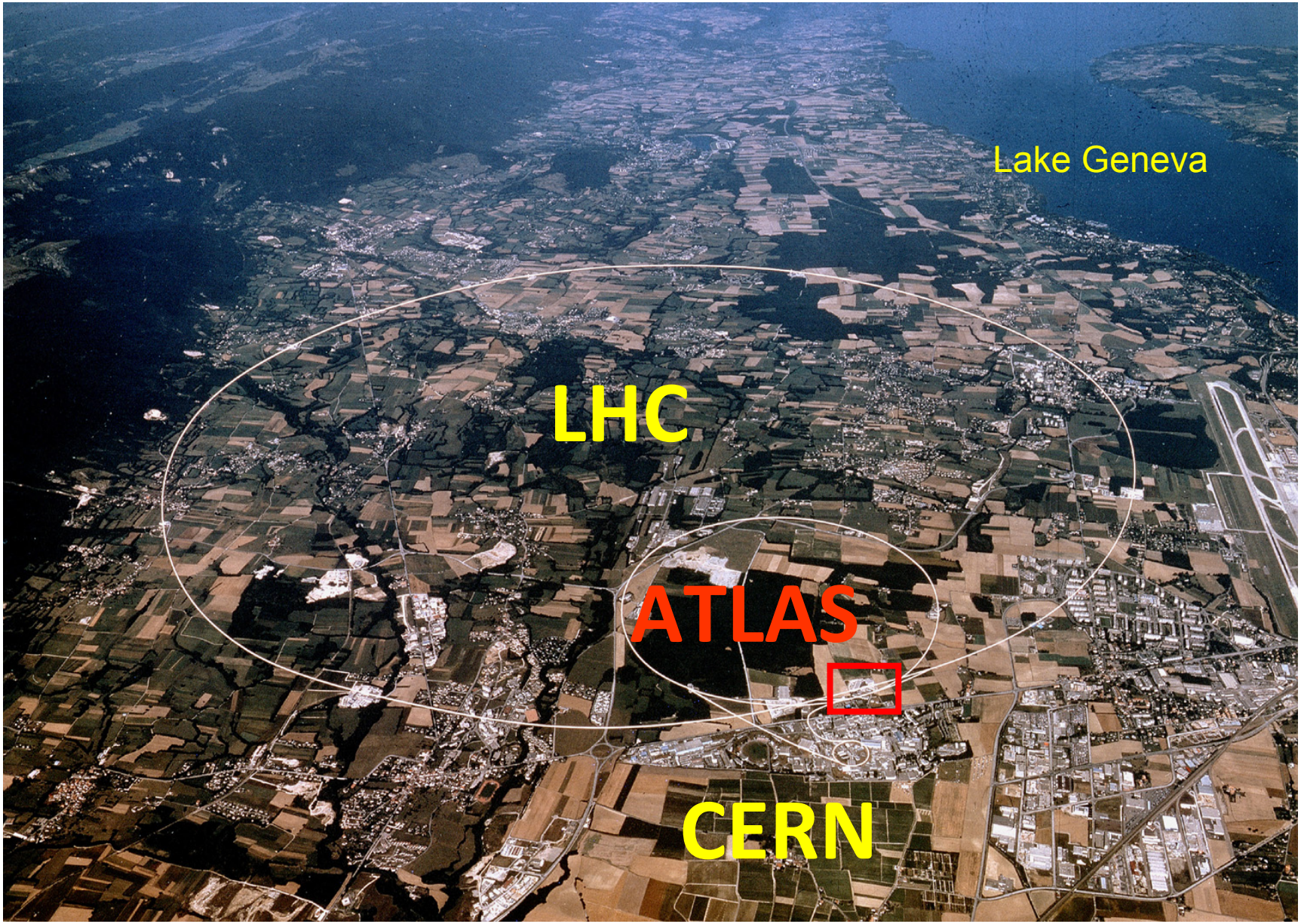
7
May 17th-21st, 2010
Fermilab, Illinois

Outline

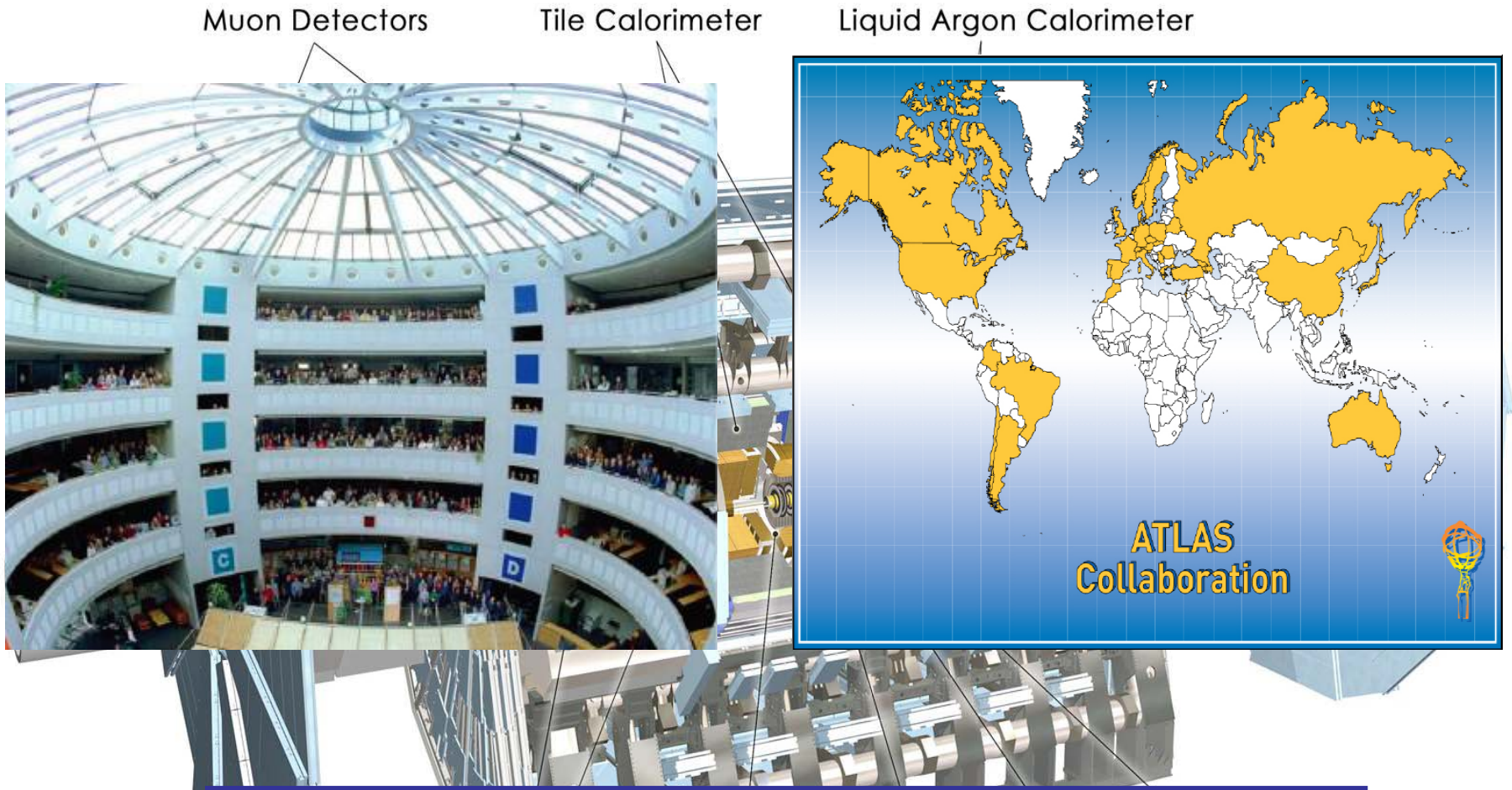
- ATLAS Status
- Performance during 2009-2010
  - Calorimetry
  - Tracking
  - Muon system
- First physics results: Charged track multiplicity at 7 TeV
- Prospects for 2010-2011



ATLAS

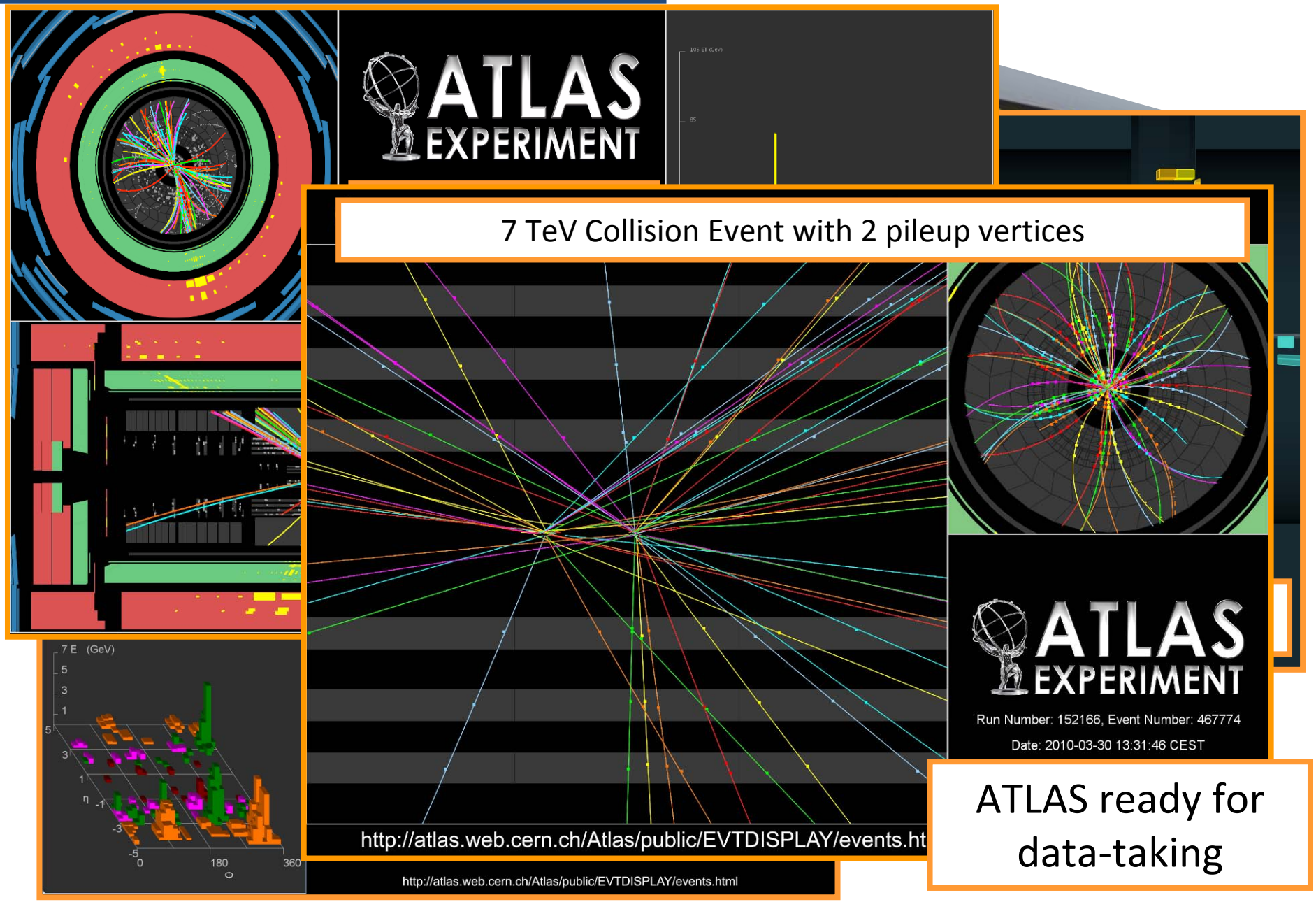


ATLAS



~3000 physicists, ~1000 students,
173 institutes, 37 countries

First LHC Beams in 2009-2010



ATLAS ready for data-taking

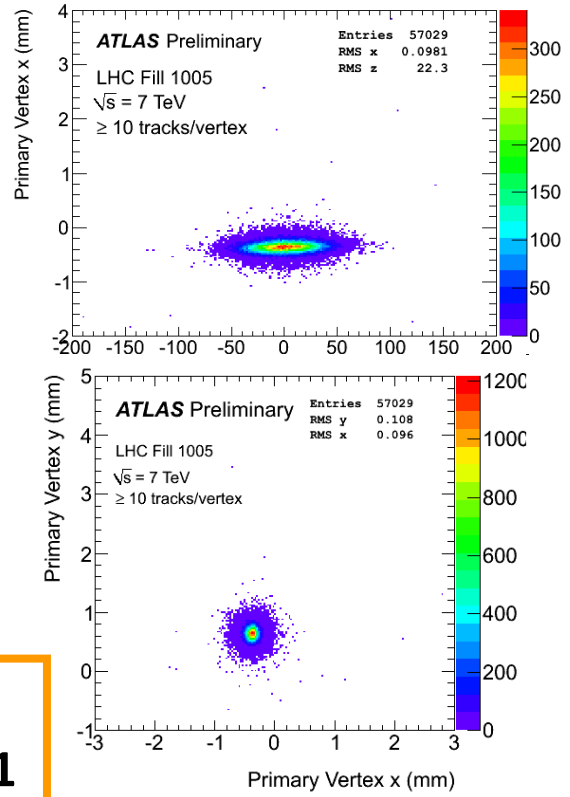
Operational Fraction (May 2010)

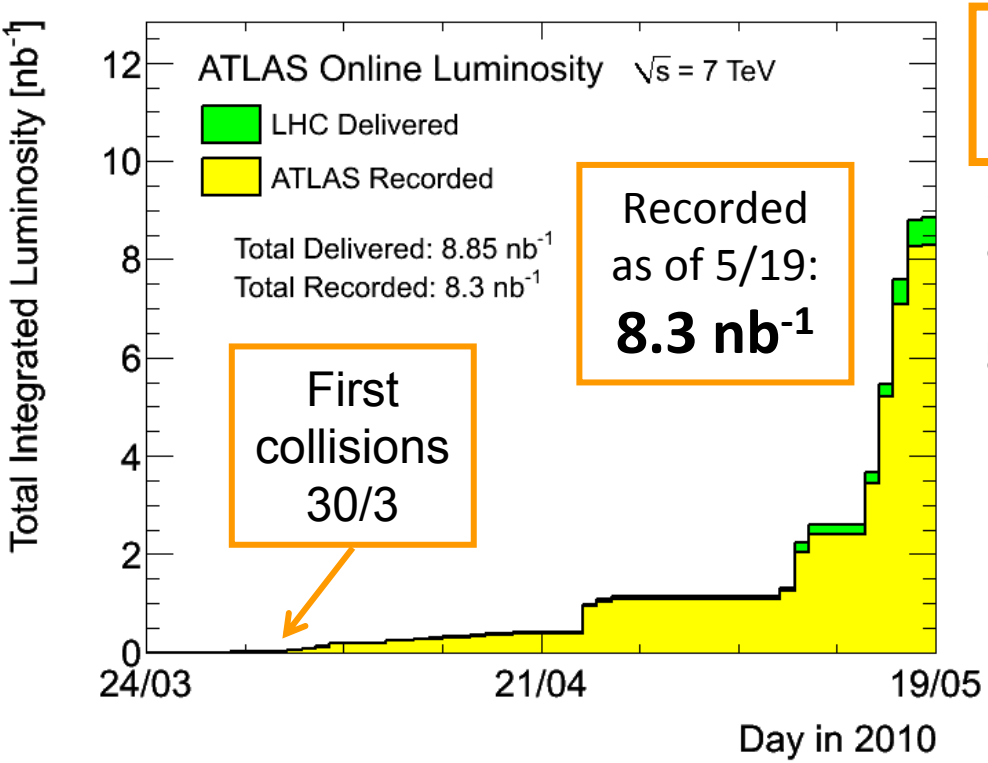
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.5%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.8%
LVL1 Muon RPC trigger	370 k	99.7%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.3%
TGC Endcap Muon Chambers	320 k	98.8%

All subsystems > 97%

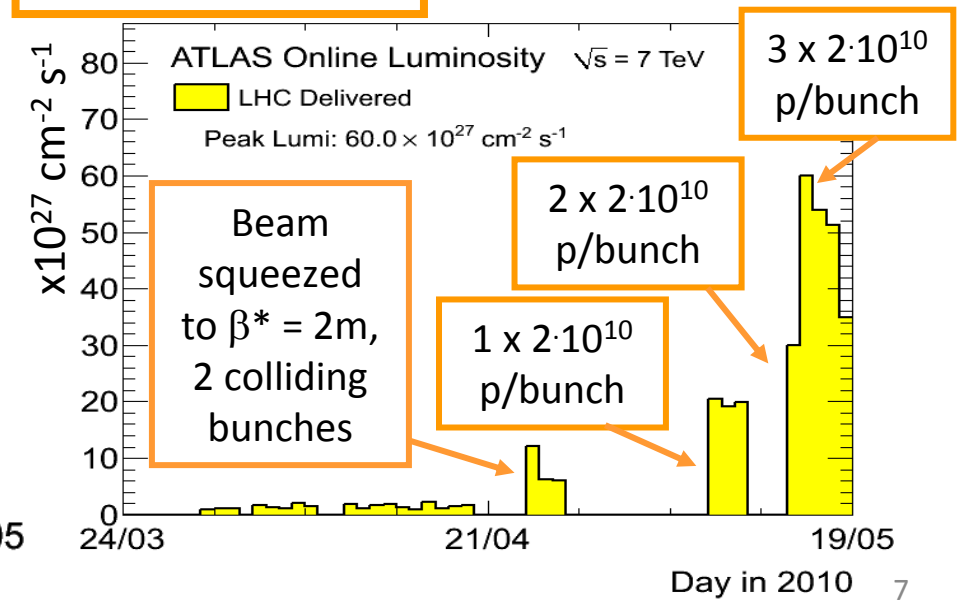
2010 Run Summary

	Initial	Current	2011	Nominal
Beam Energy	3.5 TeV	3.5 TeV	**3.5 TeV**	7 TeV
Coll. bunches	1	3	~700	2808
protons/bunch	10^{10}	$2 \cdot 10^{10}$	$\sim 10^{11}$	$1.1 \cdot 10^{11}$
β^*	11 m	2 m	~2 m	1 m
Lumi ($cm^{-2}s^{-1}$)	$\sim 10^{27}$	$6.0 \cdot 10^{28}$	$\sim 10^{32}$	10^{34}

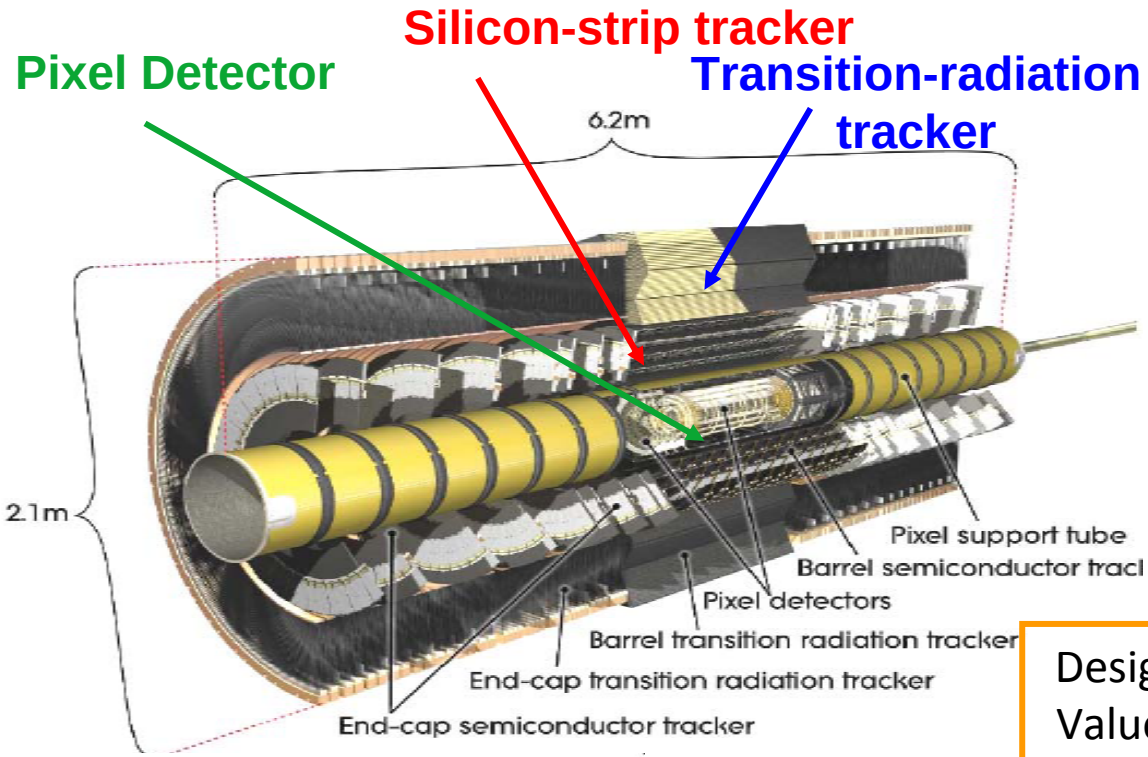


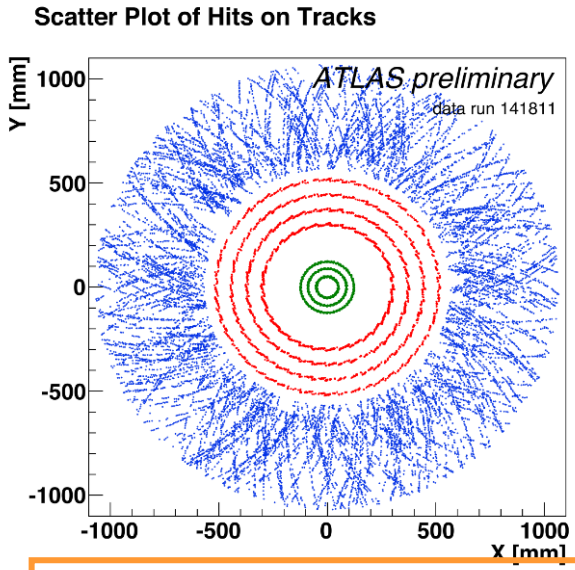


Goal: 1 fb^{-1} by the end of 2011



Inner detector



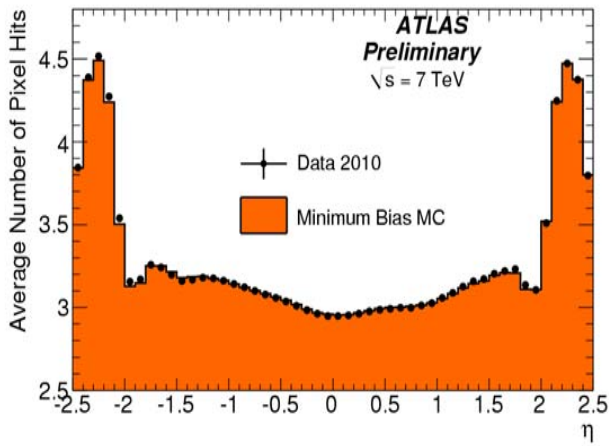


Coverage : $|\eta|<2.5$

$$\frac{\sigma(p_T)}{p_T} \cong \left(0.034 \frac{p_T}{\text{GeV}} \oplus 1.5\right)\%$$

