ATLAS: The Titan wakes

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Krakow
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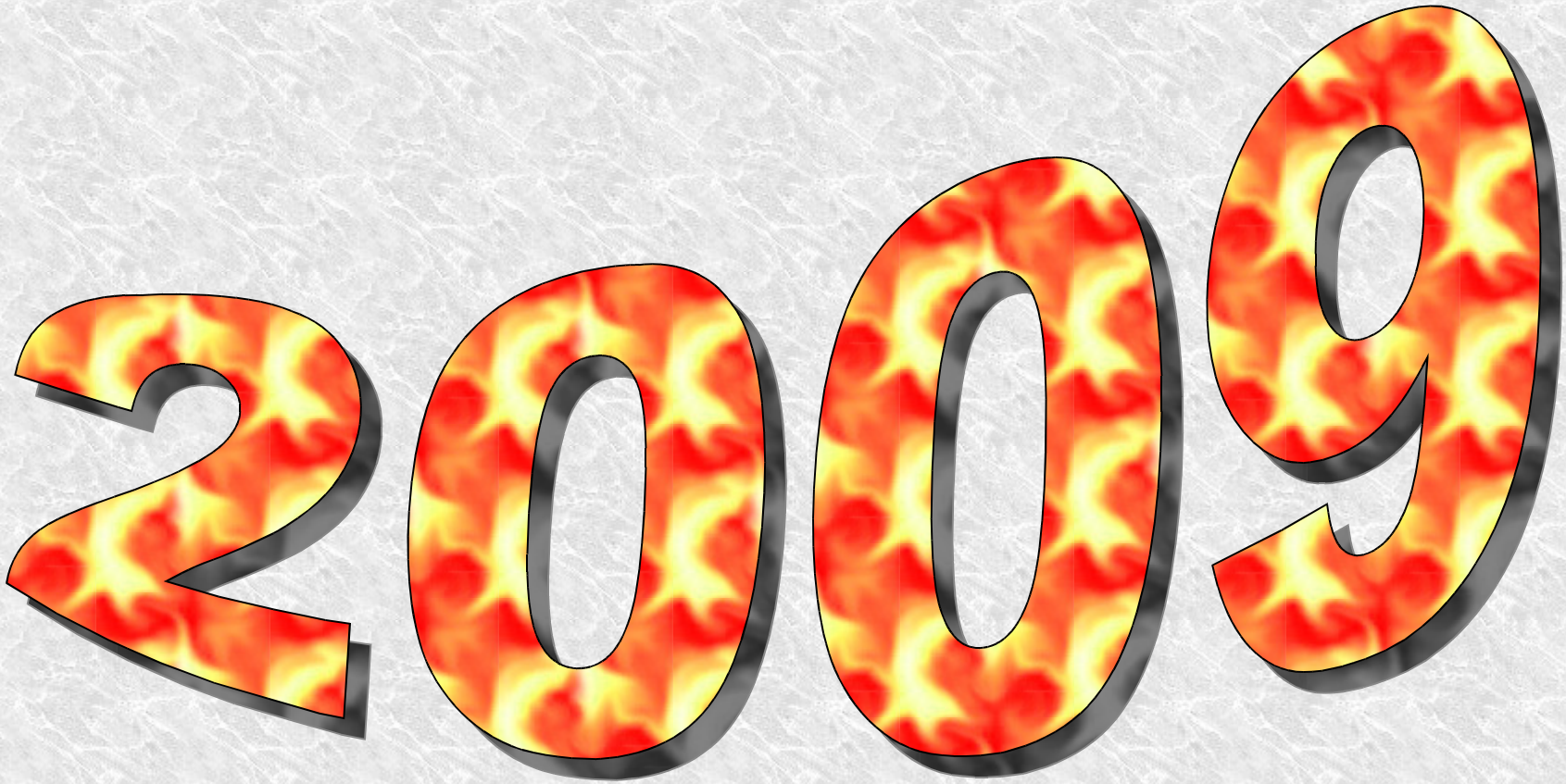
2009+:
ATLAS performance
2010-
The run scenario
Physics goals
First Physics result

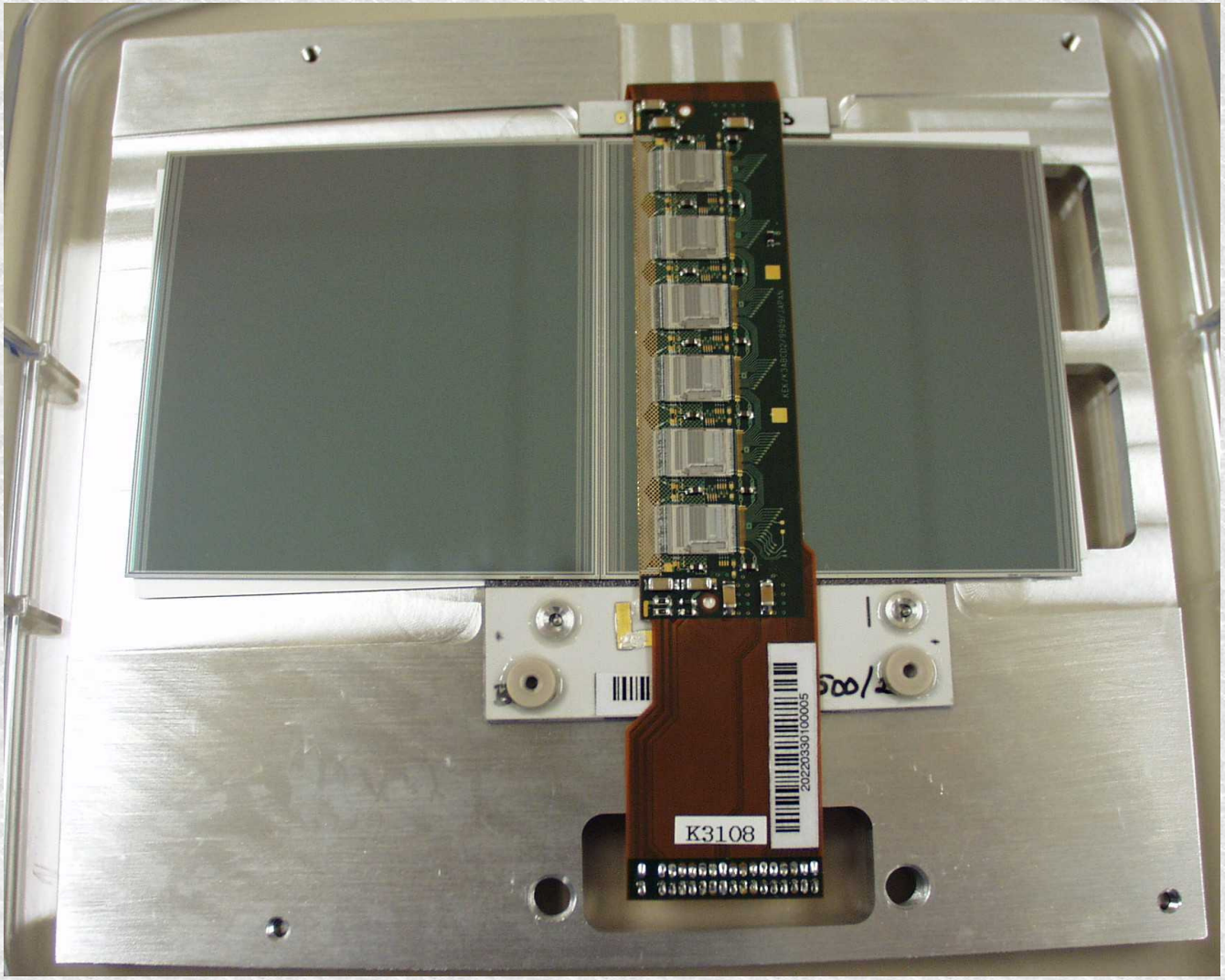
ATLAS

- Titan who fought the gods
  - Punishment: holding up the sky
- Often shown as the Earth
- Our ATLAS must be very clear to avoid such mistakes