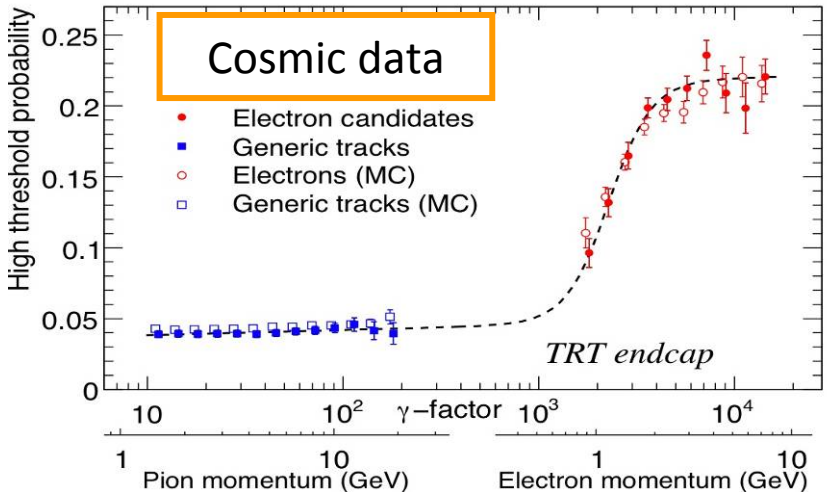
$$\frac{\sigma(d_0)}{d_0} \cong 140 \left(\frac{p_T}{\text{GeV}}\right)^{-1} \oplus 10\ \mu\text{m}$$

Design Values



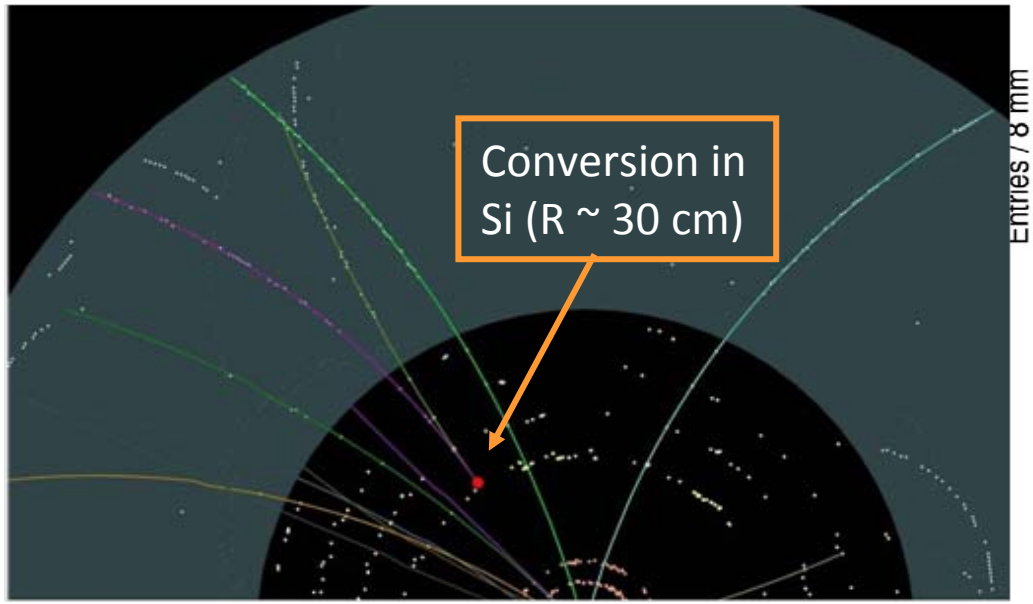
Transition radiation allows electron ID for $1<p_T<150$ GeV

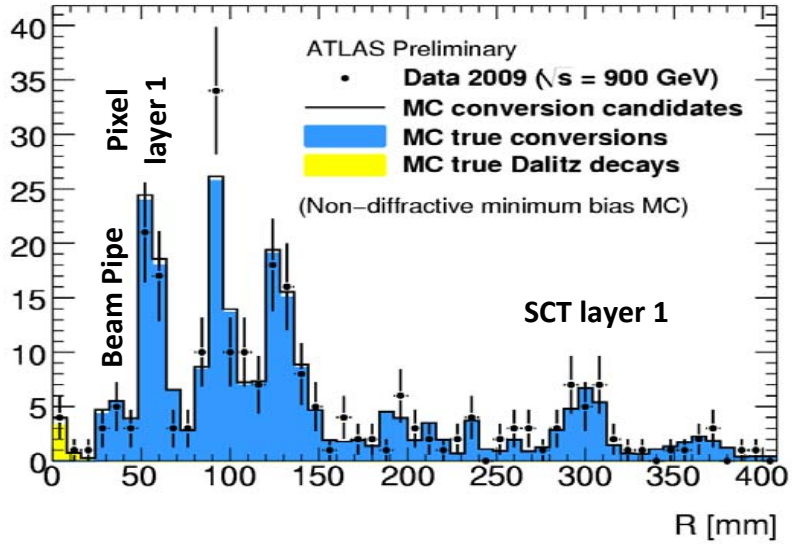
=> $J/\psi \rightarrow ee$

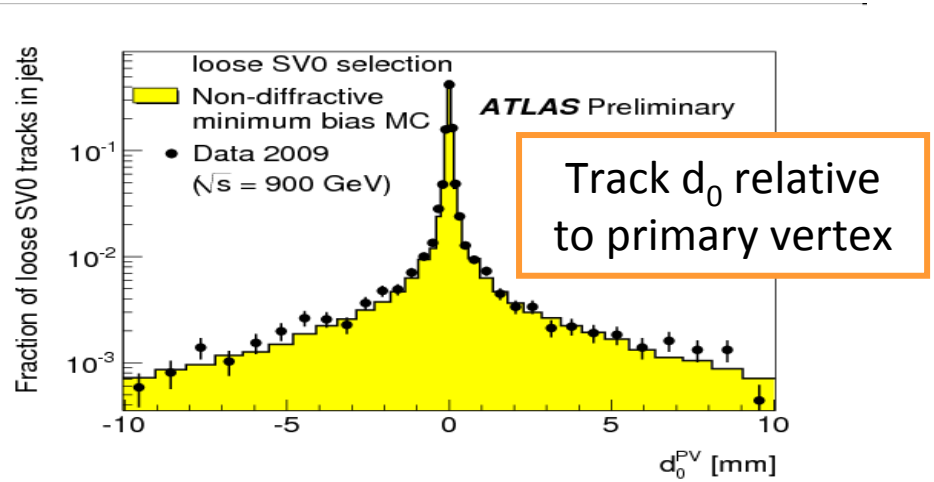


Vertexing

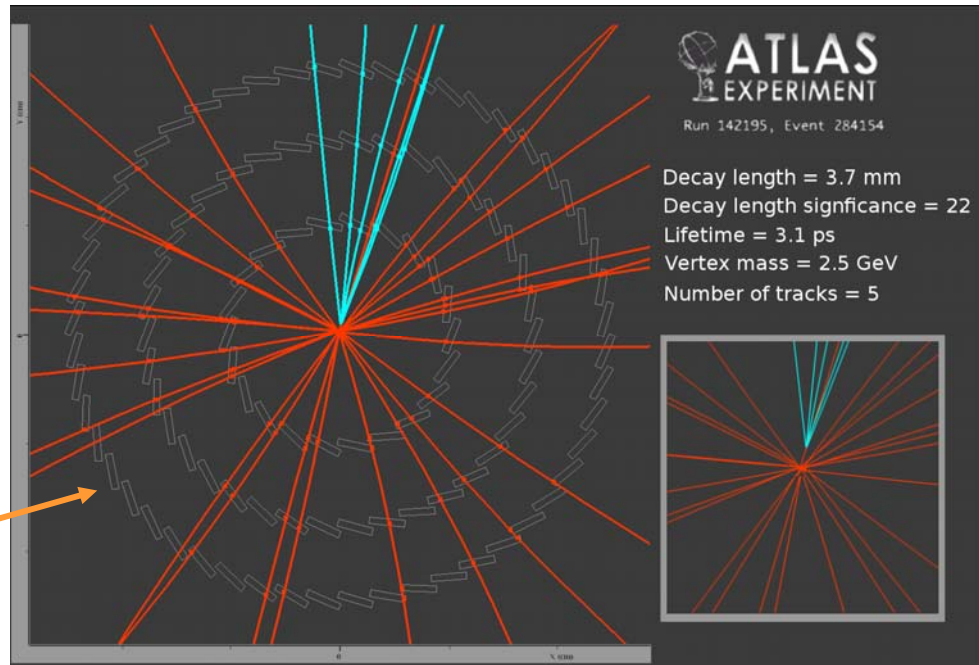
Reconstruct conversions: Can help to validate ID material description
⇒ Improve tracking efficiency error





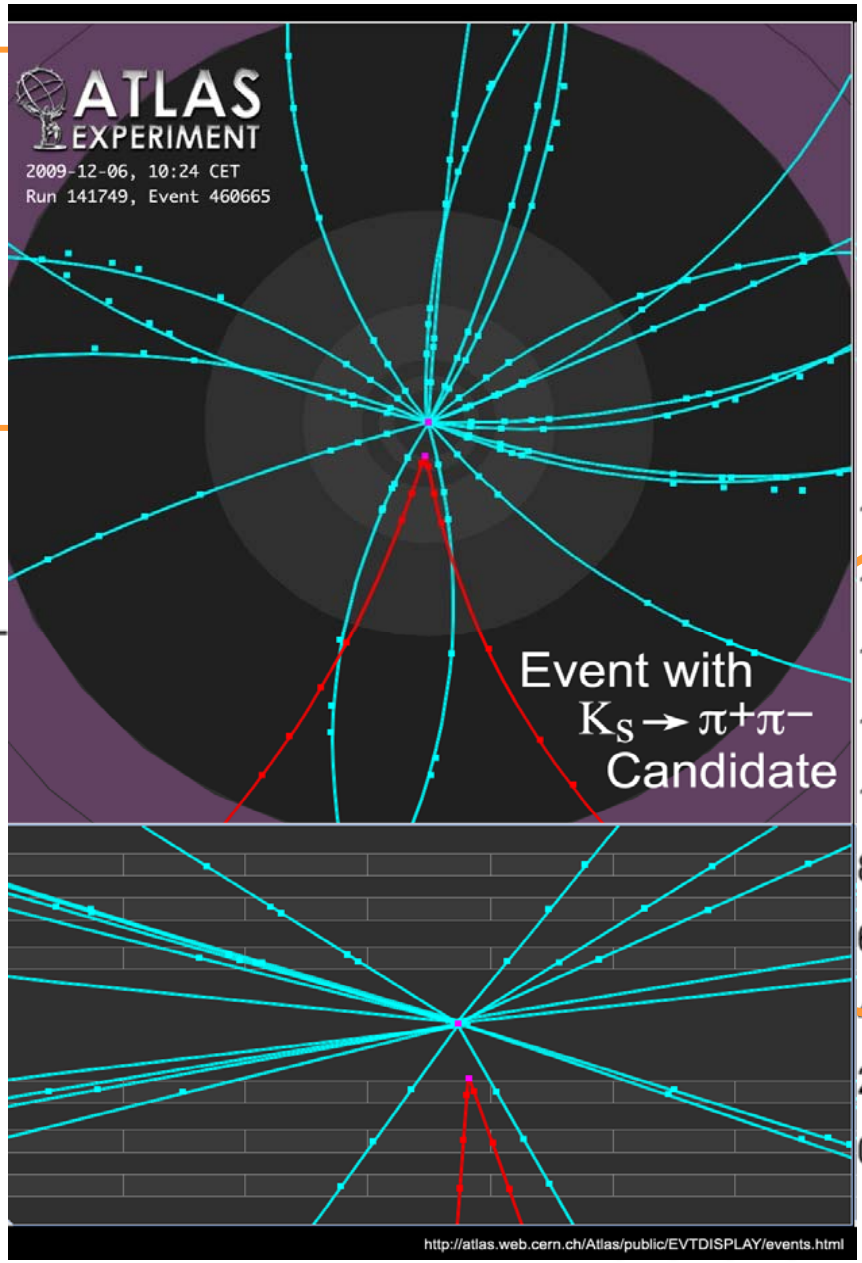


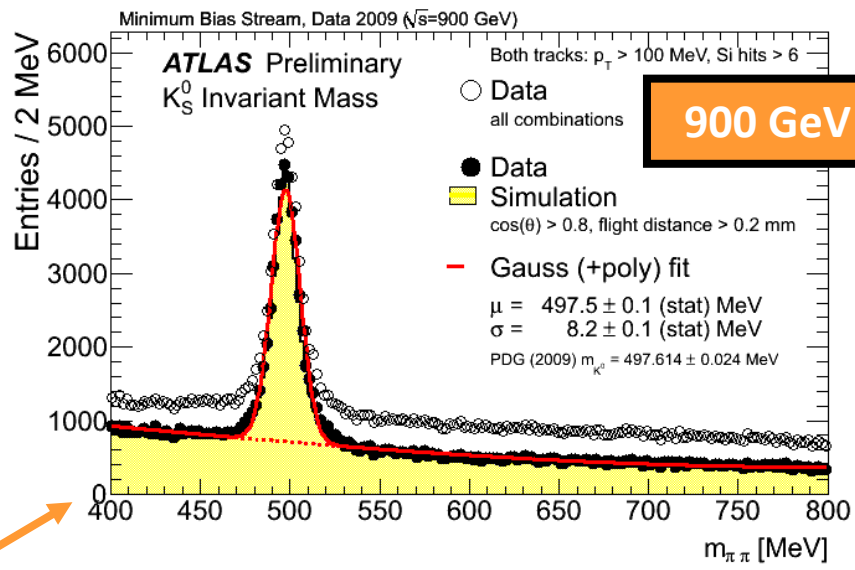
Track d_0 relative to primary vertex



A collision event with a displaced vertex: Towards b-tagging…

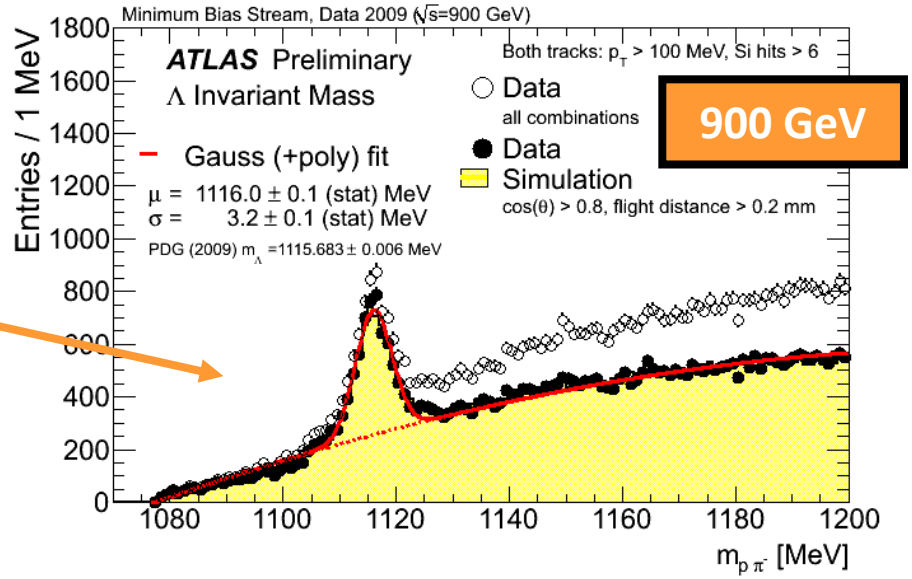
Weakly decaying hadronic states





900 GeV

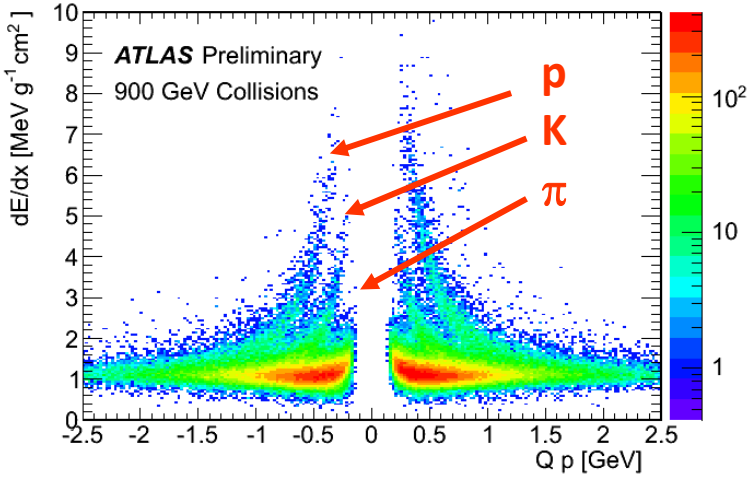
K_S peak position sensitive to material in inner detector

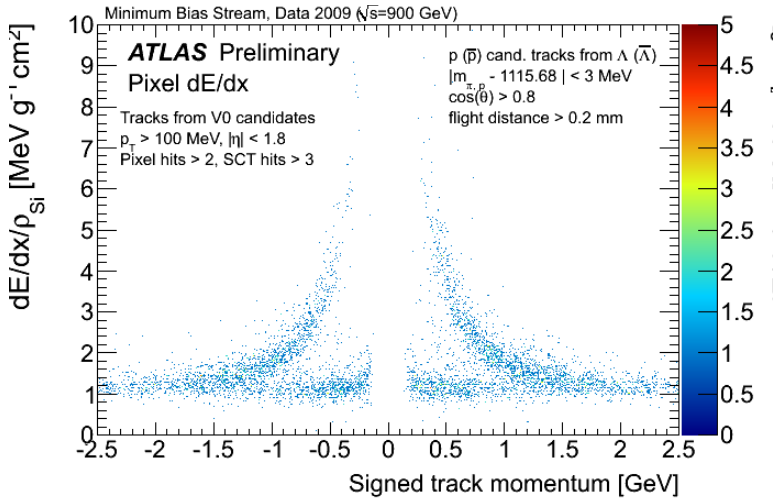


900 GeV

Particle identification, $\phi \rightarrow K^+K^-$

dE/dx from Pixels

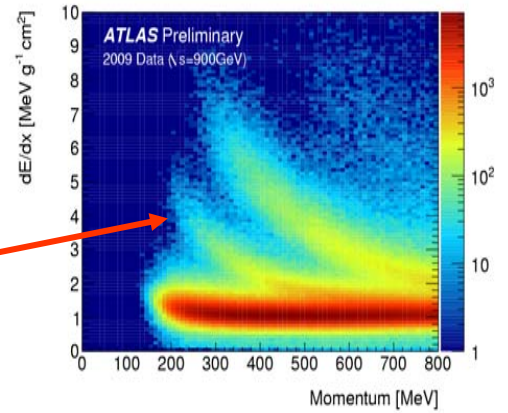




Same for events in Λ peak

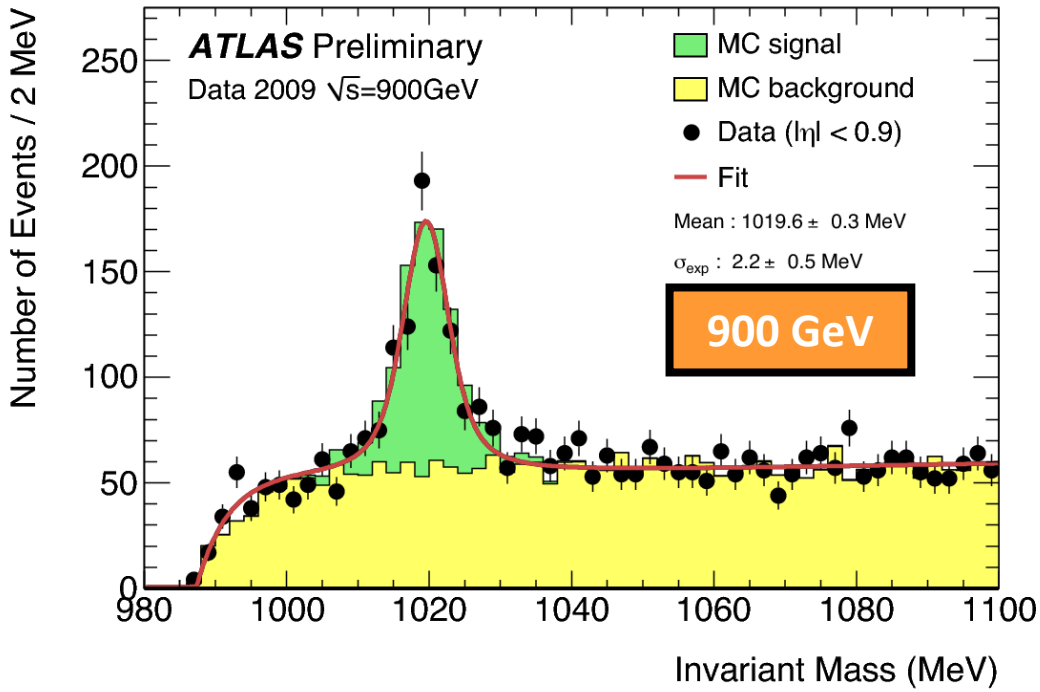
ϕ reconstruction

- Require tracks with Si hits coming from IP
- dE/dx in kaon band

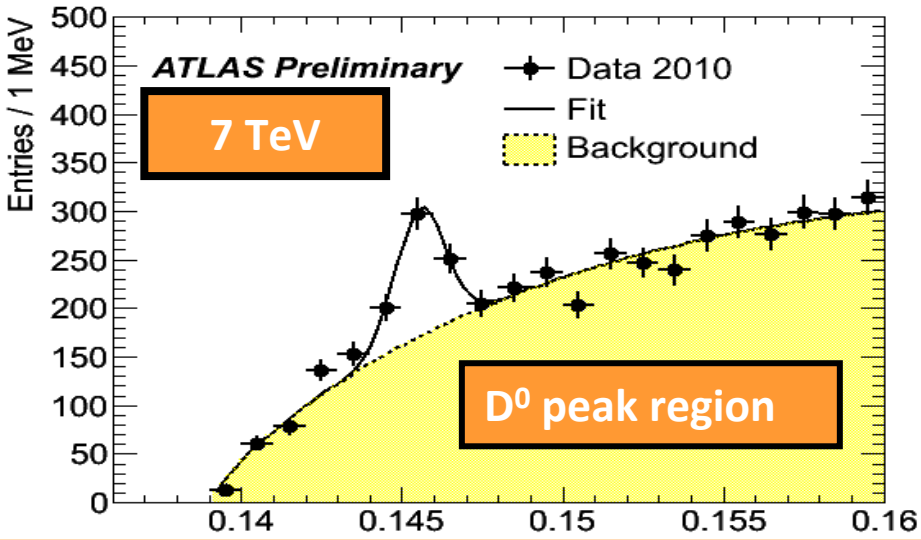


- $100 < p_T < 800$ MeV,

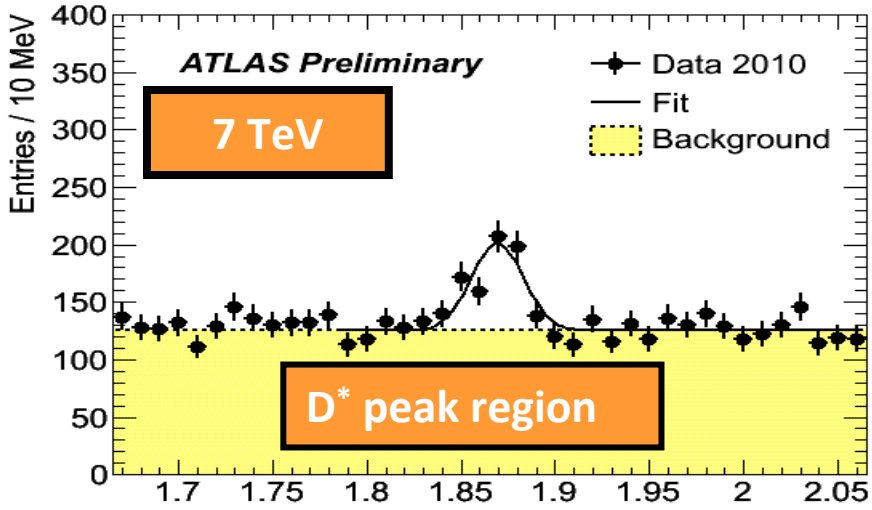
(upper cut to avoid merging of K,π dE/dx bands)



D^0, D* peaks



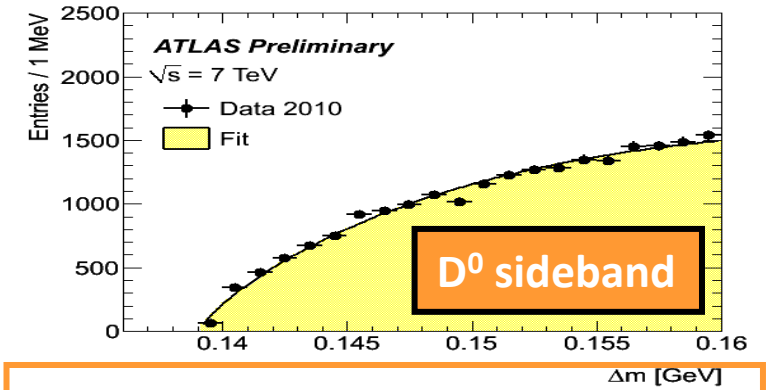
$m(K\pi\pi) - m(K\pi)$ for $|m(K\pi) - 1865| < 20$ MeV



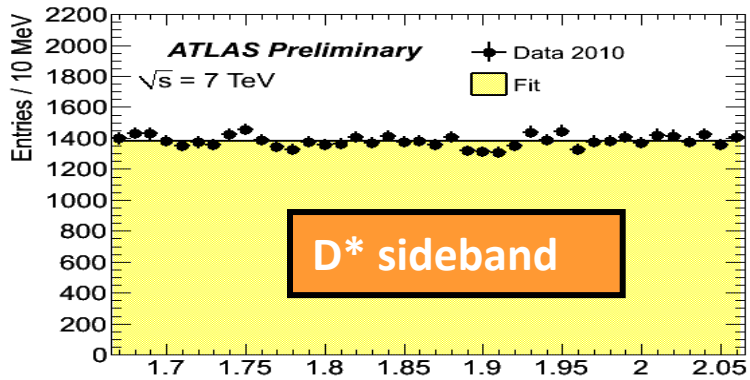
$m(K\pi)$ for $143.9 < |\, m(K\pi\pi) - m(K\pi)| < 146.9$ MeV

Reconstruct $D^* \rightarrow D\pi$, $D \rightarrow K\pi$

- Require tracks with Si hits coming from IP
- Require $p_T > 1$ GeV for D daughters



$m(K\pi\pi) - m(K\pi)$ for
$100 < |m(K\pi) - 1865| < 200$ MeV



$m(K\pi)$ for
$150 < |\, m(K\pi\pi) - m(K\pi)| < 170$ MeV

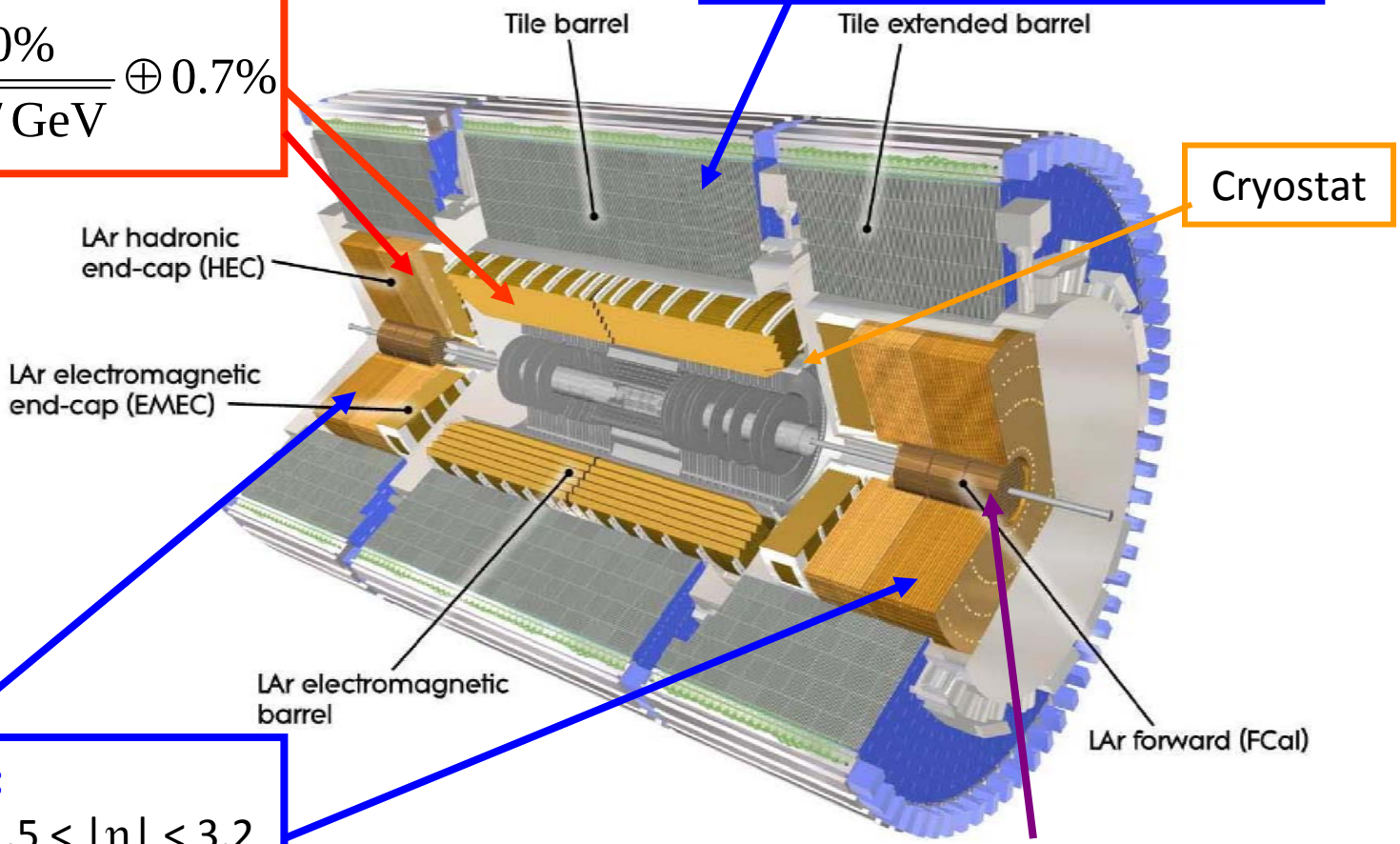
ATLAS Calorimeters

Hadronic Barrel :
Scintillator/Fe, $|\eta| < 1.7$

$$\left.\frac{\sigma(E)}{E}\right|_{Jet} \cong \frac{50\%}{\sqrt{E/\mathrm{GeV}}} \oplus 3\%$$

EM Calorimetry :
Liquid-Argon/Pb, $|\eta|<3.2$

$$\left.\frac{\sigma(E)}{E}\right|_{e/\gamma} \cong \frac{10\%}{\sqrt{E/\mathrm{GeV}}} \oplus 0.7\%$$



(Resolutions shown here are Design values.)

Hadronic End-cap:
Liquid Argon/Cu, $1.5 < |\eta| < 3.2$

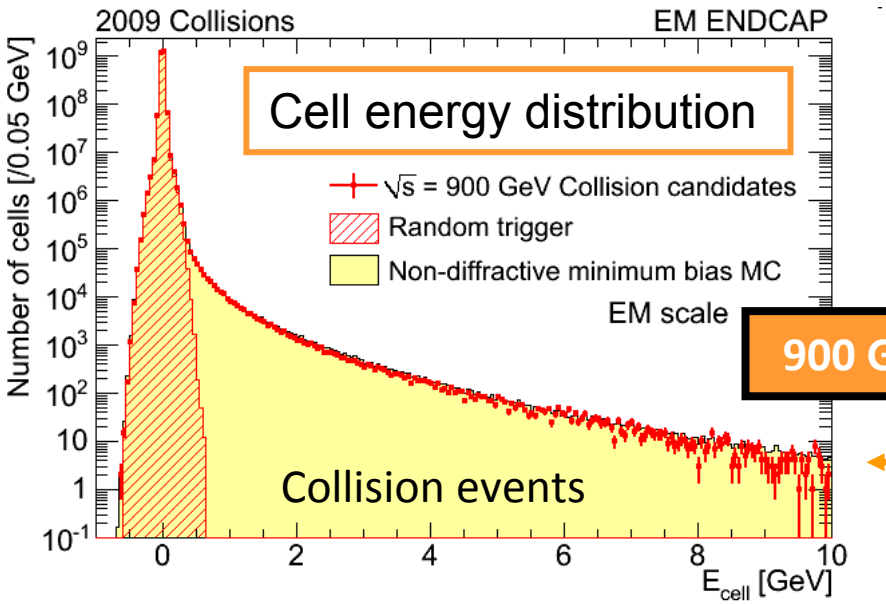
$$\left.\frac{\sigma(E)}{E}\right|_{Jet} \cong \frac{50\%}{\sqrt{E/\mathrm{GeV}}} \oplus 3\%$$

Forward Calorimeters:
Liquid Argon/Cu/W,
$3.1 < |\eta| < 4.9$

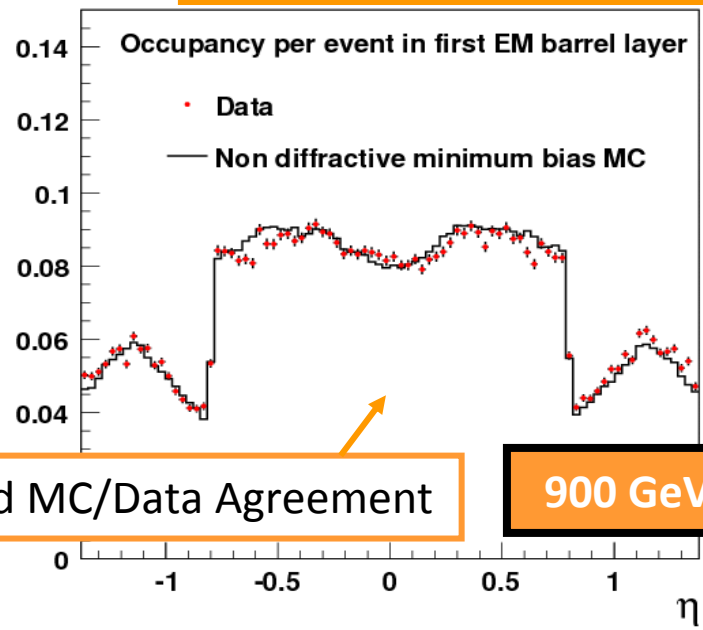
$$\sigma(E)/E\big|_{Jet} \cong \frac{100\%}{\sqrt{E/\mathrm{GeV}}} \oplus 10\%$$

Calorimeter Performance

MC normalization taken from data all MC/Data comparisons

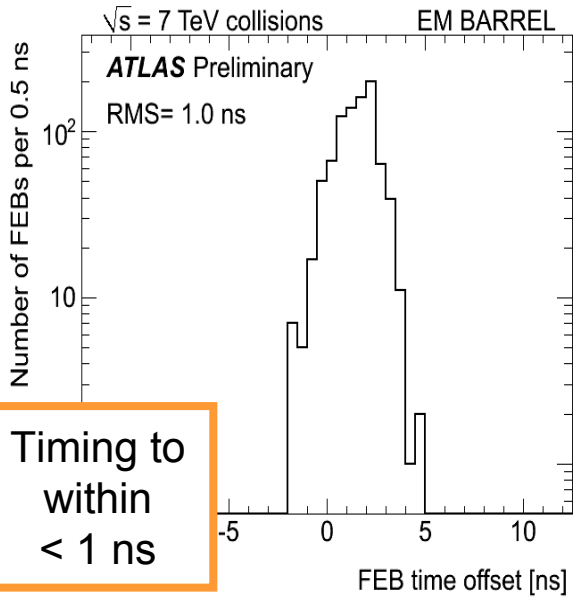


900 GeV

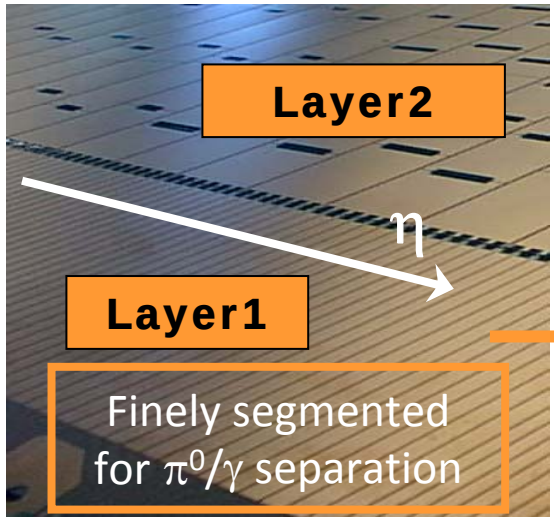


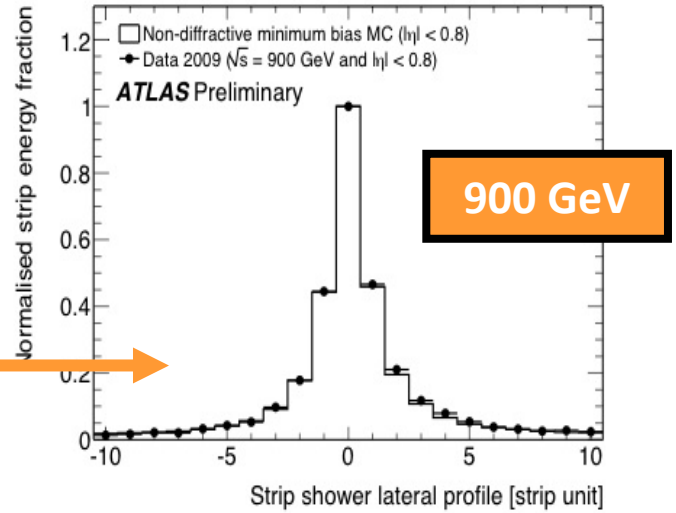
Good MC/Data Agreement

900 GeV



Timing to within < 1 ns





900 GeV

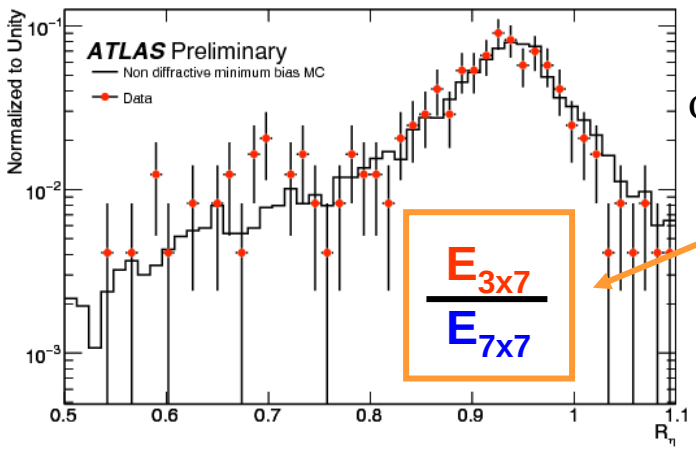
Reconstruction of γ, π^0, η

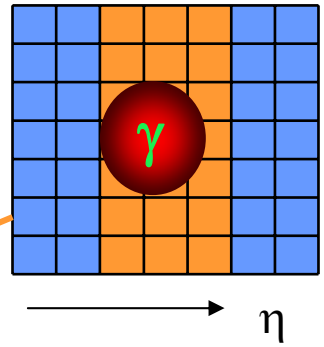
π^0/η Search:

Select photons with $|\eta|<2.37$, $E_T > 800$ MeV, Shower-shape cuts

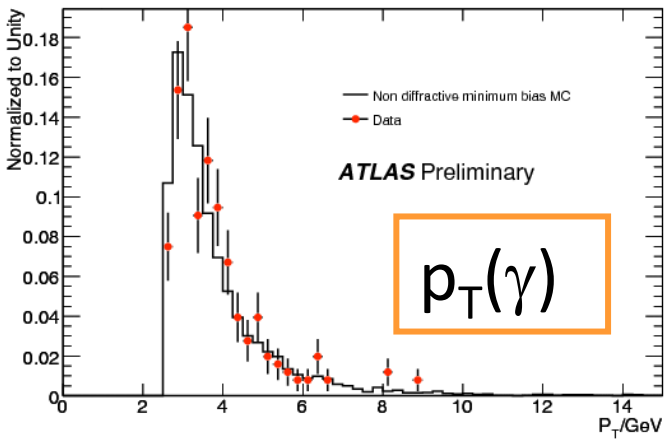
- $p_T(\text{pair}) > 2.2$ GeV
- Reject if track pointing to cluster