2009


ATLAS

SCT modules



12cm by 6cm
1536 readout strips
12 chips read at 40MHz
1DVD data per second
Incredibly light
Heat conductivity exceeds diamond
Precision 1μm
Accuracy 20μm

The SCT Barrel assembly

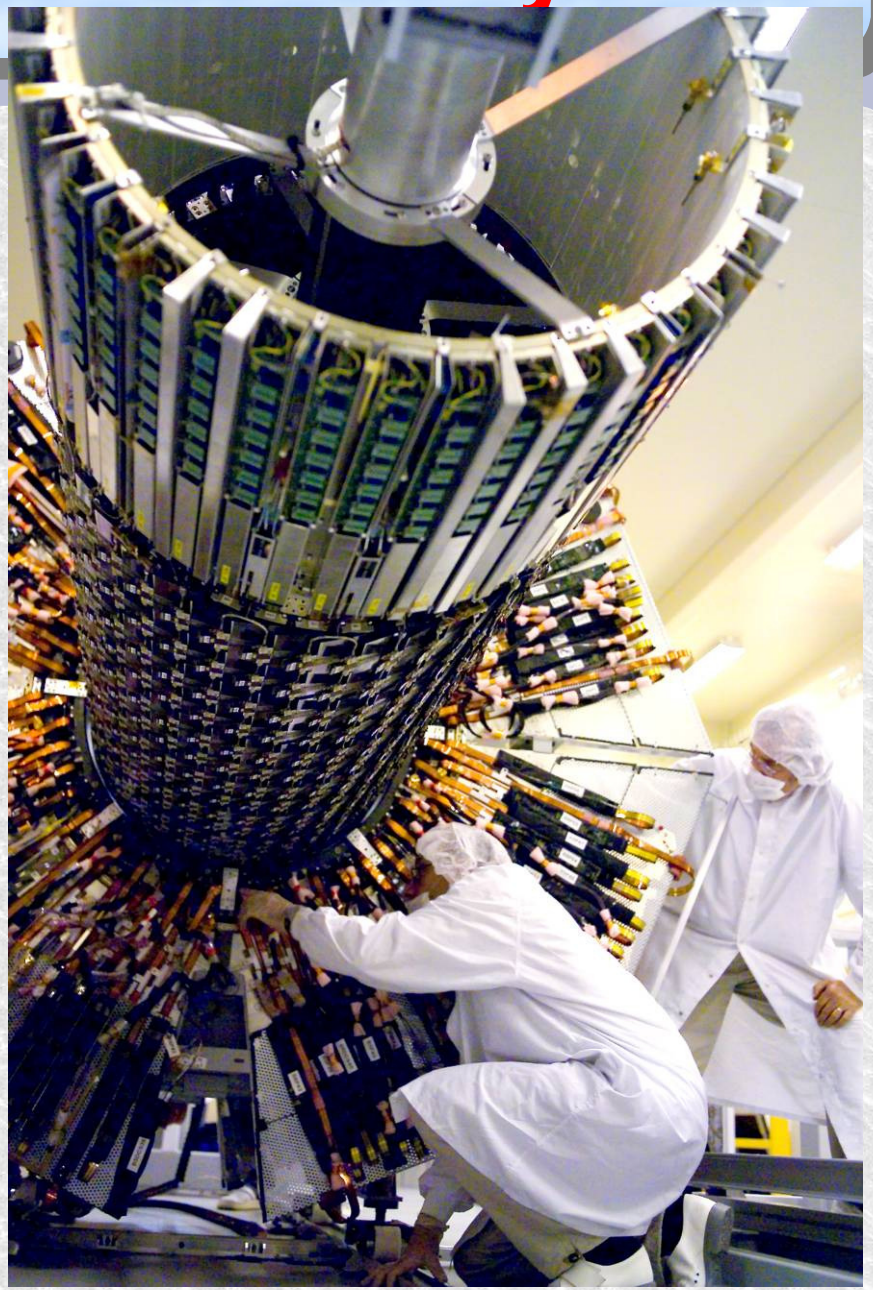
4 barrels:

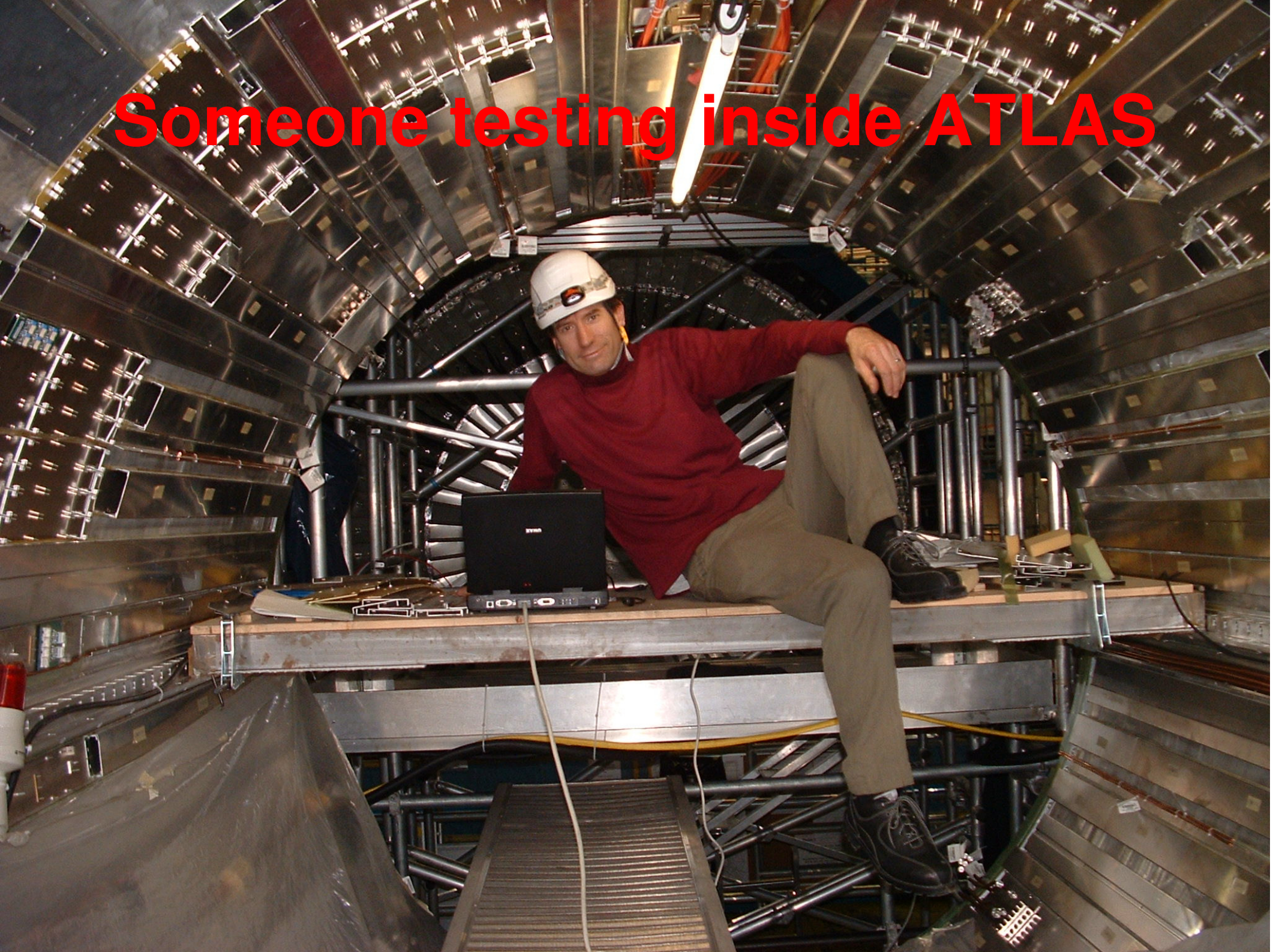
The last is being inserted in the other 3 in the picture

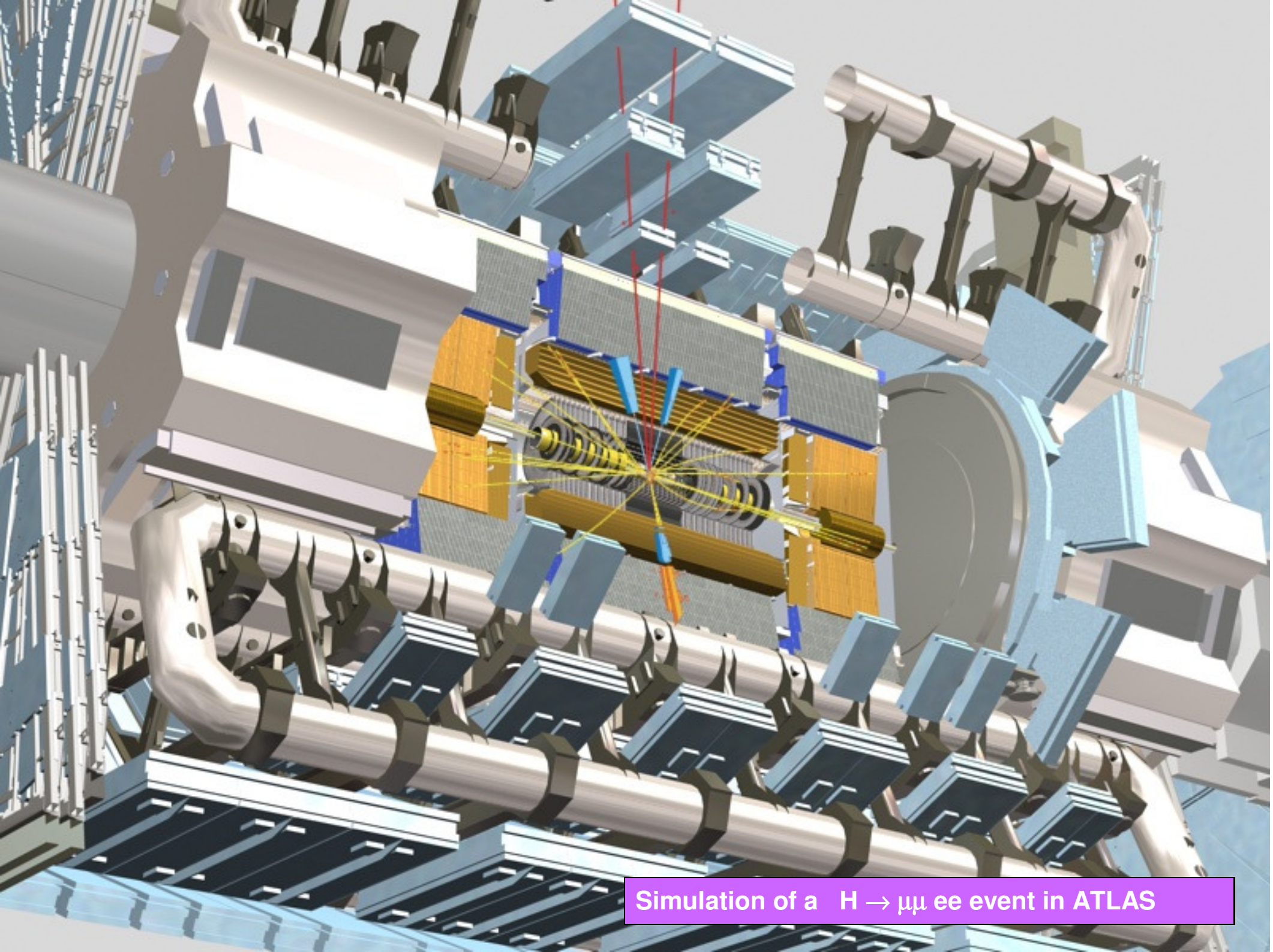
UK, Japan, US, Scandinavia

We built 730 modules at RAL

- Measured 3D,
- Tested,
- Mounted
- Re-tested
- Installed
- Re-tested




Someone testing inside ATLAS



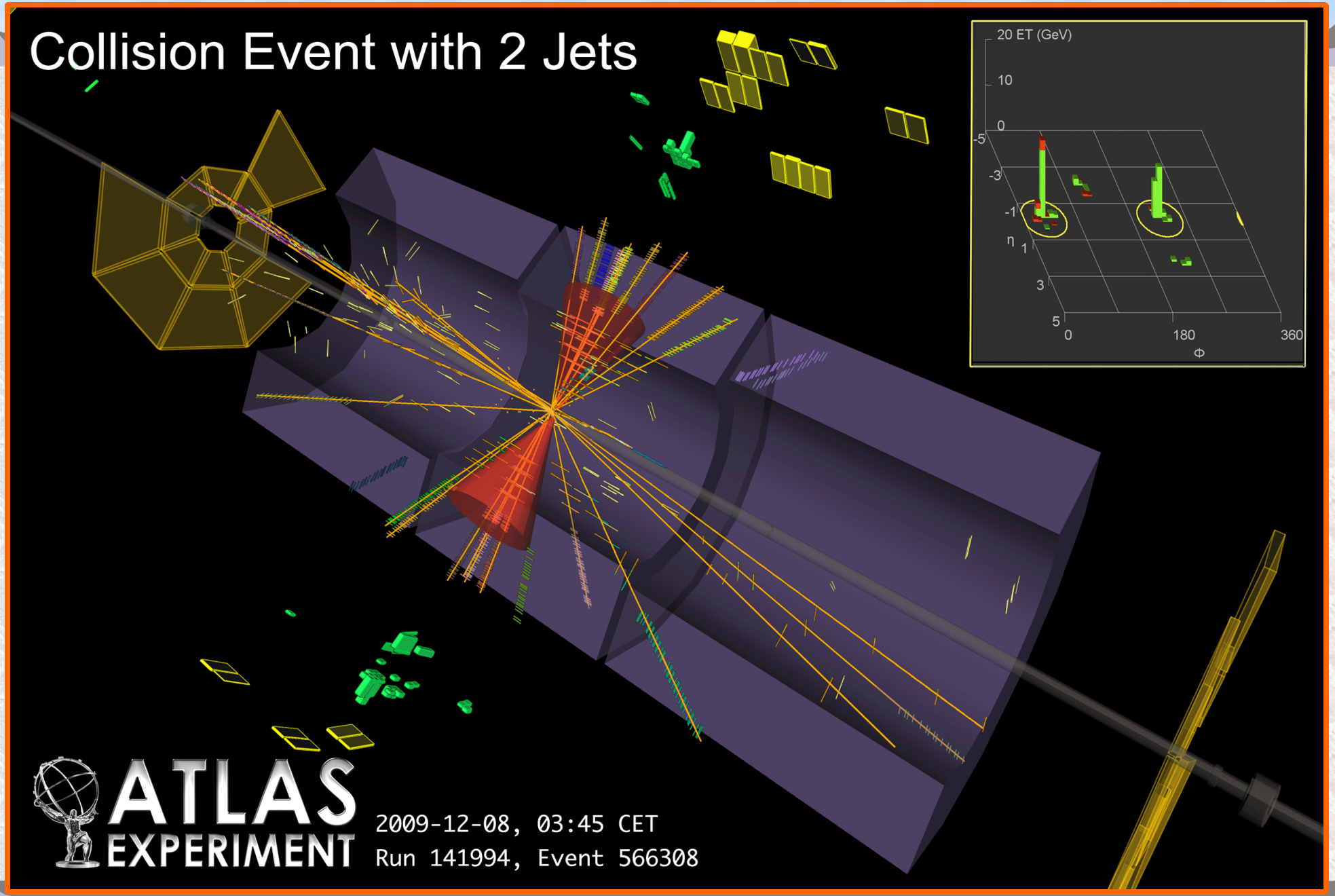
Simulation of a $H \rightarrow \mu\mu$ ee event in ATLAS