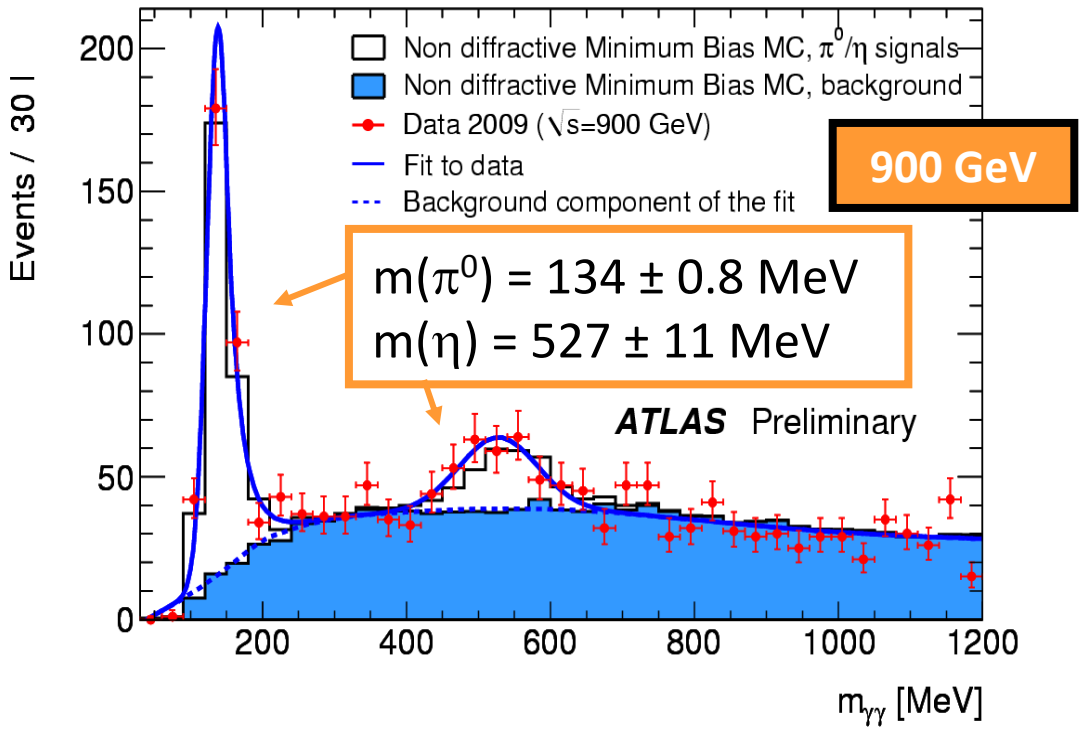
$\Rightarrow$~400k candidates $\mathscr{L} \sim 9\ \mu b^{-1}$





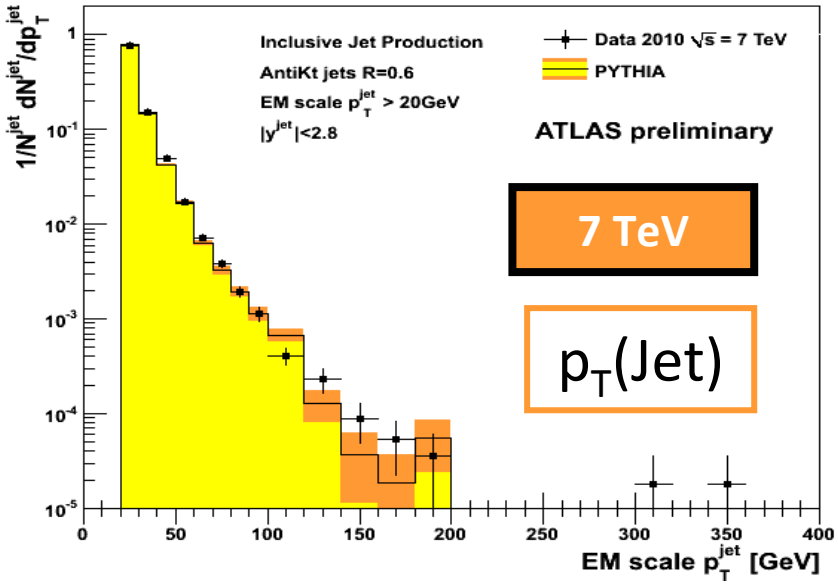
MC : good description of photon ID variables and spectrum



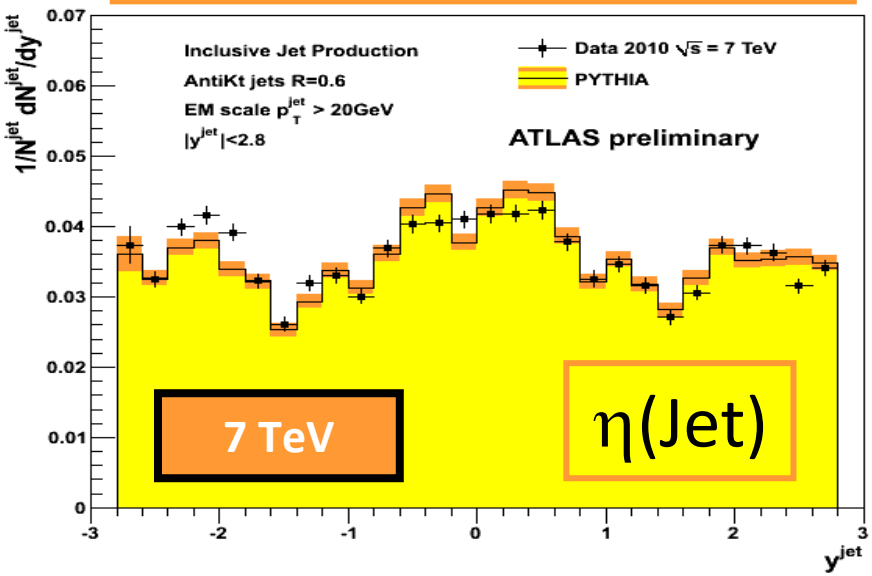


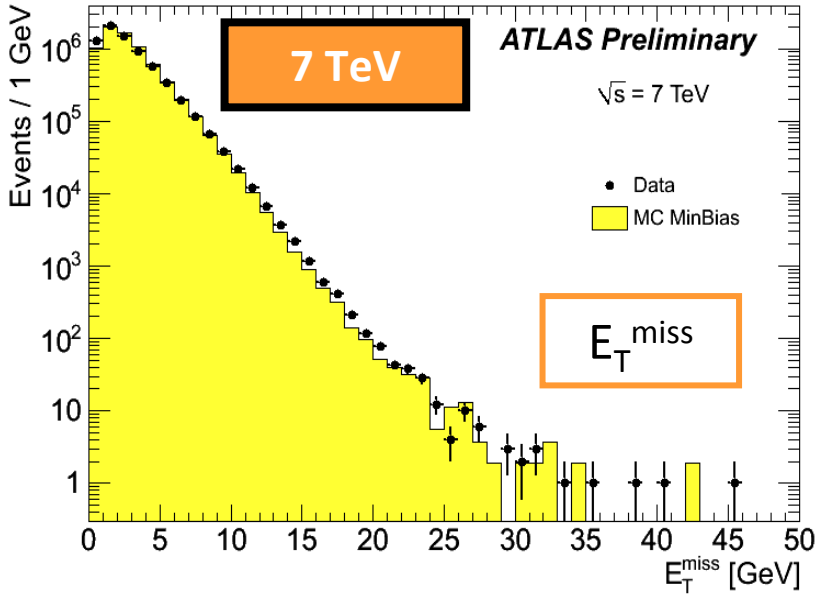
π^0 mass $\Rightarrow$ Energy scale to ~1%, uniformity to ~2%

Jets and E_T^{miss}

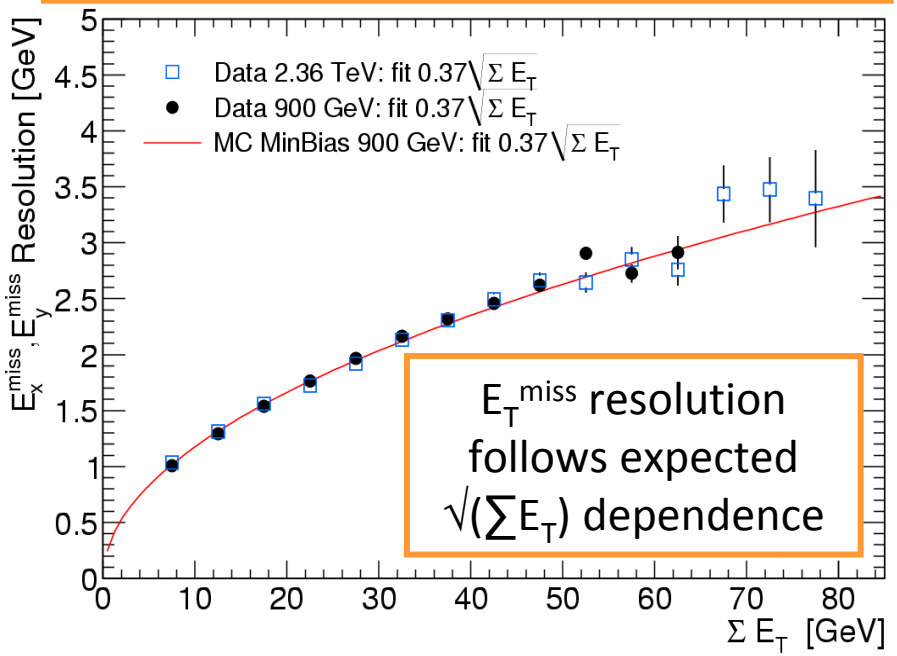


Data well reproduced by MC





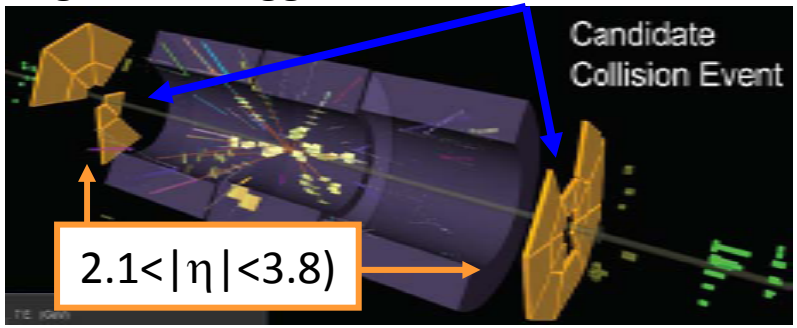
Good MC/data agreement for E_T^{miss} tails



Charged particle multiplicities at 7 TeV

Selection

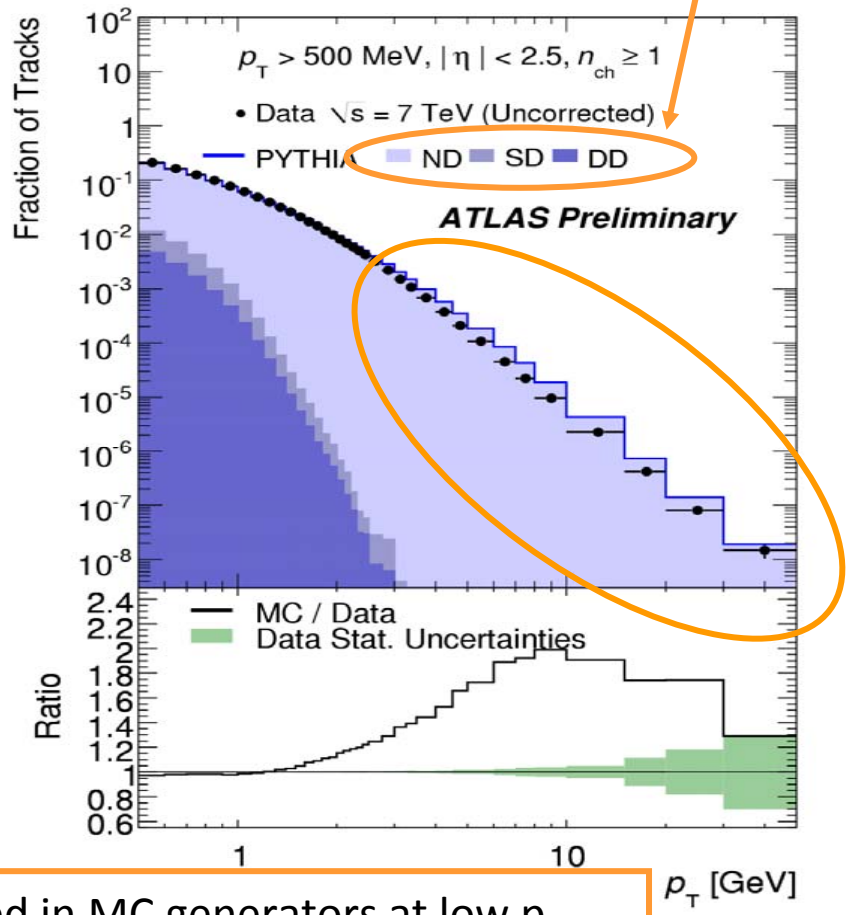
- Exactly 1 primary vertex
- Single-arm trigger from **scintillator counters**



⇒ 370k events, L ~ 7 μb^{-1}

- Study tracks with p_T>500 MeV, |η|<2.5 coming from primary vertex
- dominant uncertainty : material (tracking efficiency syst. ~4%)

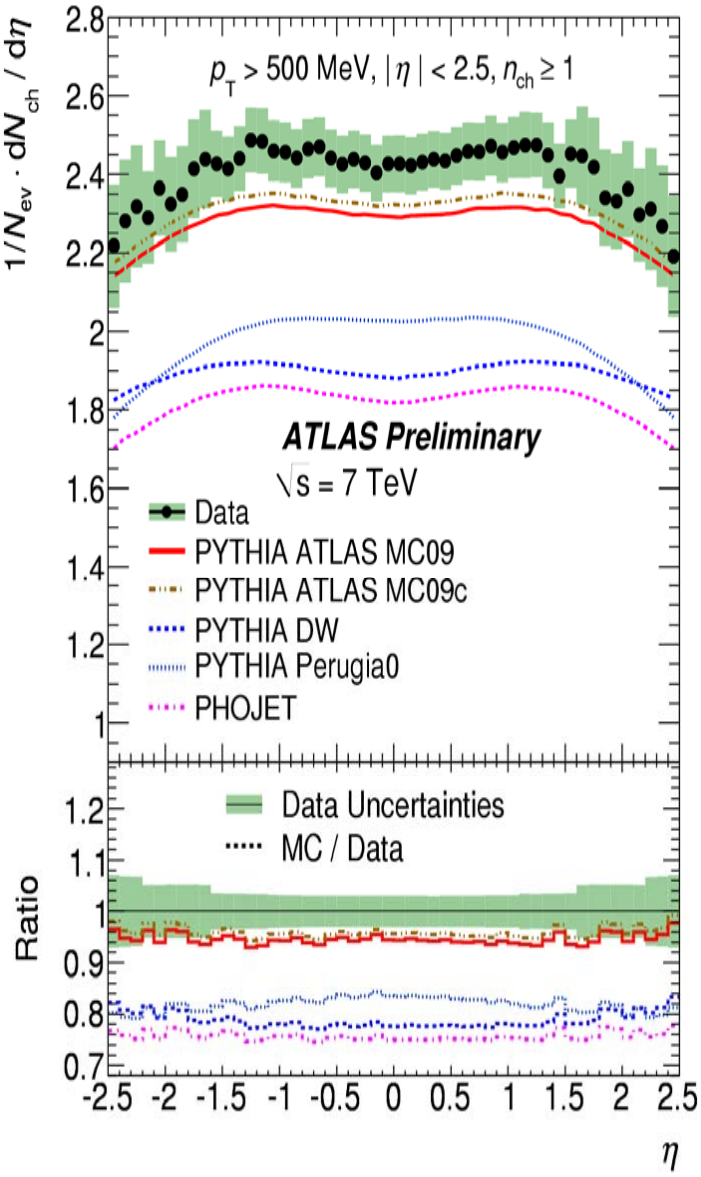
Sensitive to Single/Double diffractive components of cross-section



Allows testing of phenomenological models used in MC generators at low p_T
⇒ important for good description of underlying event in 7 TeV collisions.

Similar analysis at 900 GeV already published: Phys. Lett. B **688**, Issue 1, 21-42

Charged particle multiplicities at 7 TeV

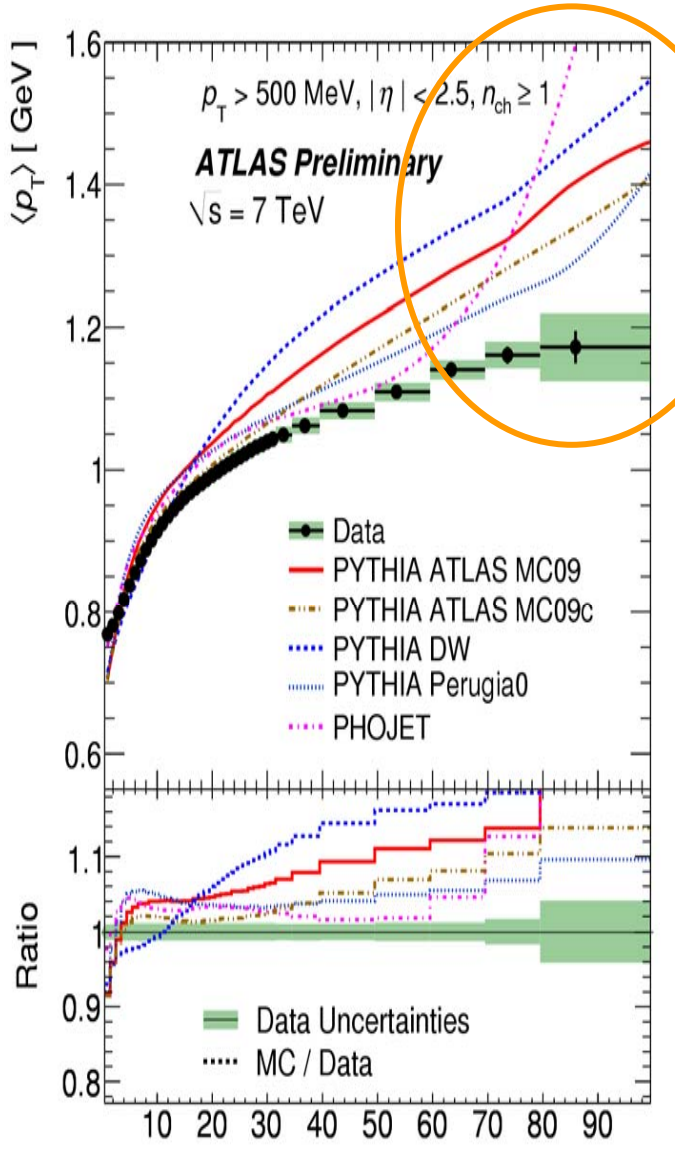


ATLAS MC09: pythia 6.4.21 with pT-ordered showers, MRST LO* PDFs

ATLAS MC09c: improved tuning of color-recombination term

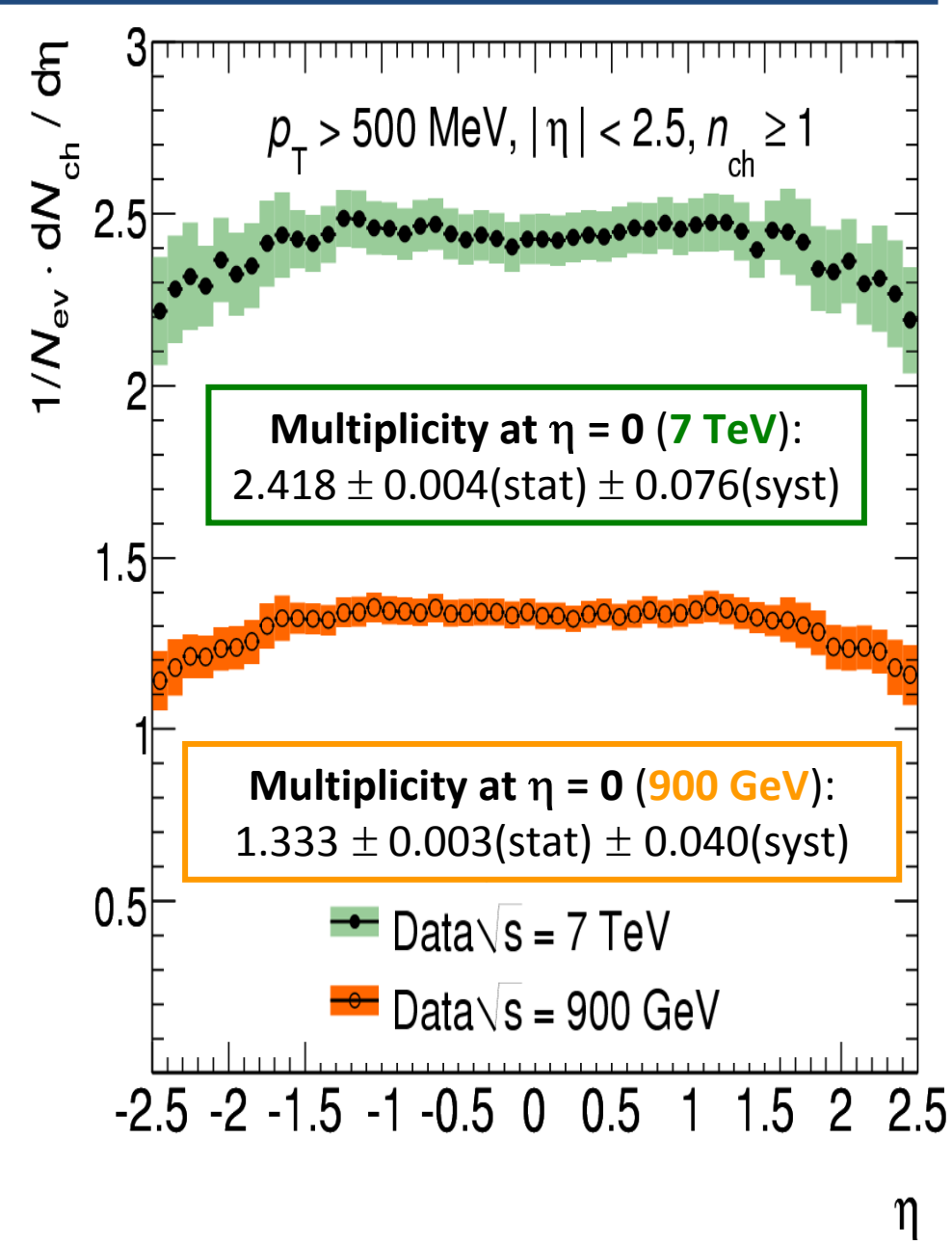
Pythia DW: virtuality-ordered showers tuned from CDF run II.