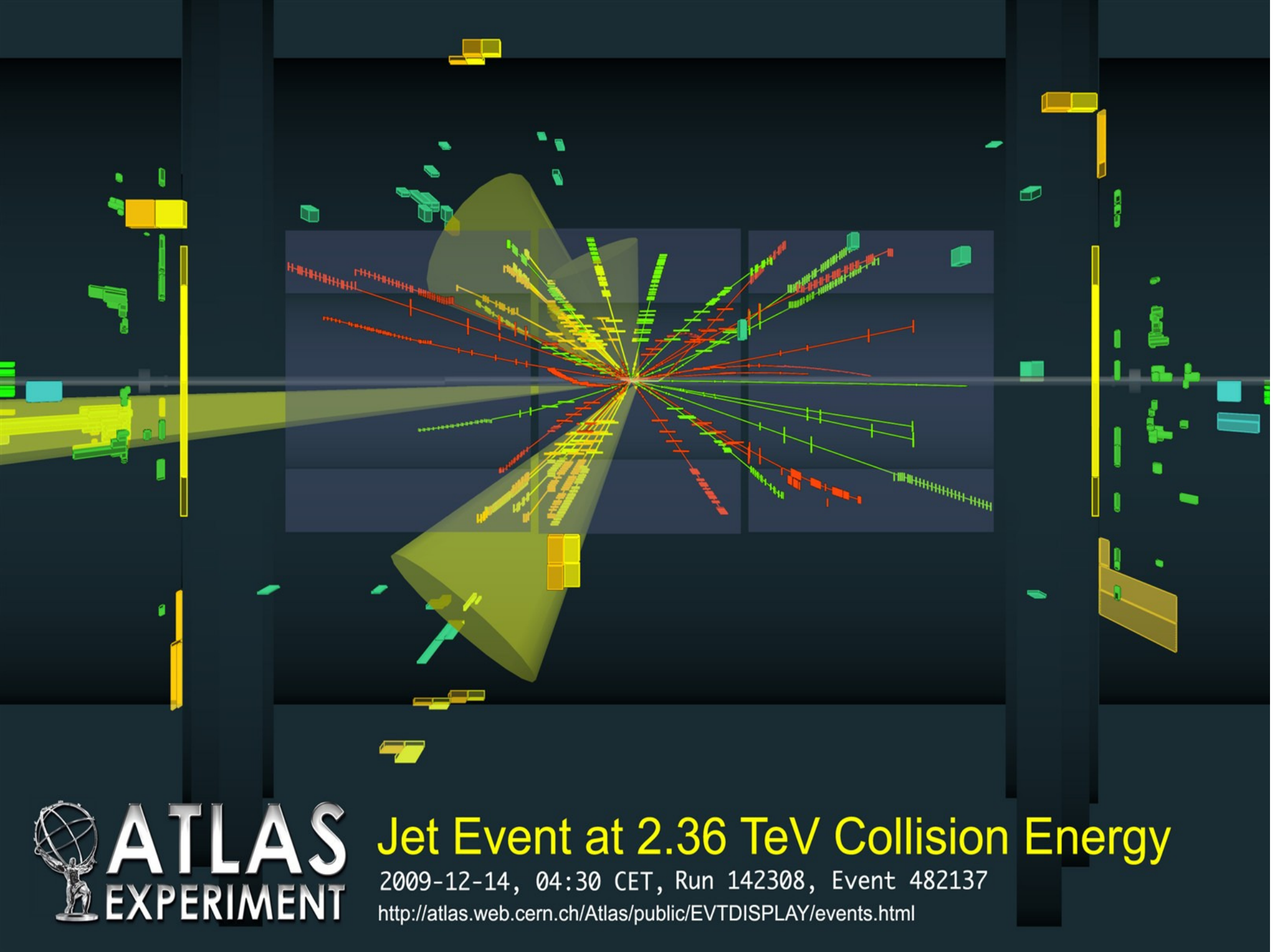
Sunday 6th December 2009

Stable Beam at last!

- 900GeV – LHC injection energy from SPS
  - But this is pp, not pp.
  - Only previous pp collider: ISR, 28GeV
- Machine Protection System commissioned
  - (At 900GeV – must be redone at other energies)
- Silicon trackers can go to nominal voltage
- All of ATLAS operational

A selected minimum bias event




ATLAS
EXPERIMENT
Jet Event at 2.36 TeV Collision Energy
2009-12-14, 04:30 CET, Run 142308, Event 482137
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Data collected

Data delivered in 10 crazy days in December

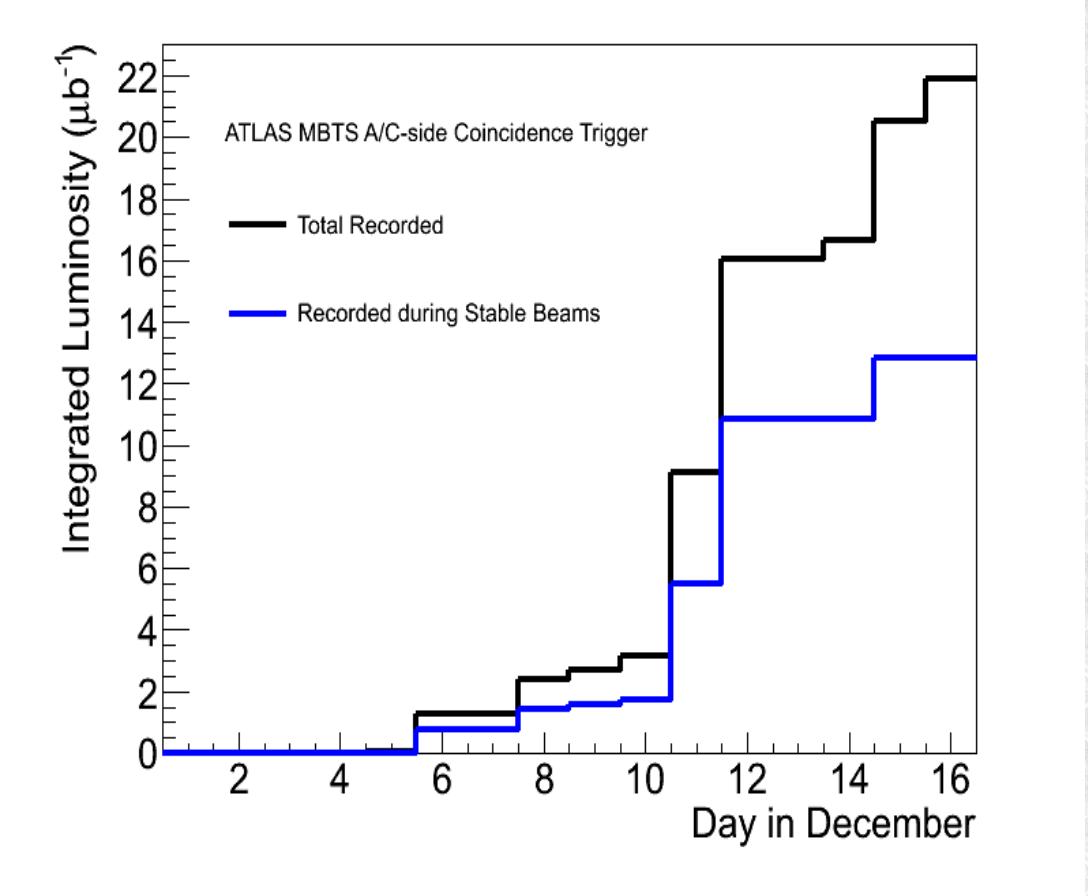
All experiments working well

ATLAS detector components typically 99% operational

e.g. SCT 0.7% off

70% 'tracker on'

30% comes from turn-on times in short fills



How much data?

	0.9TeV		2.36TeV	
	σ	Events	σ	Events
Delivered	22μb	~1M	1μb	46,000
Stable Beams	13μb	~500,000	0	0
Tracker On	9μb	~350,000	0	0

350000 good events allows many QCD studies

- 1/3 tracker loss from ramping volts in short fills

But 10μb is 1/100,000th of the coming run

We have lots...and very little

- Over a million good tracks
- Thousands of jets
- Dozens of muons

Triggering

Normally critical to any LHC physics

ATLAS triggers ready: muon, jet, E_T^{miss}, b, γ etc.

- But for 2009 simple scintillators in the forward/backward regions were enough

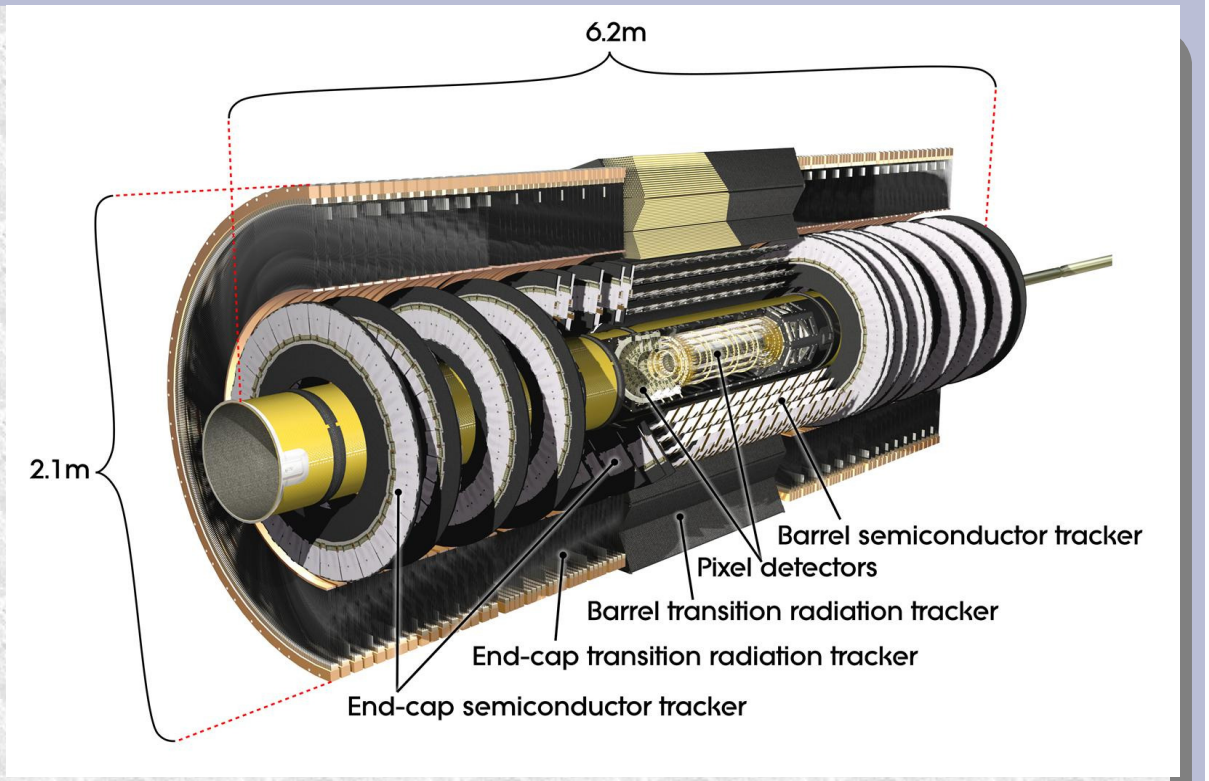
We came close to pre-scaling the minimum bias but did not have to

We did run HLT jet triggers in 'pass through' mode to calibrate/test

Tracker Performance

The ATLAS tracker is 3 concentric systems:
- Pixel detector
- SCT
- TRT

Barrels and endcap disks



	Pixels	SCT	TRT
Radius	5-12.2cm	30-51cm	55-108cm
Hits	3	4 double	36 typical
Precision	10μm by 115μm	20μm by 580μm	130μm