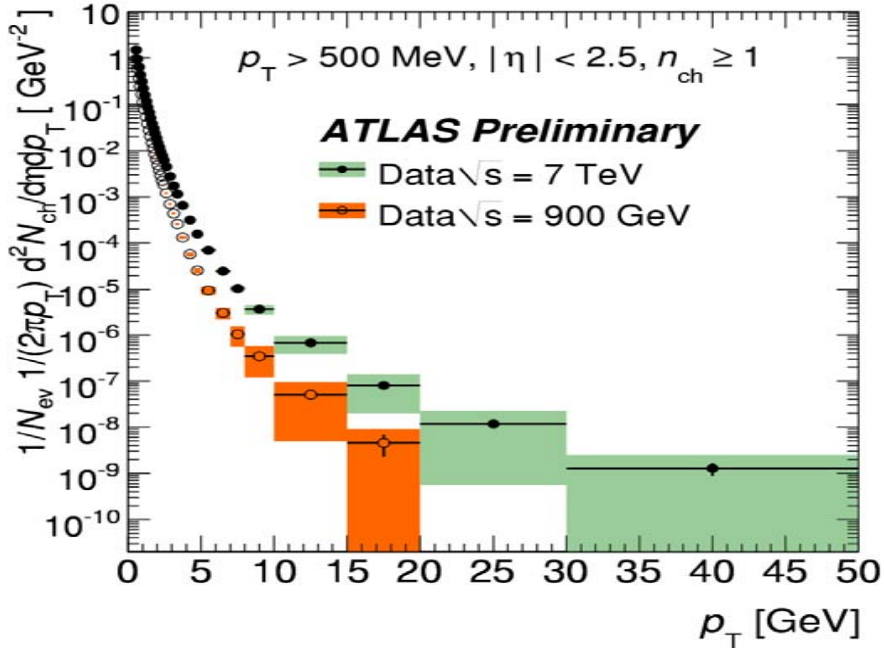
PYTHIA Perugia0: Alternative tune based on TeVatron and SPS data only

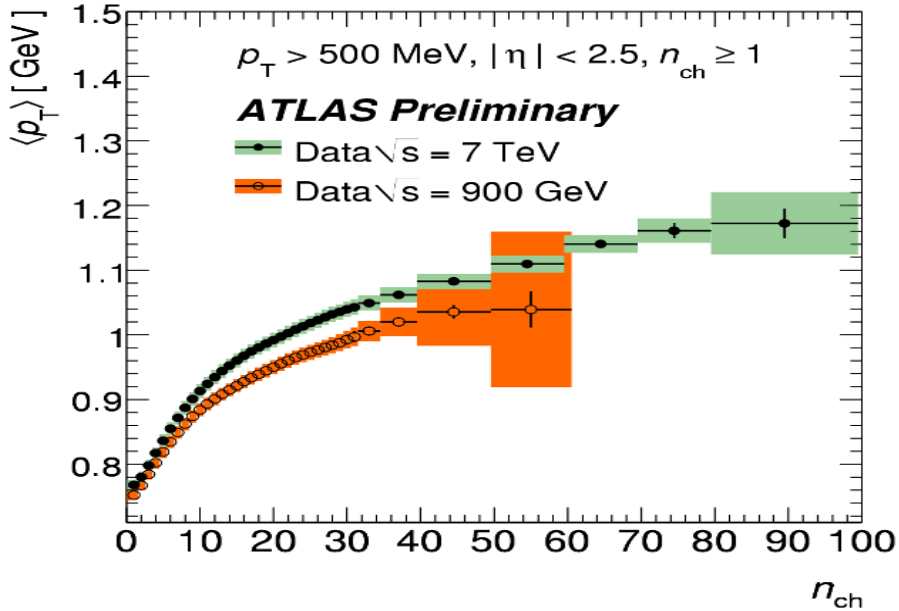


Tuning studies ongoing; sufficient for early physics

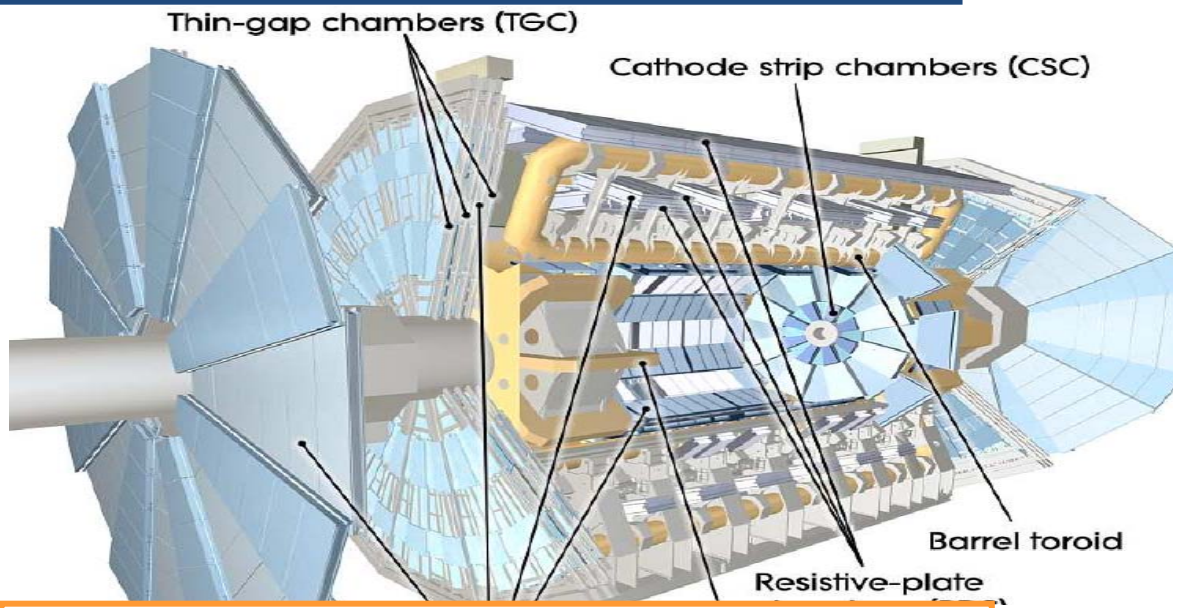
7 TeV vs. 900 GeV Comparison

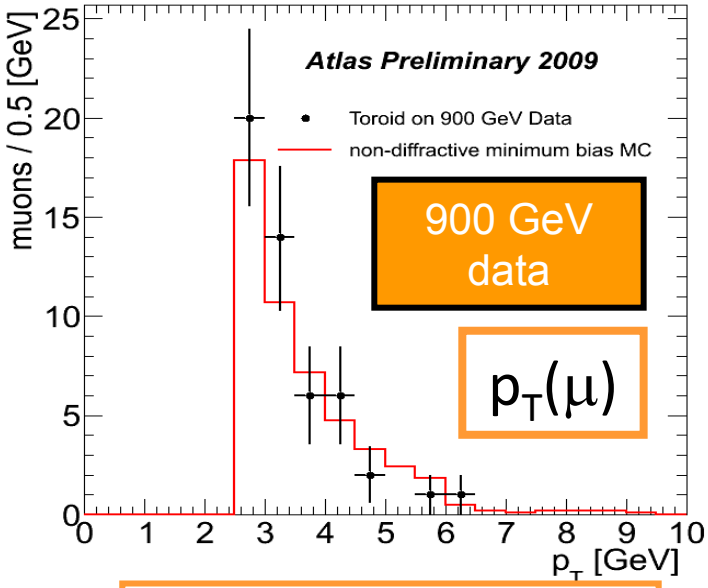






$J/\psi \rightarrow \mu^+\mu^-$

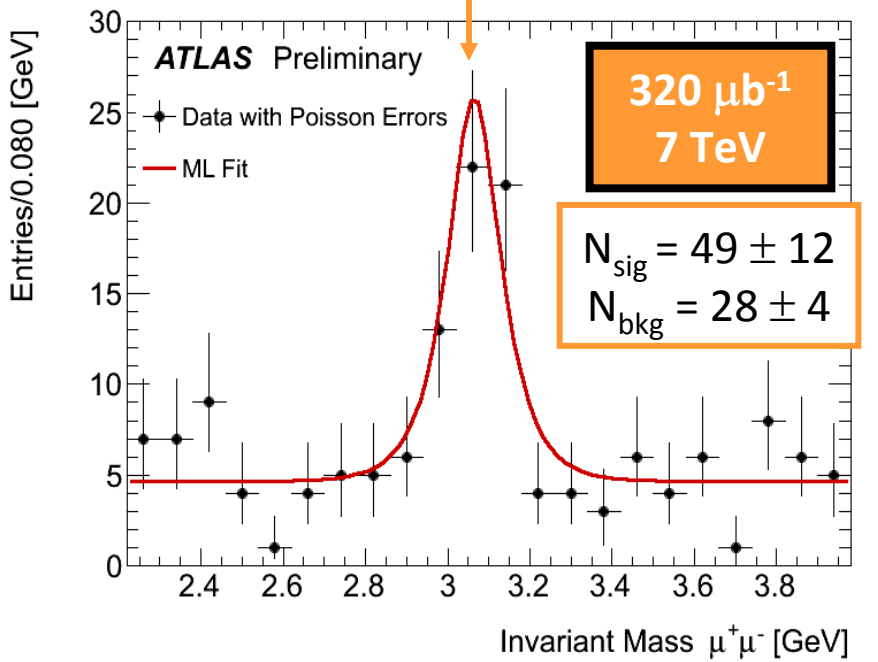




$m(J/\psi) = 3.06 \pm 0.02$ GeV
$\sigma = 80 \pm 20$ MeV

Muon Spectrometer : $|\eta| < 2.7$

- Standalone: $\left.\frac{\sigma(p)}{p}\right|_{\mu} \cong 3\%(100\,\mathrm{GeV}) - 10\%(1\,\mathrm{TeV})$
- Combined with inner tracker: $\left.\frac{\sigma(p)}{p}\right|_{\mu} \cong 2\% \ \ (p_T < 50\,\mathrm{GeV})$



$J/\psi \rightarrow \mu^+\mu^-$ Reconstruction:

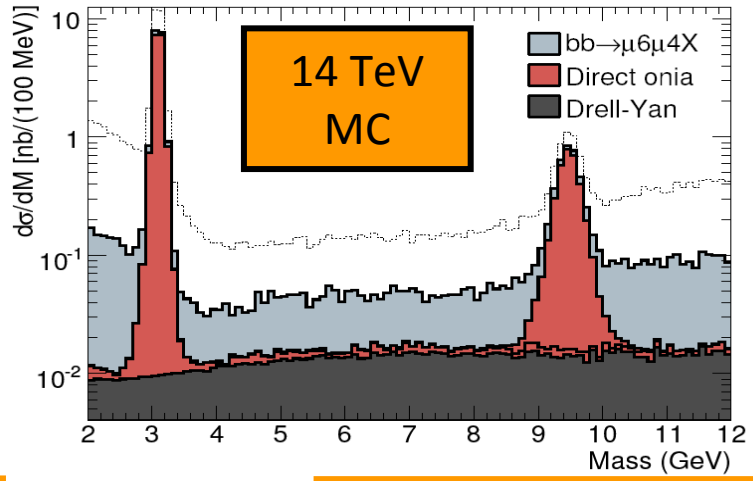
- Require E(μ) > 3 GeV,
- at least one muon combined with tracker

Prospects for quarkonia

Production in μμ channel (√s = **10 TeV**)

$p_T > 4$ GeV, $|\eta| < 2.5$

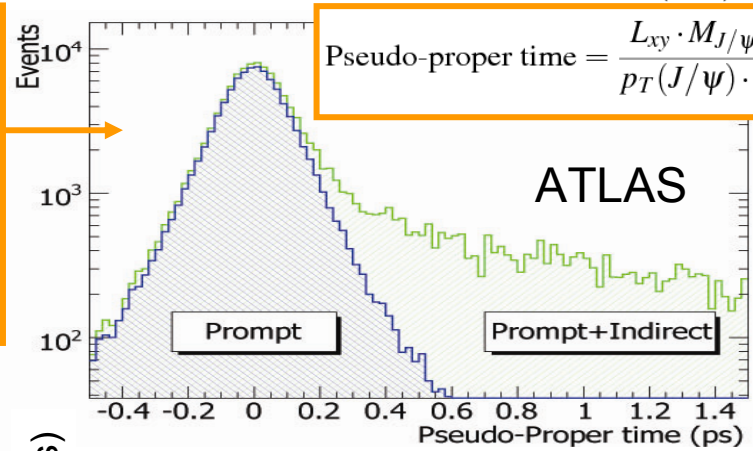
ψ→μμ	Υ(1S) →μμ	Υ(2S) →μμ	Υ(3S) →μμ
30 nb	20 nb	10 nb	9 nb



- ee channel: doable with TRT-based e-ID, larger bkg.
- **1% stat. precision with 10 pb^{-1}.**
- Luminosity error >> 1%, cancels in prompt/indirect ratio, p_T shape

Proper time provides separation of prompt and indirect (B decay) contributions

$$\text{Pseudo-proper time} = \frac{L_{xy} \cdot M_{J/\psi}}{p_T(J/\psi) \cdot c},$$

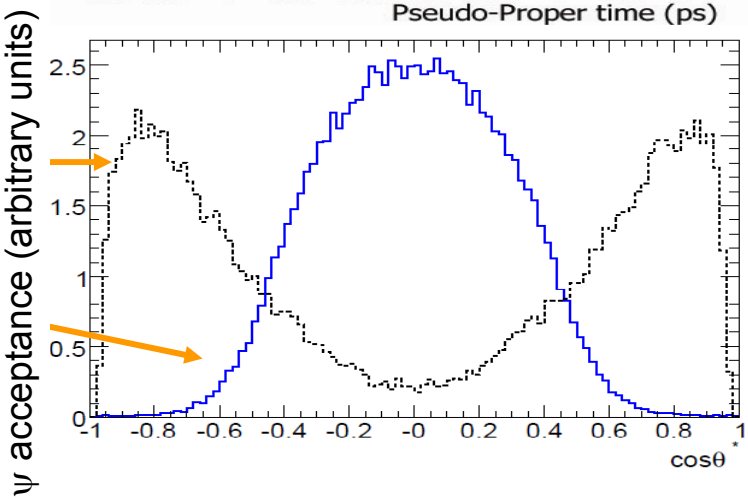


Polarization:

- powerful tool to discriminate production models
- Incompatible CDF & D0 results for Υ.
- Single-object trigger increases cos θ* range

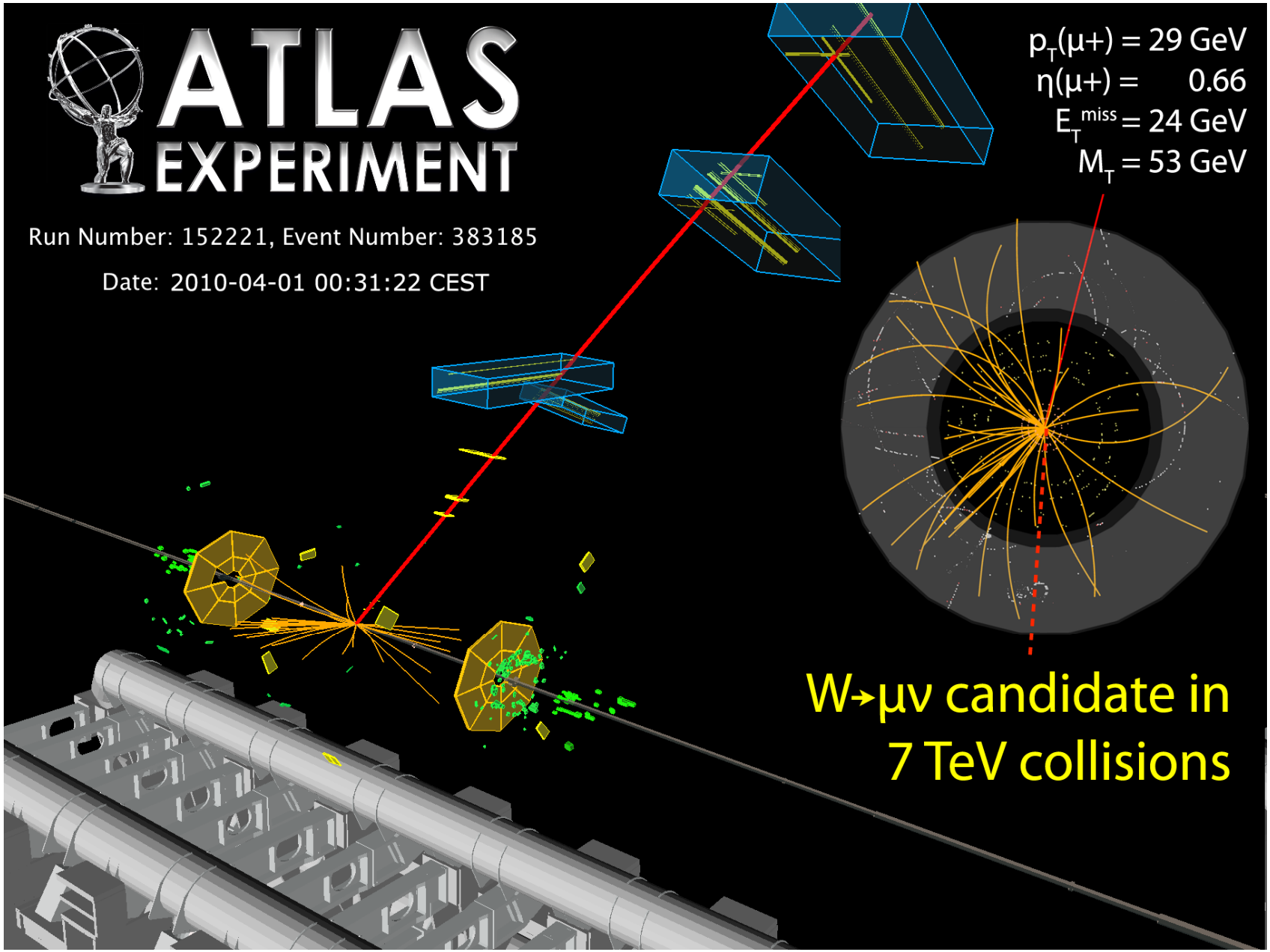
Trigger on 1μ(p_T>10 GeV), add low-p_T track

Trigger on 2μ(p_T > 6 GeV, p_T > 4 GeV)