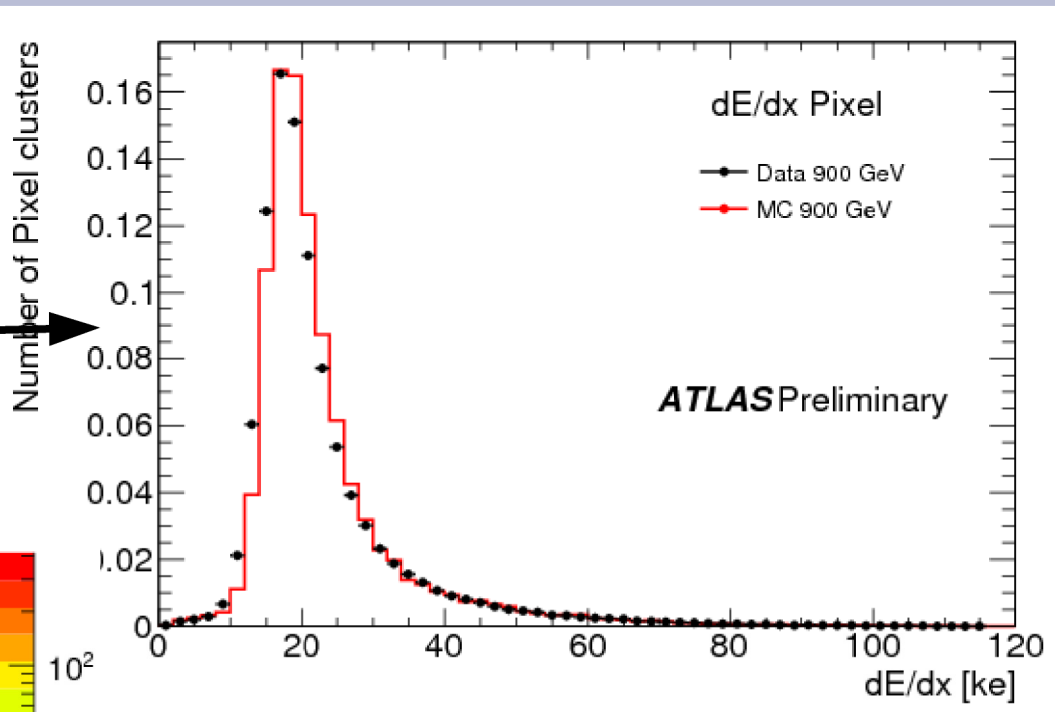
Pixel de/dx

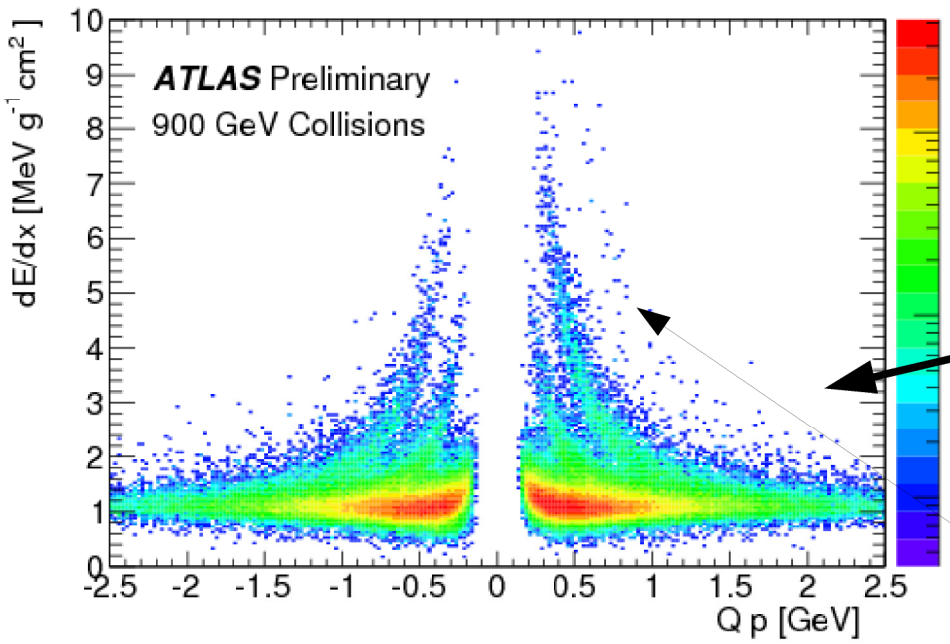
Pixel measures Time-over-threshold

Gives de/dx

MC already good

This detector works



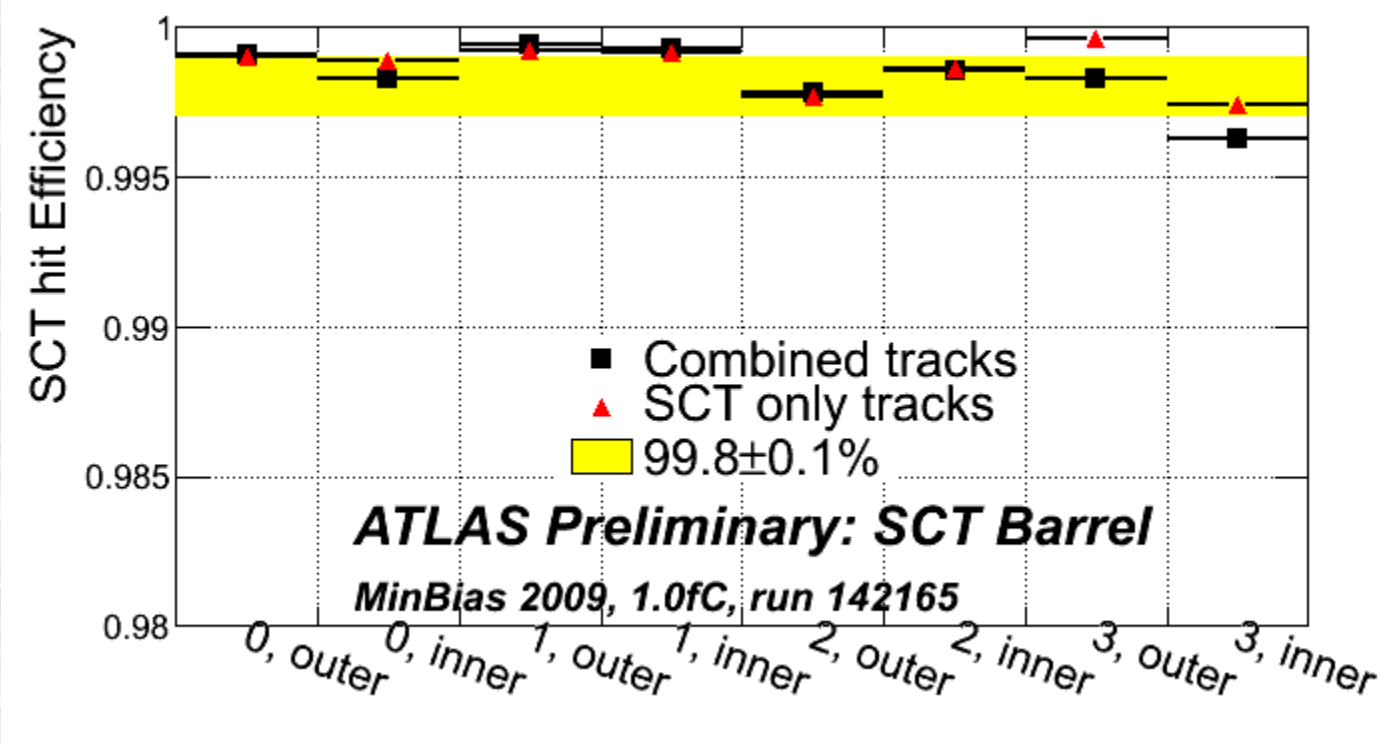


de/dx versus momentum

π, K, proton bands visible

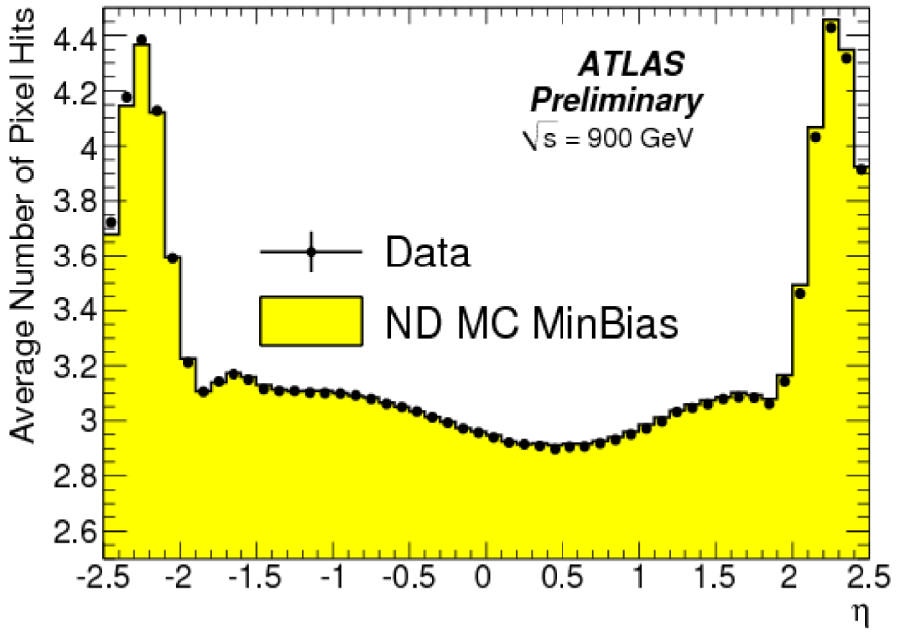
Is that a deutron?

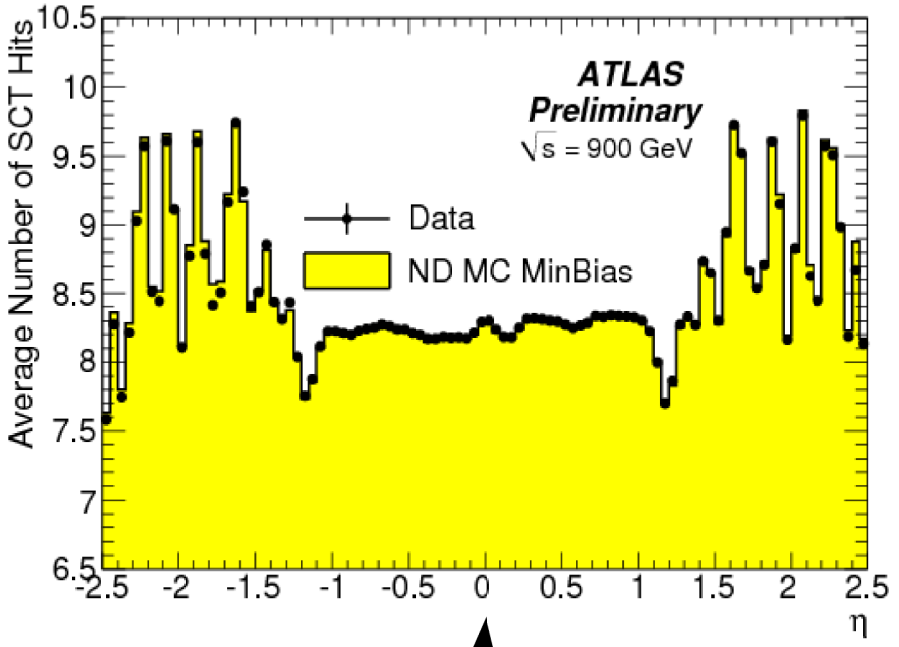
SCT Efficiency



4 double layers
Typically 99.8% efficient
This detector works

Tracking





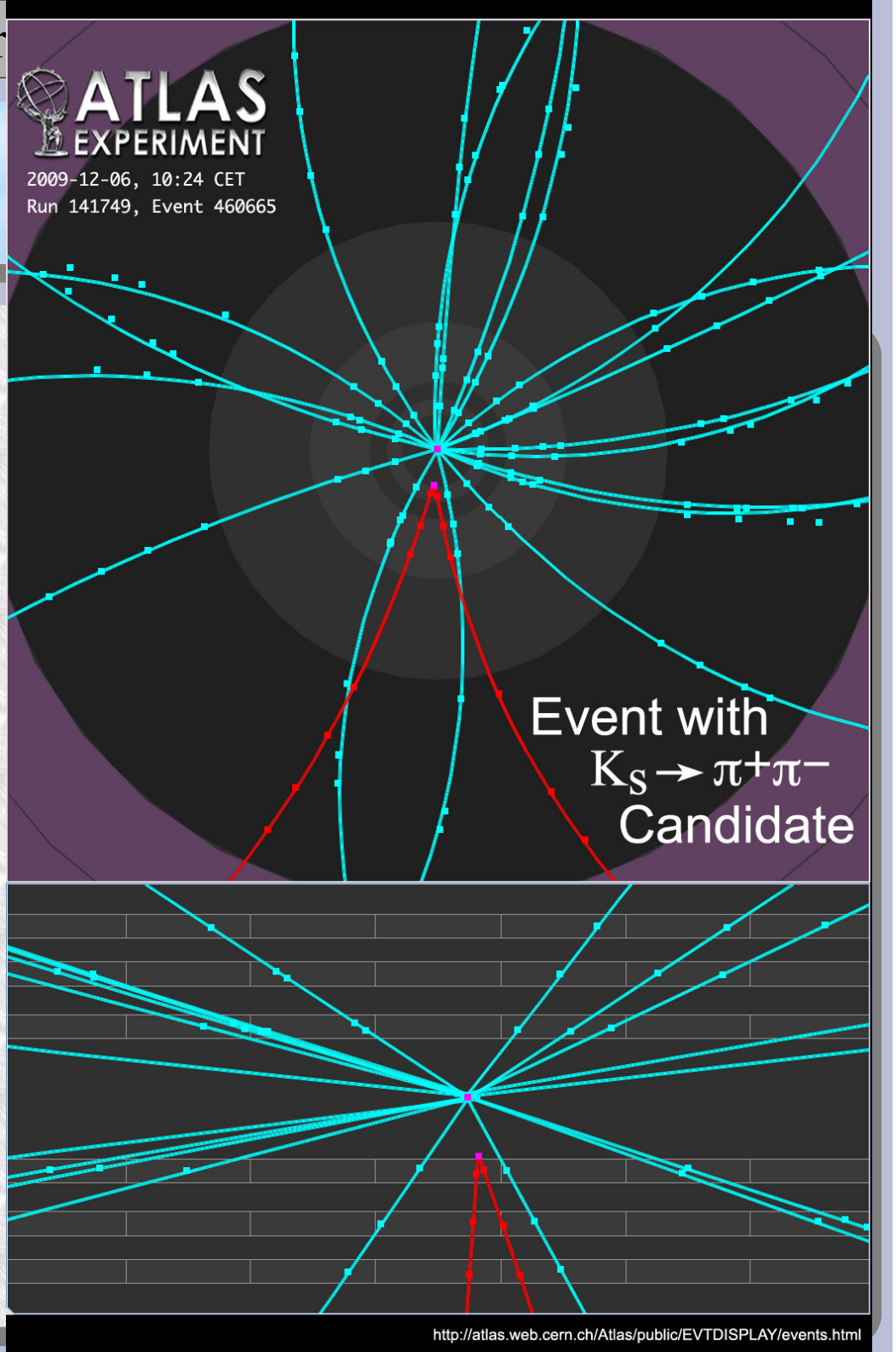
Number of hits versus η in pixels and SCT