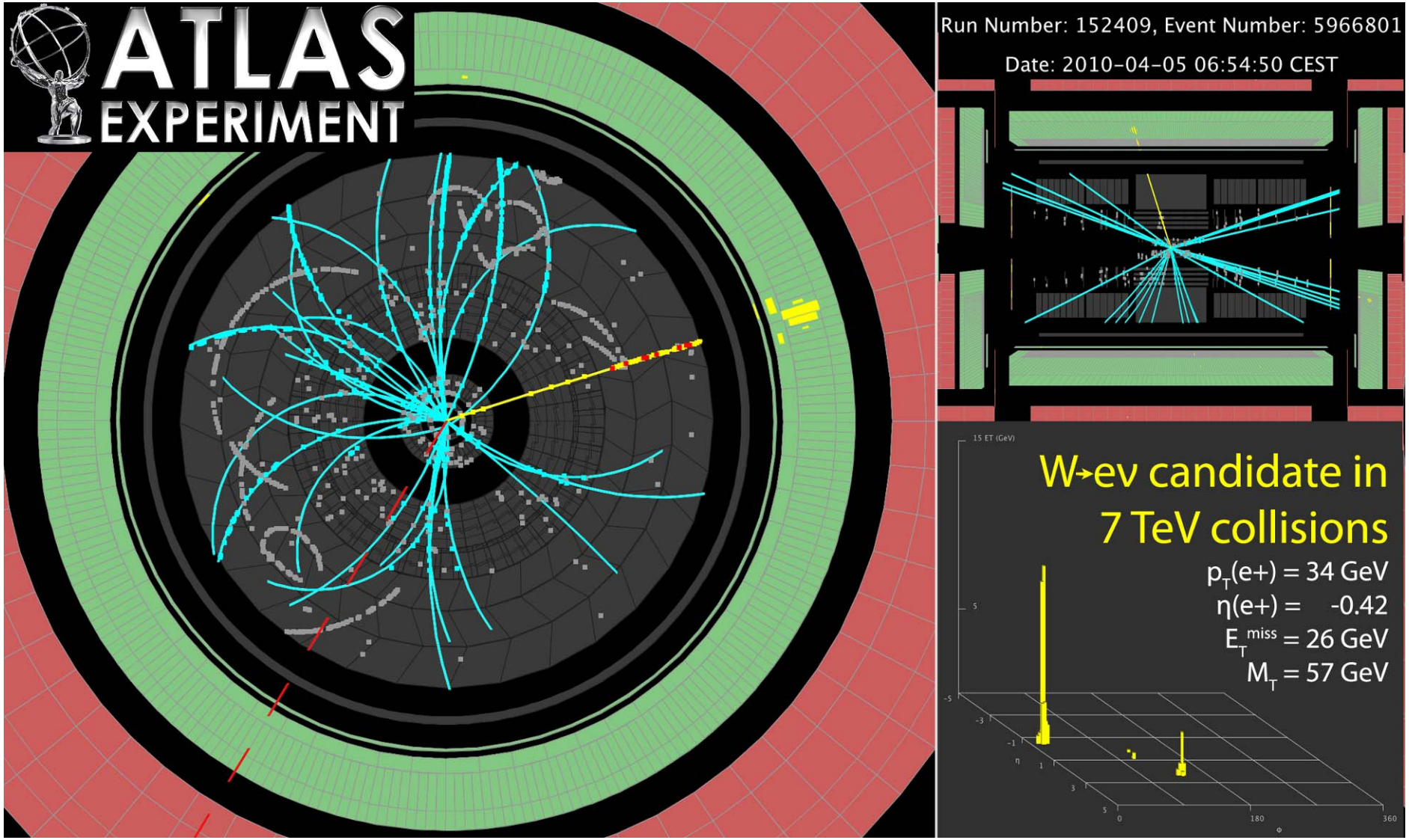


- **ATLAS polarization results for 10-100 pb^{-1} should be ~ 1 fb^{-1} @ TeVatron**

W→μν candidate



W→eν candidate



Conclusion

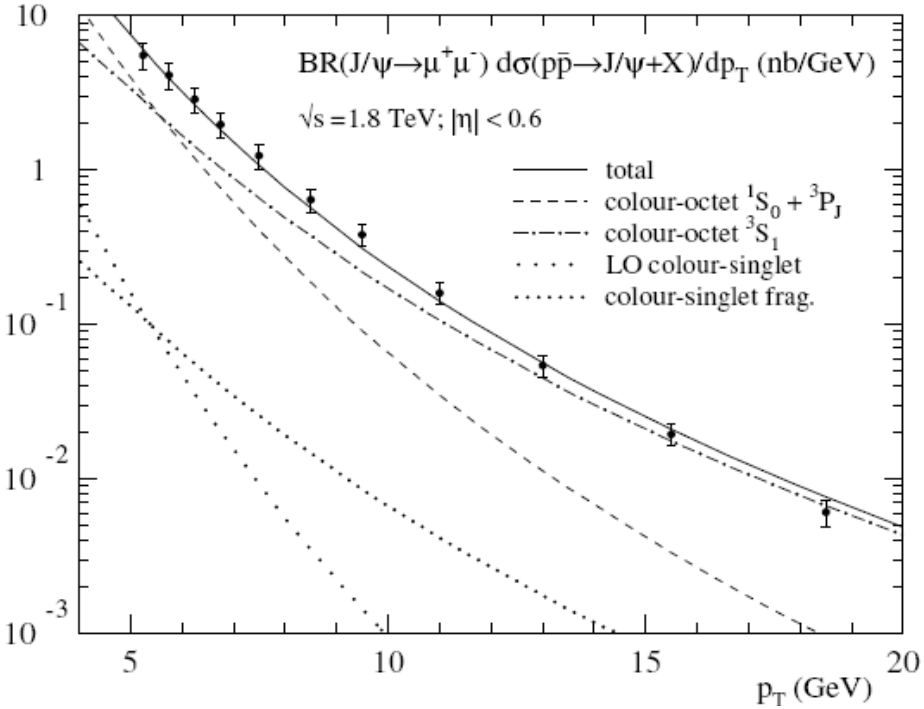
- After 20 years of preparation, ATLAS is collecting LHC data (8 nb^{-1} so far)
- Detector performance matches MC expectation
- Data collection is proceeding smoothly
- First physics results already out, many more to come

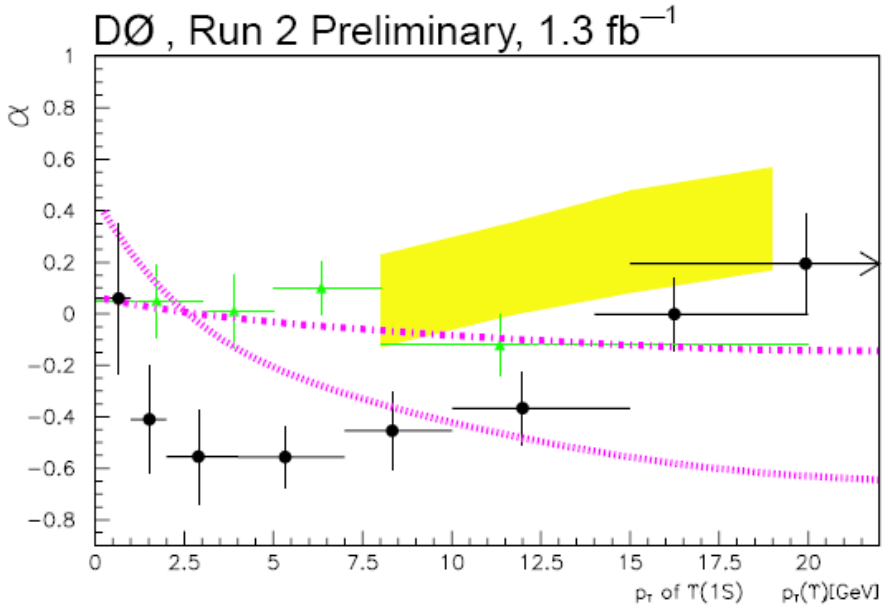
- 2010-2011 will provide an exciting physics program:

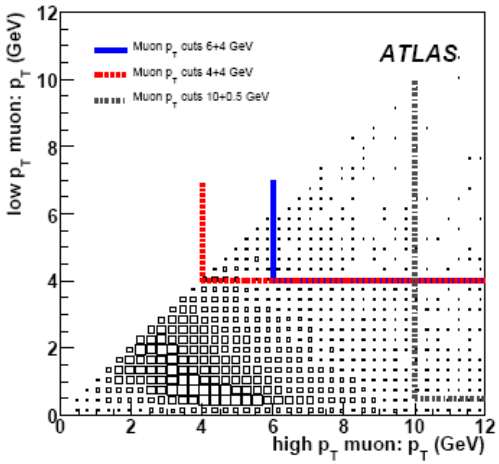
	N(ttbar $\rightarrow$ l+jets)	Z' $\rightarrow$ll mass limit (95% C.L.)	$\tilde{q}, \tilde{g}$ mass limit (95% C.L)
CDF+D0	**~6000**	**~1 TeV**	**~400 GeV**
ATLAS 1 fb^{-1}	**~6000**	**~1.5 TeV**	**~800 GeV**

Backups

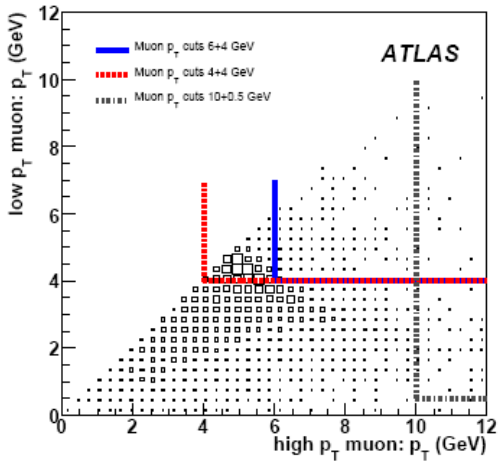
Quarkonium production





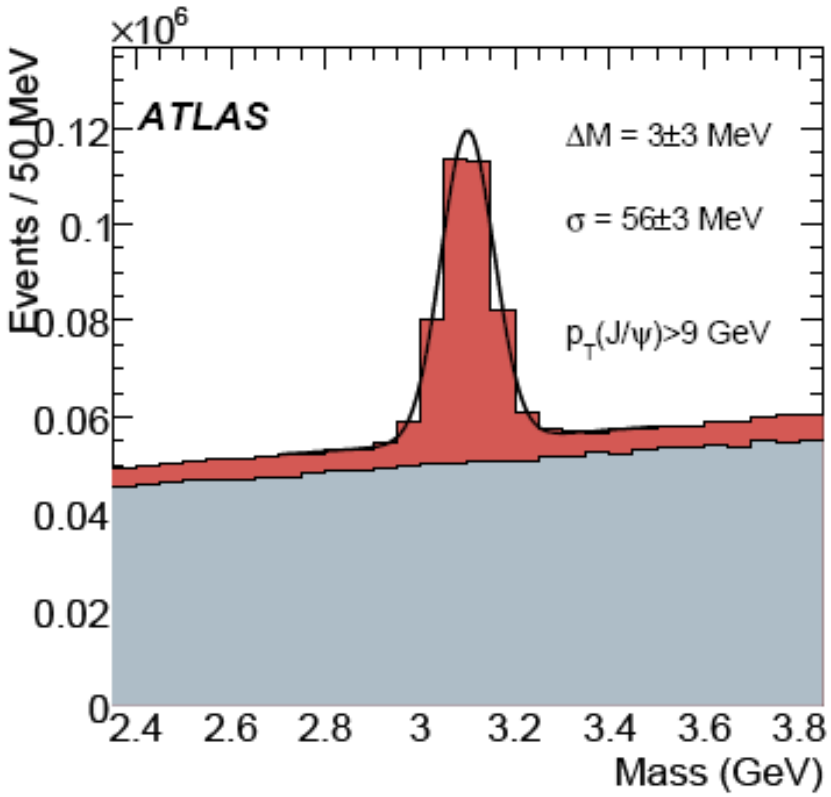


(a) J/ψ

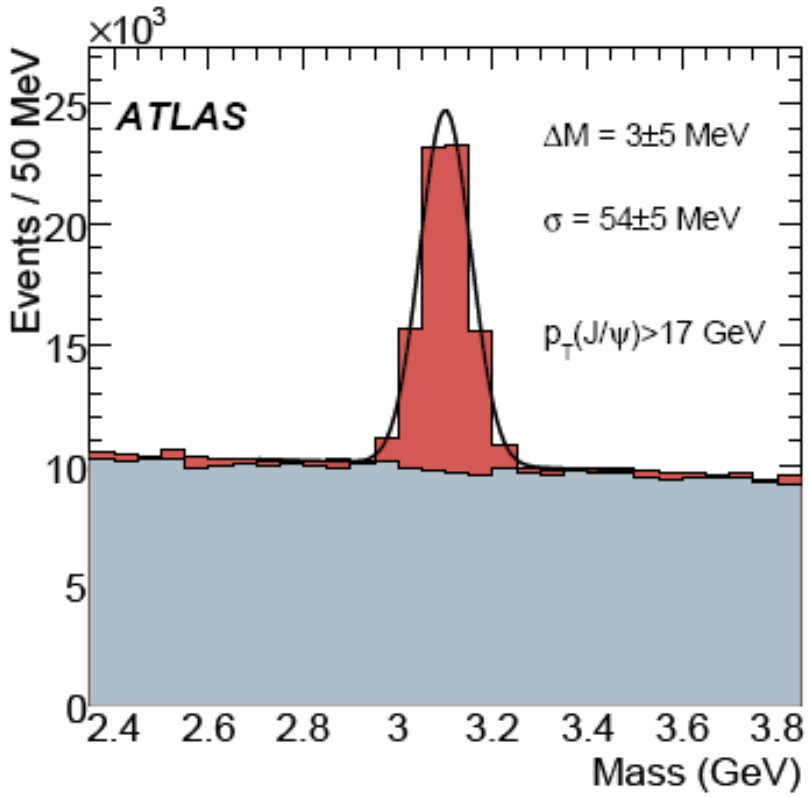


(b) Υ

Background in single-muon trigger

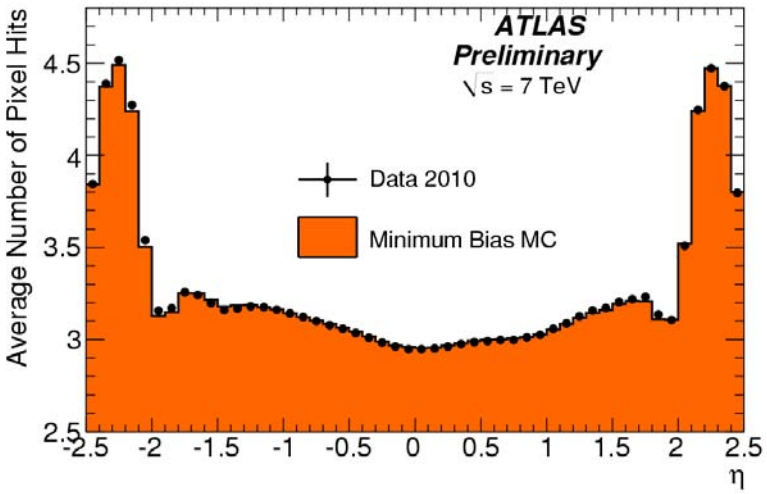


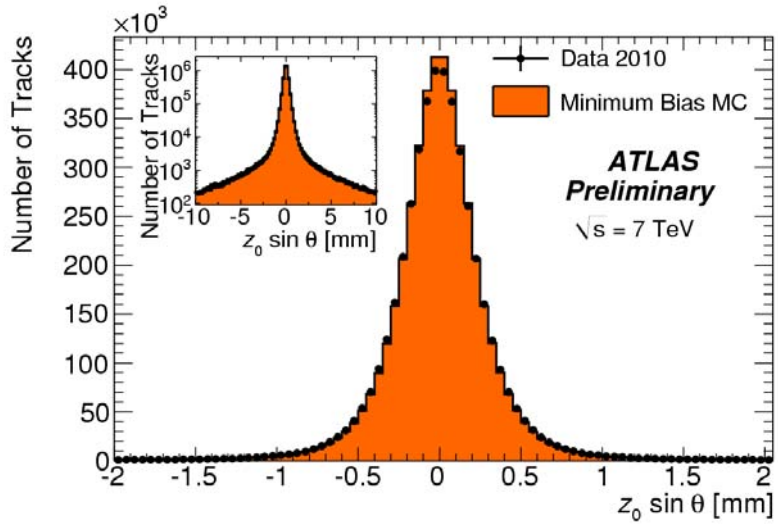
(a) J/ψ with $p_T > 9$ GeV

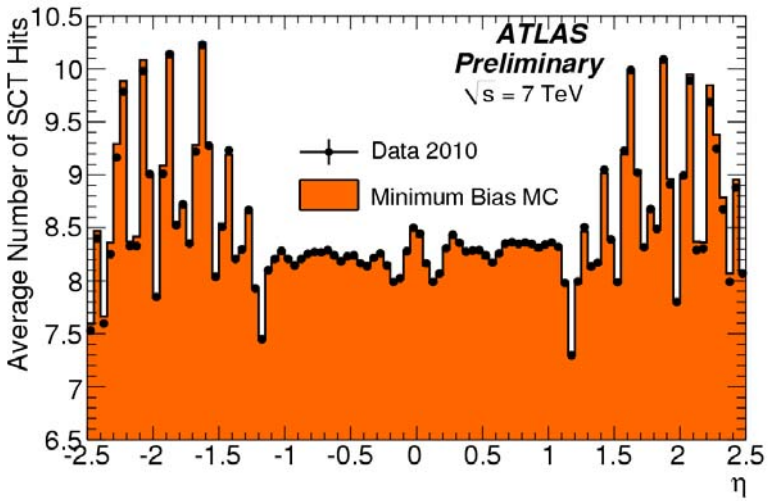


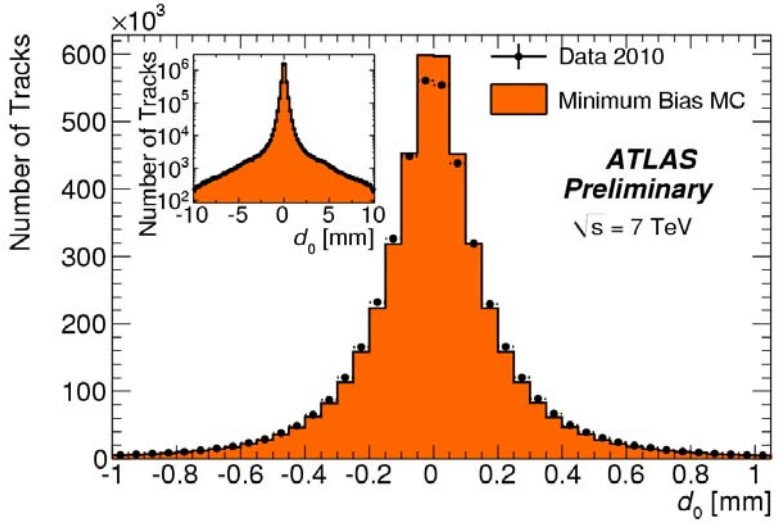
(b) J/ψ with $p_T > 17$ GeV

Pixel/SCT Performance

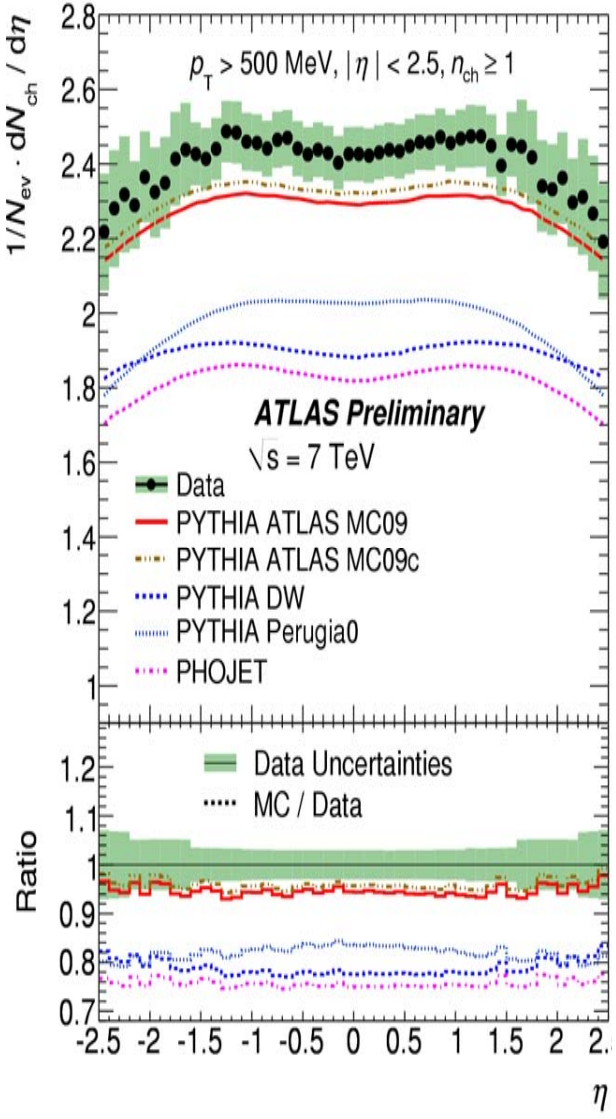


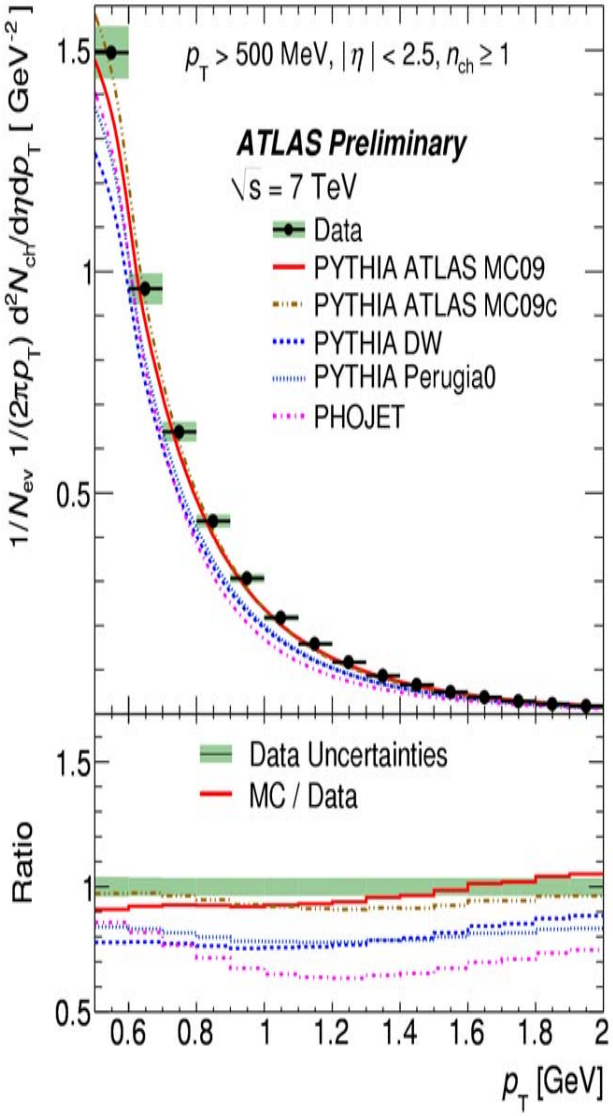


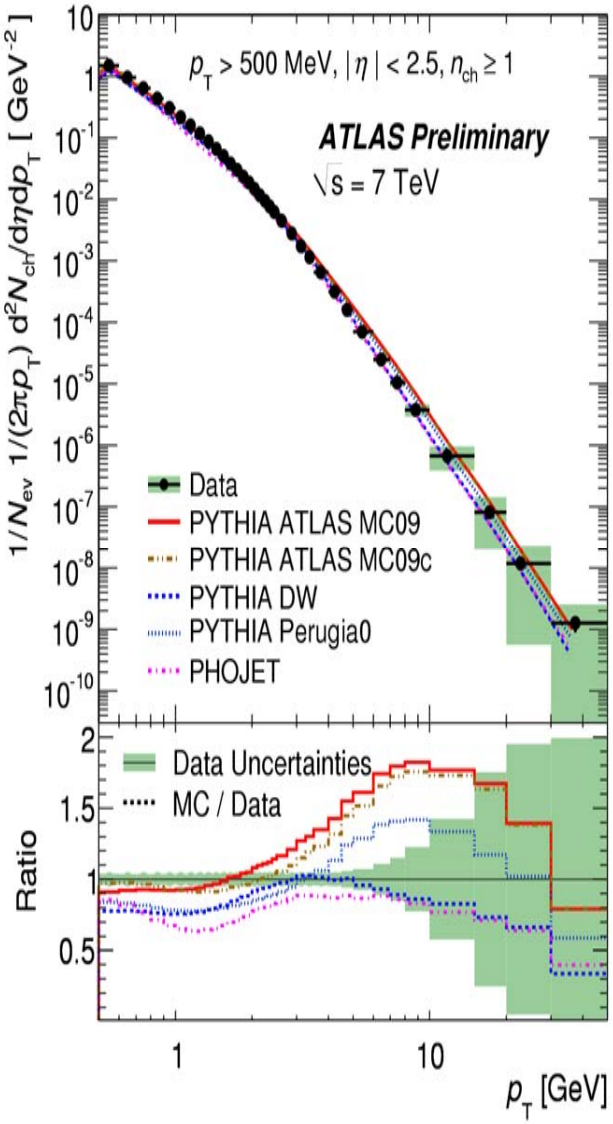




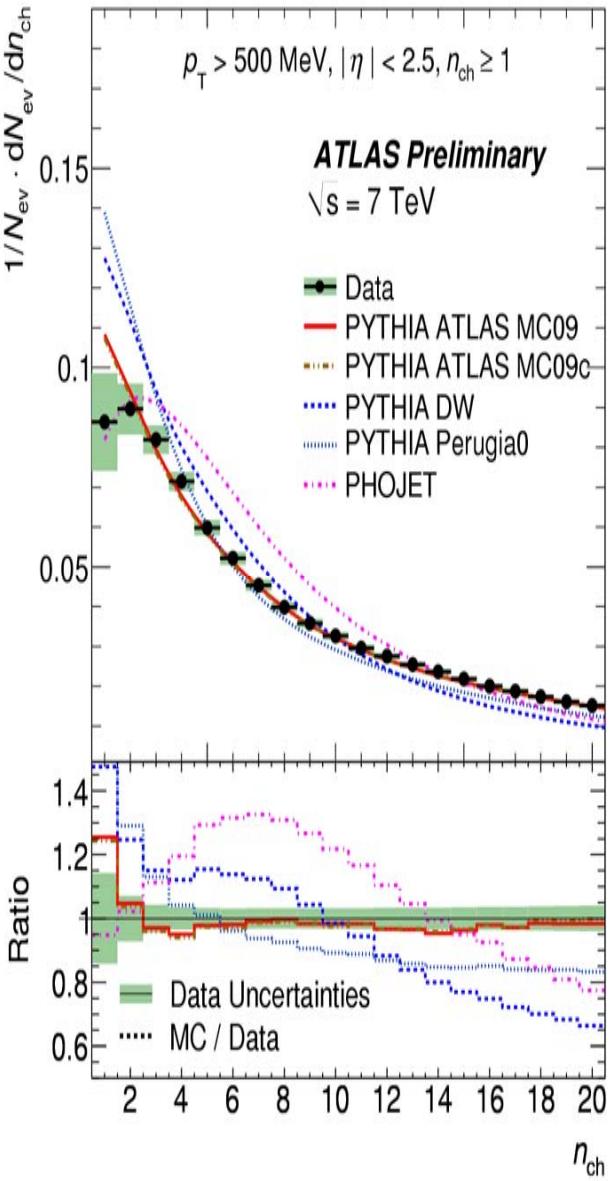
Charged Particle Multiplicities (1)

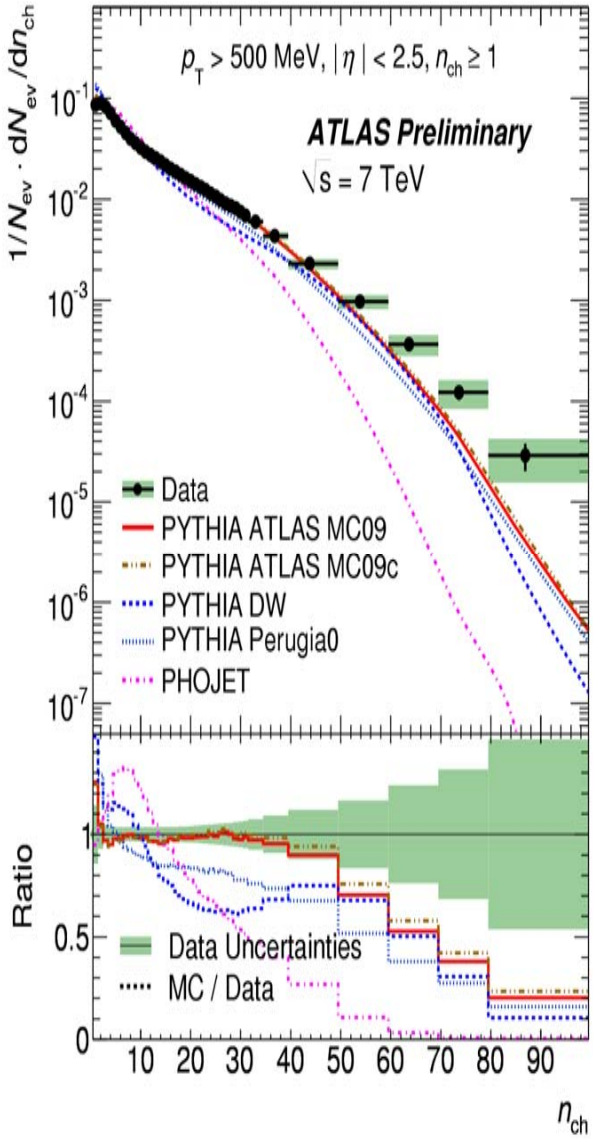


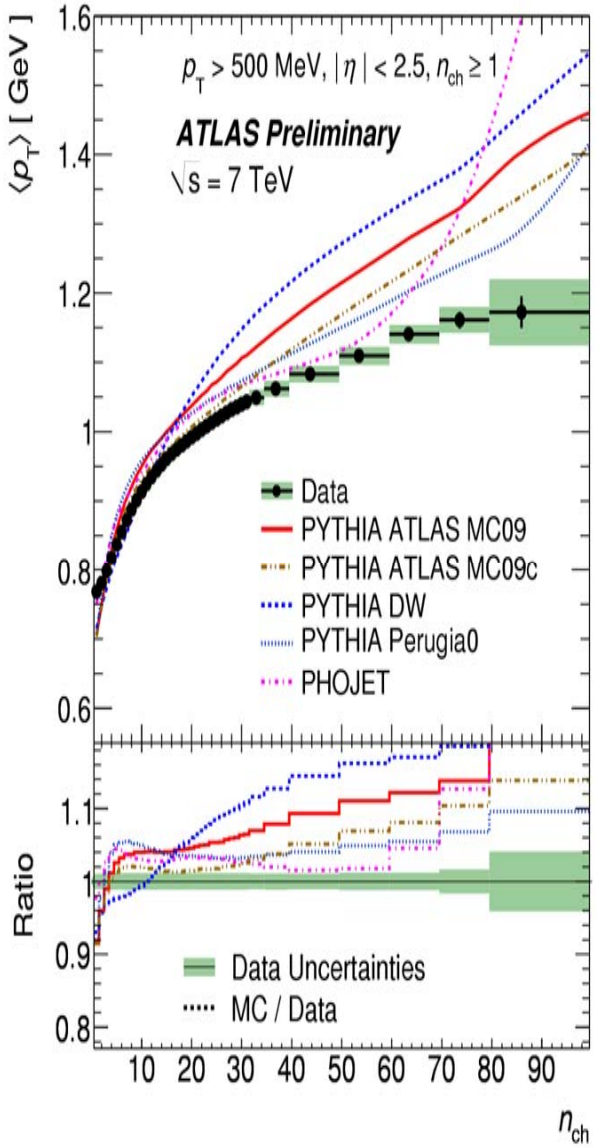




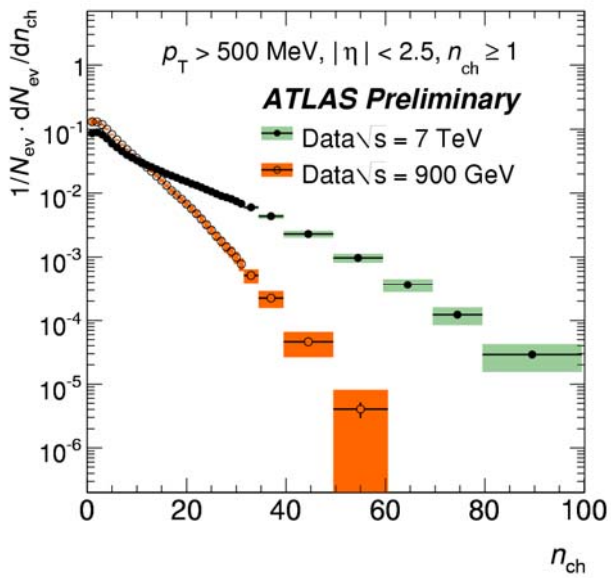
Charged Particle Multiplicities (2)

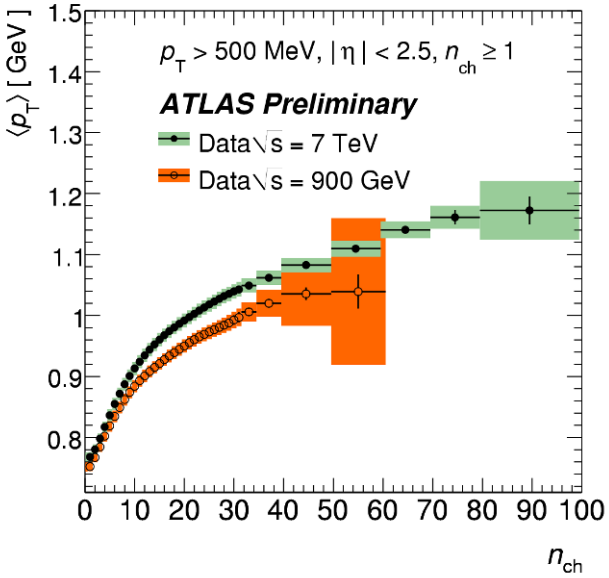


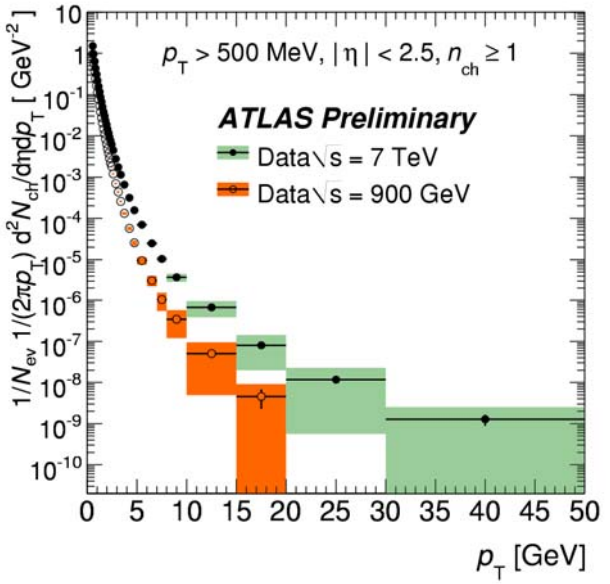


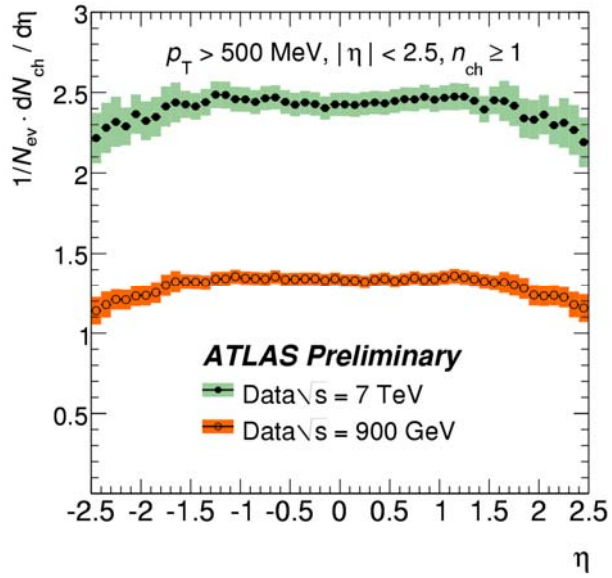


Charged Particle Multiplicities (3)

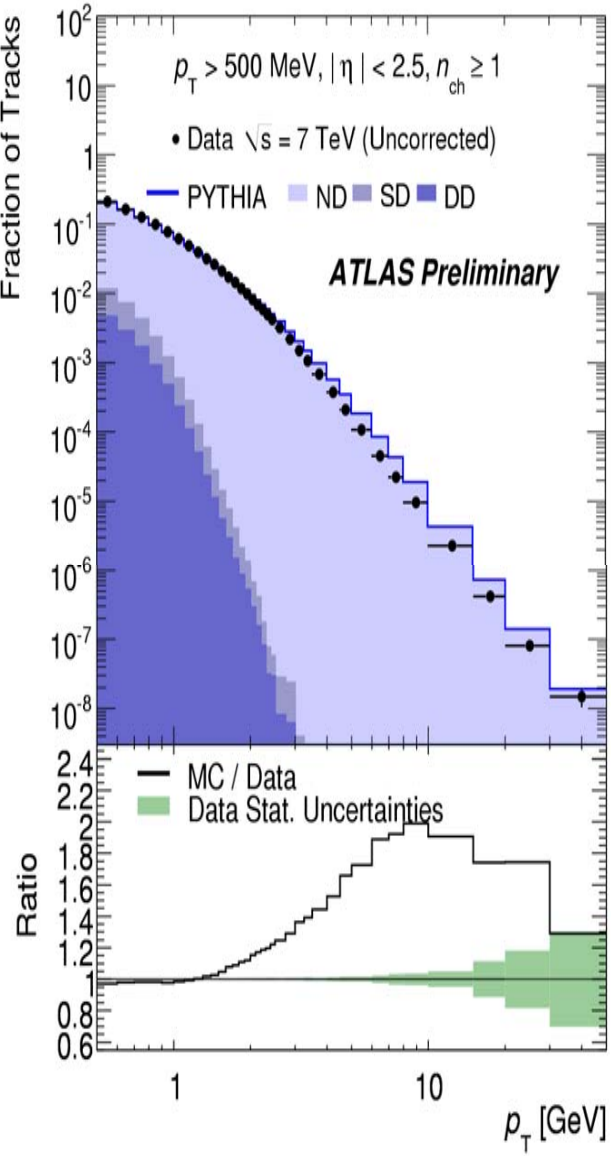


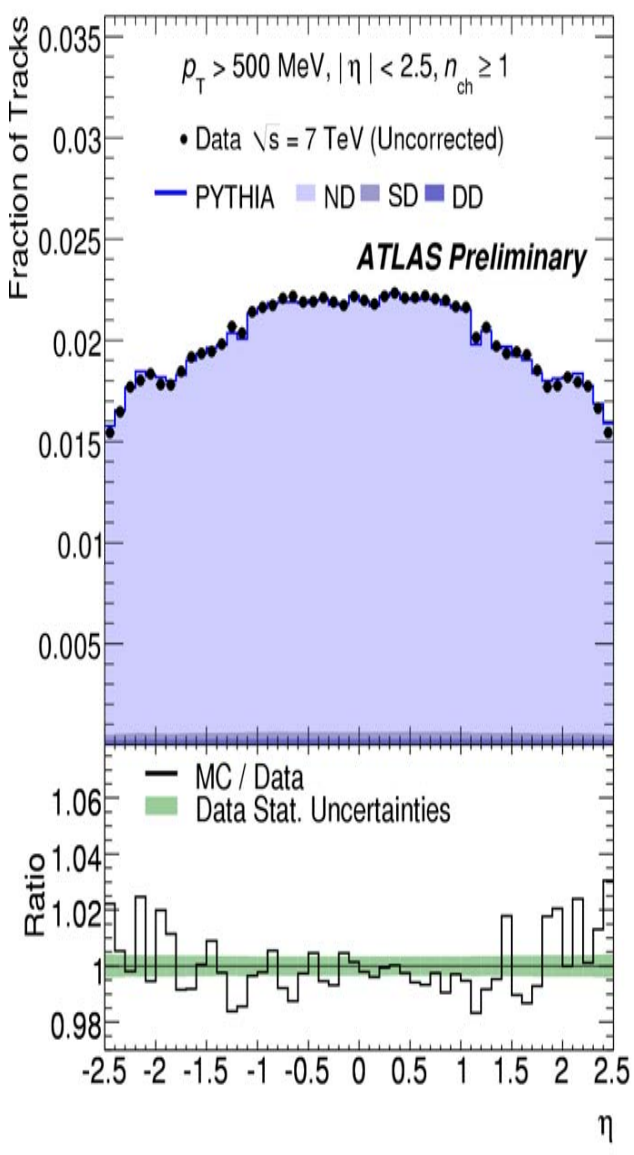


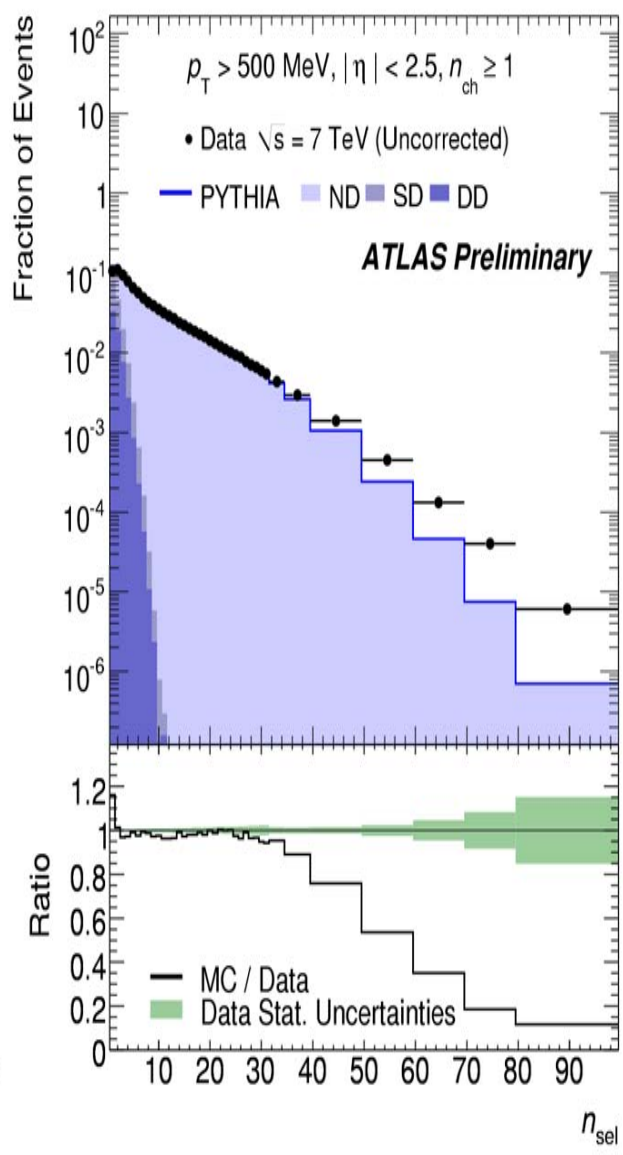




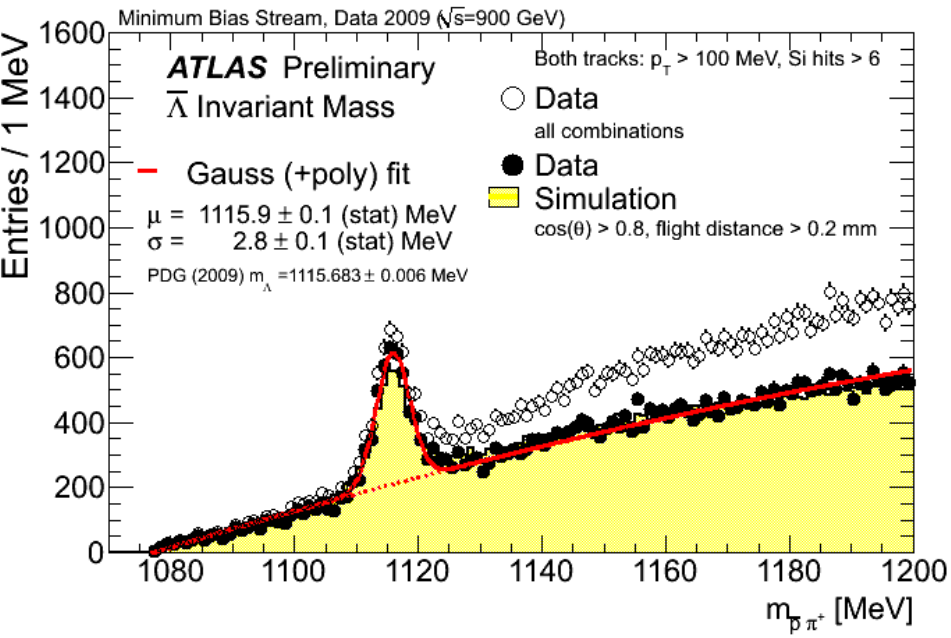
Charged Particle Multiplicities (4)

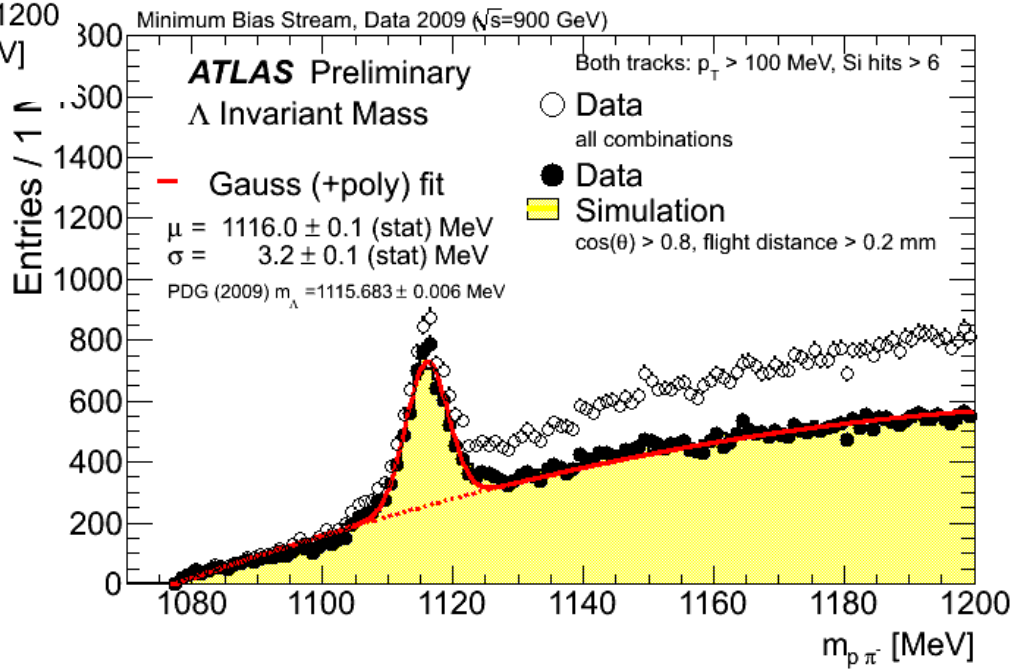






Λ, $\overline{\Lambda}$ comparison





LHC planning and scenario for the coming 8 years

This scenario is based on the outcome of the recent 'Chamonix' meeting (one month ago) where the machine experts, the experiments and the CERN Management have reviewed the current LHC situation

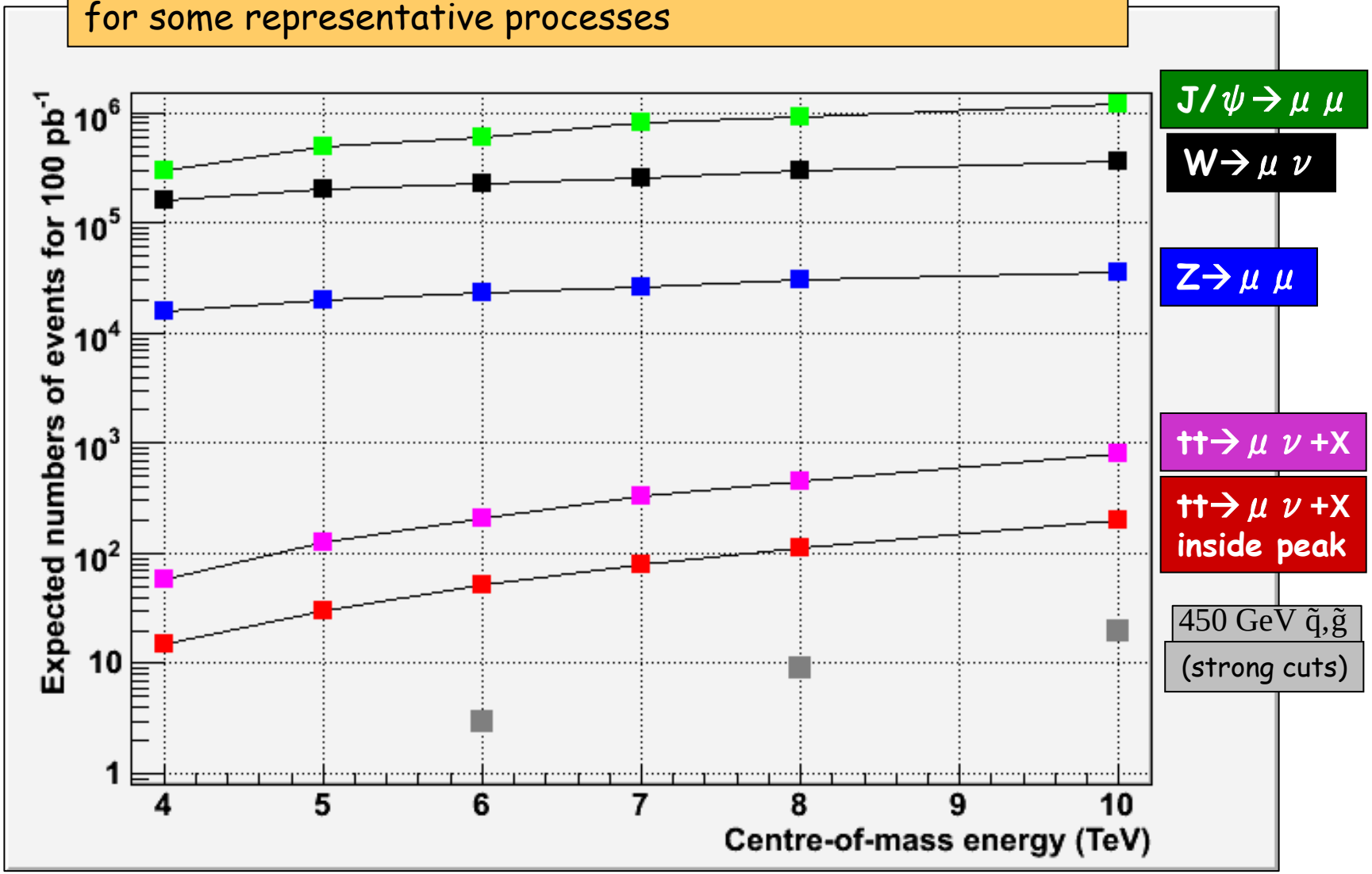
($cm^{-2}s^{-1}$) ($cm^{-2}s^{-1}$) (integrated luminosities in fb^{-1})

Year	Months	energy	beta	ib	nb	Peak Lumi	Lumi per month	Int Lumi Year	Int Lumi Cul
2010	8	3.5	2.5	7 e10	720	1.2 e32	-	0.2	0.2
2011	8	3.5	2.5	7 e10	720	1.2 e32	0.1	0.8	1.0
2012									
2013	6	6.5	1	1.1 e11	720	1.4 e33	1.1	7	8
2014	7	7	1	1.1 e11	1404	3.0 e33	2.3	16	24
2015	4	7	1	11 e10	2808	6 e33	4.6	18	43
2016	7	7	0.55	11 e10	2808	1 e34	7.4	52	96

Note:
- **Long shutdown in 2012 for preparing design-energy running**
- **6 months shutdown in 2015 to bring in LINAC4**
- **Nominal LHC design performance aimed at 2016**
- **Likely a long shutdown in 2017 (or around that time)**

ATLAS Data sample

Expected number of events in ATLAS for 100 pb^{-1} after cuts for some representative processes



Two relevant examples

Process	7 TeV 200 pb^{-1}	7 TeV 1 fb^{-1}
Z→ ee	51300	256000
tt → l+jets	1200	5900

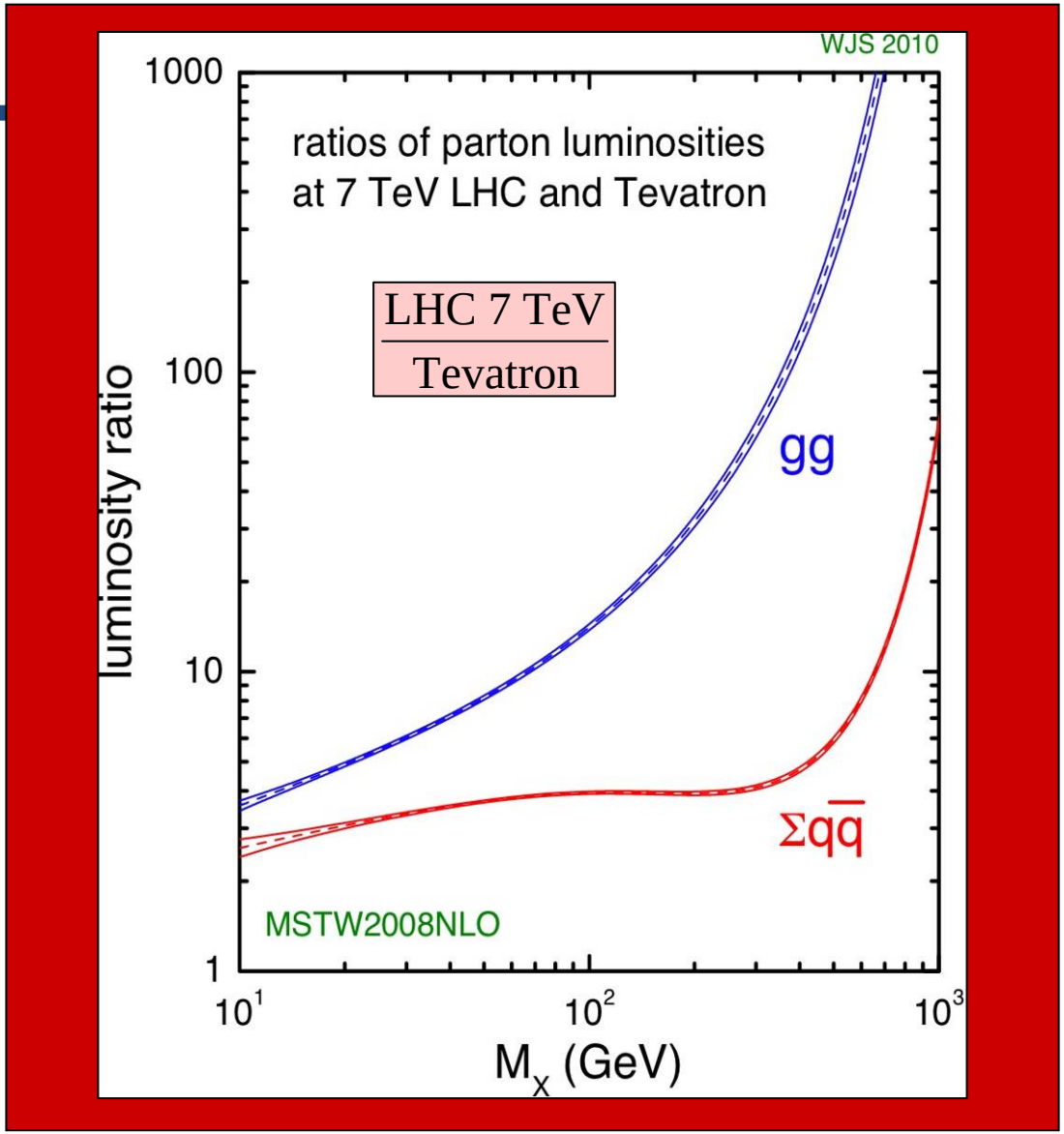
Expected number of events after cuts for one experiment

Z → ll: with 1 fb^{-1} large enough sample to calibrate the detector to the "ultimate" precision: e.g. ECAL inter-calibration ~ 0.5%, absolute E/p momentum scale to ~ 0.1%, etc; much less needed to understand trigger and lepton efficiency

tt → l+jets: statistics with 1 fb^{-1} is ~ 2 times larger than one Tevatron experiment with 10 fb^{-1}

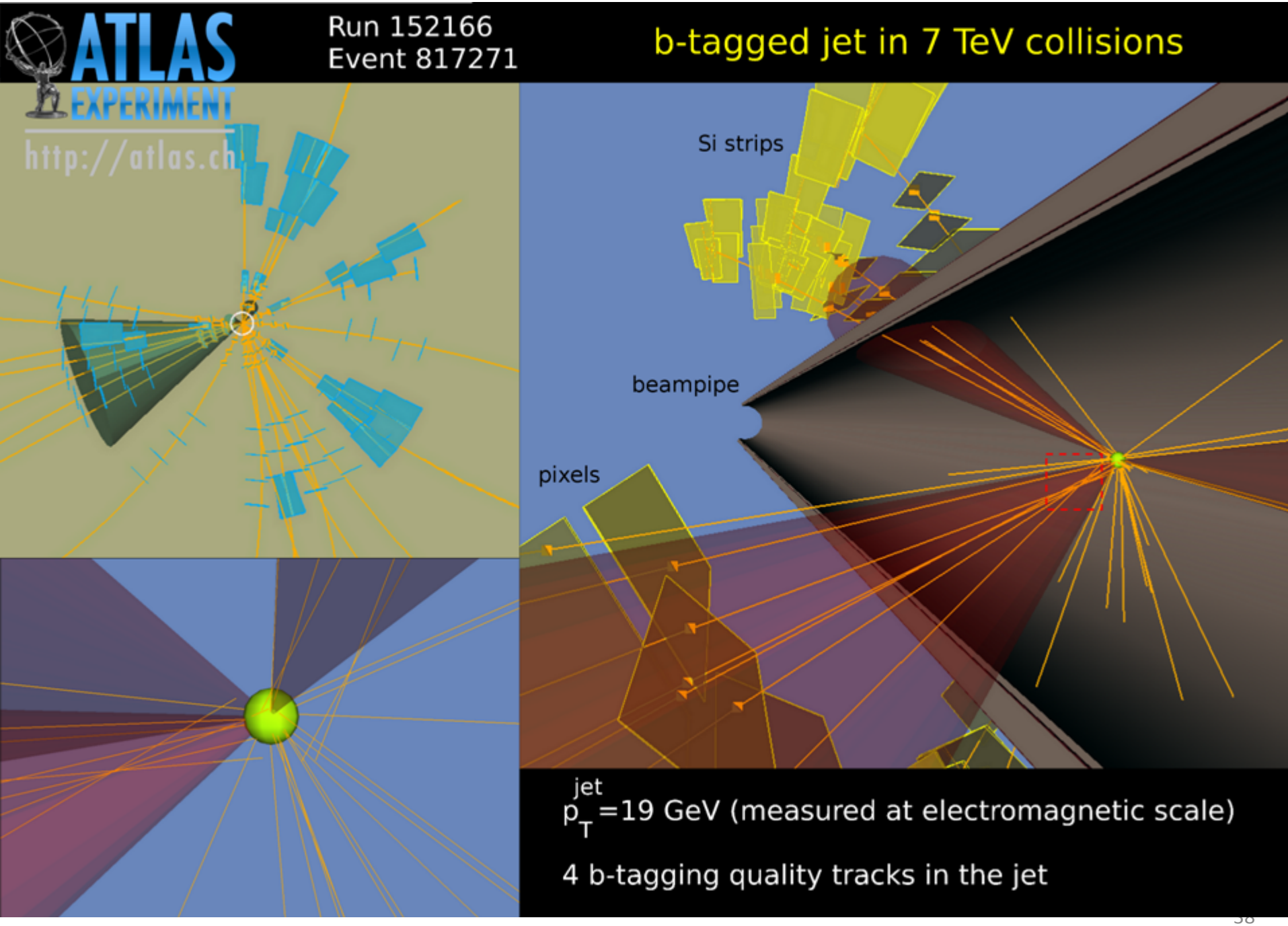
Note: first observation of top-quark signal in Europe with few $O(10\ pb^{-1})$

Note: Tevatron expects ~ 10 fb^{-1} of "analyzable" luminosity by end 2011

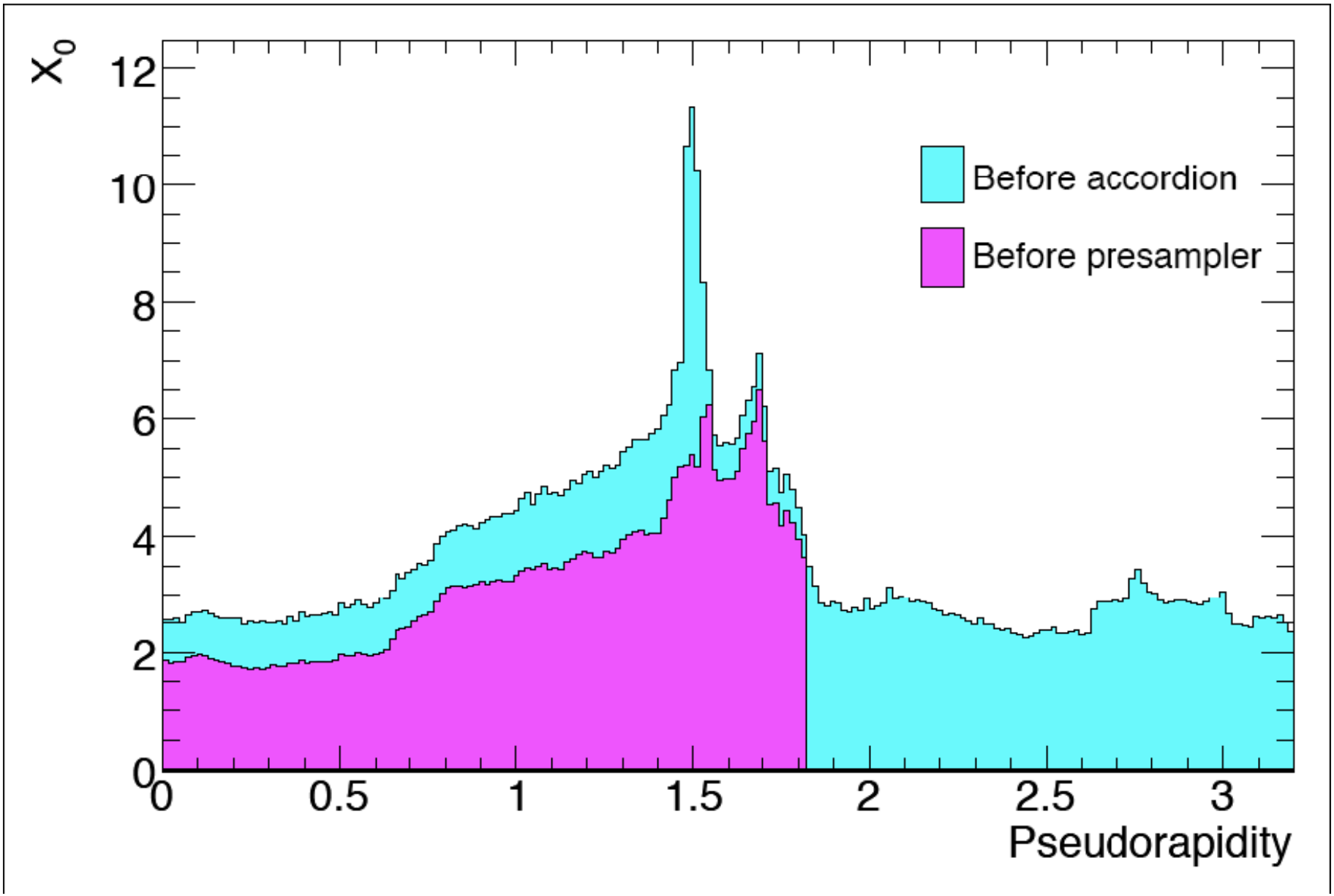


More in
Chris Quigg's talk

Cross-section	Tevatron	LHC@7TeV/Tevatron	LHC@14TeV/Tevatron
W/Z → lν , ll	2.5/0.25 nb per family	~ 5	~ 10
tt production	7.2 pb	~ 20	~ 100


ATLAS
EXPERIMENT
http://atlas.ch
Run 152166
Event 817271
b-tagged jet in 7 TeV collisions
Si strips
beampipe
pixels
p_T^{jet}=19 GeV (measured at electromagnetic scale)
4 b-tagging quality tracks in the jet

Material before EM calorimeter



Muon tracking resolution