Excellent agreement with simulation

- Needs beamspot Z size correct
- Also map of the (few) dead modules

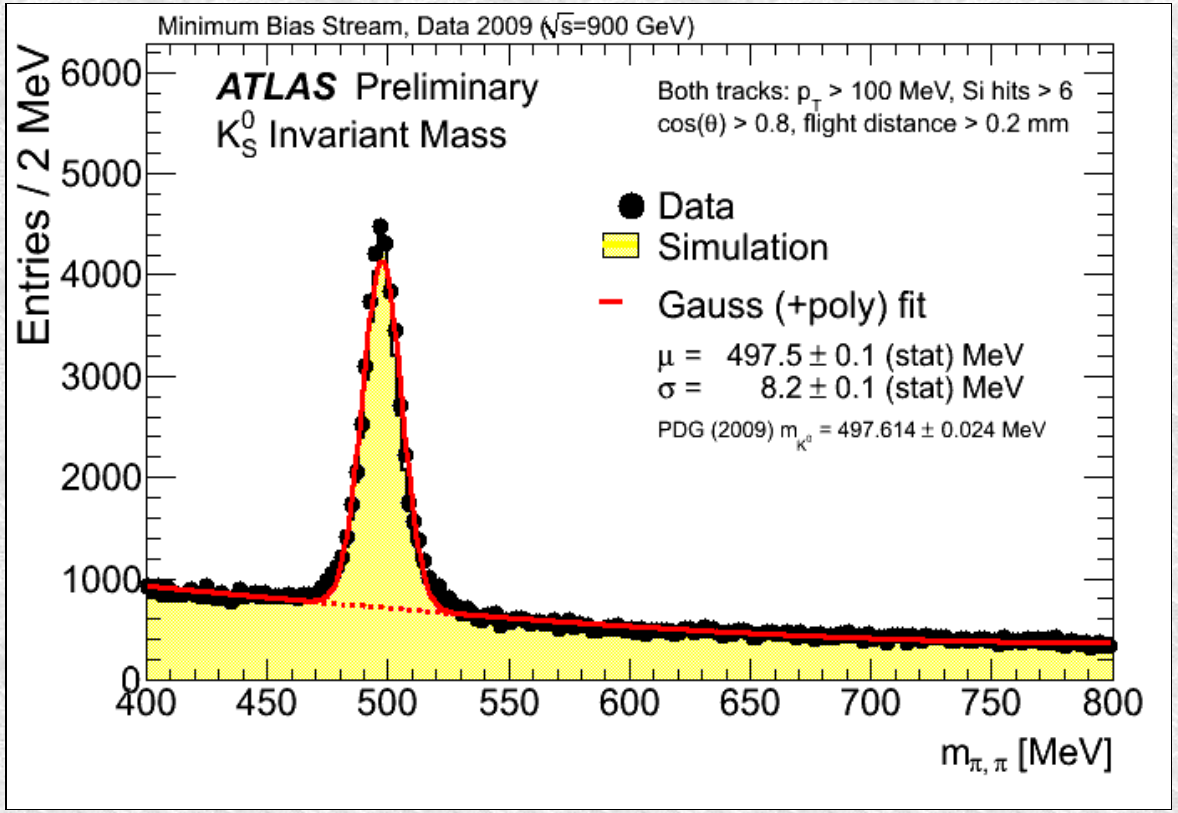
K^0 candidate

- Nicely observed K^0
- Distinct in Rφ and z views
- Tracking is working well

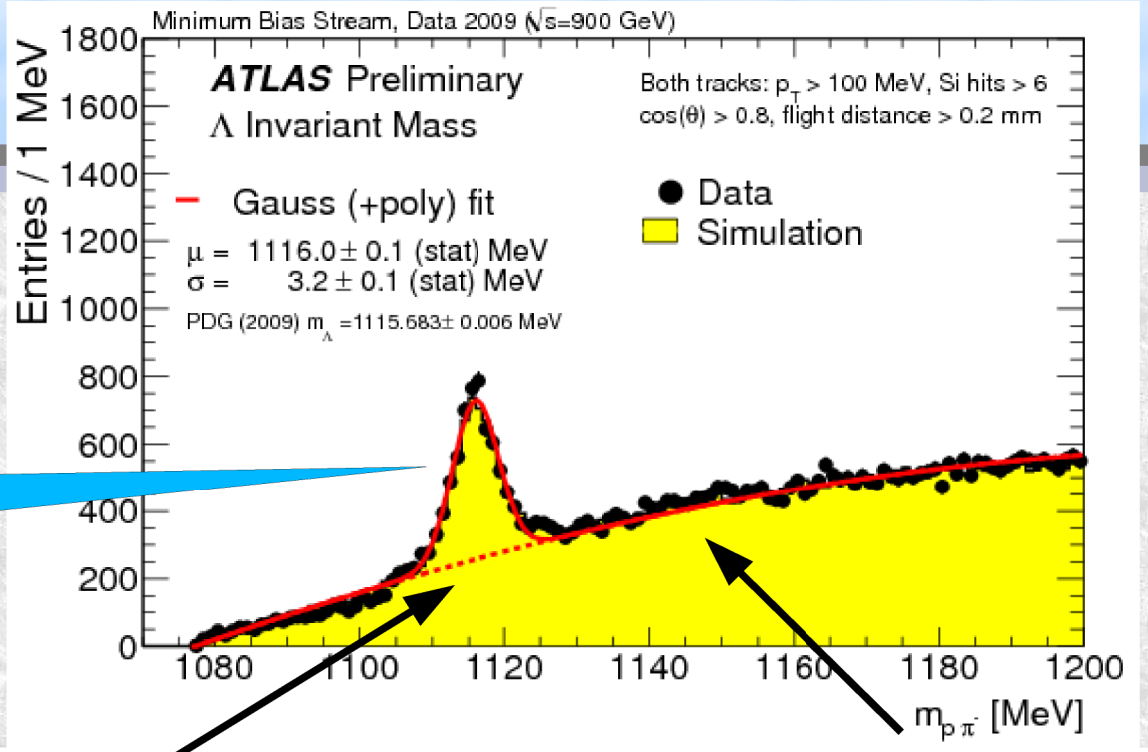


The K^0 mass spectrum

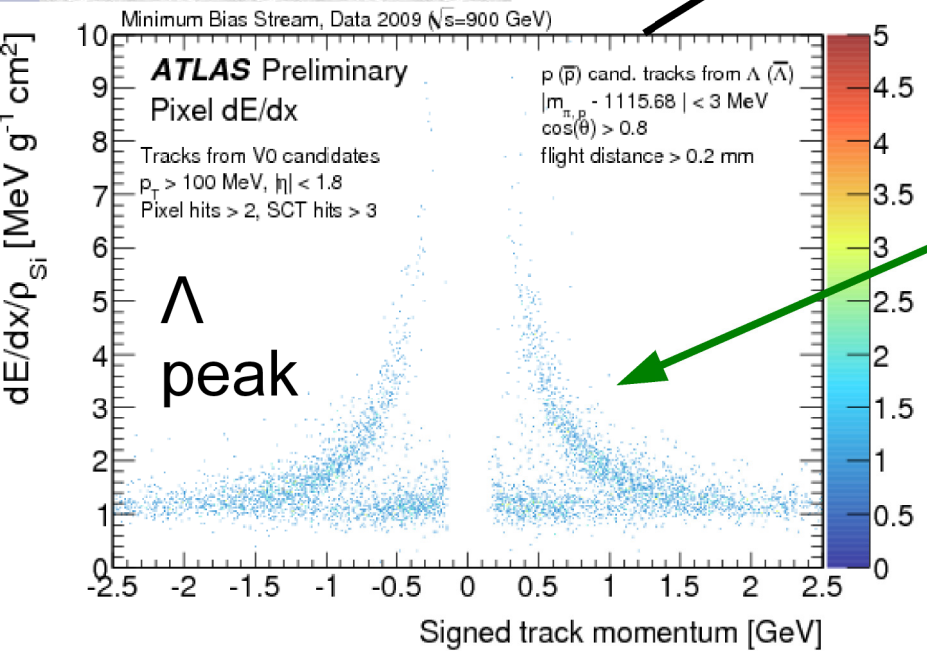
- Tracking down to 100MeV/c
- Mass matches PDG to .02%
- Momentum scale good
- Material de/dx losses being probed



Λ → pπ

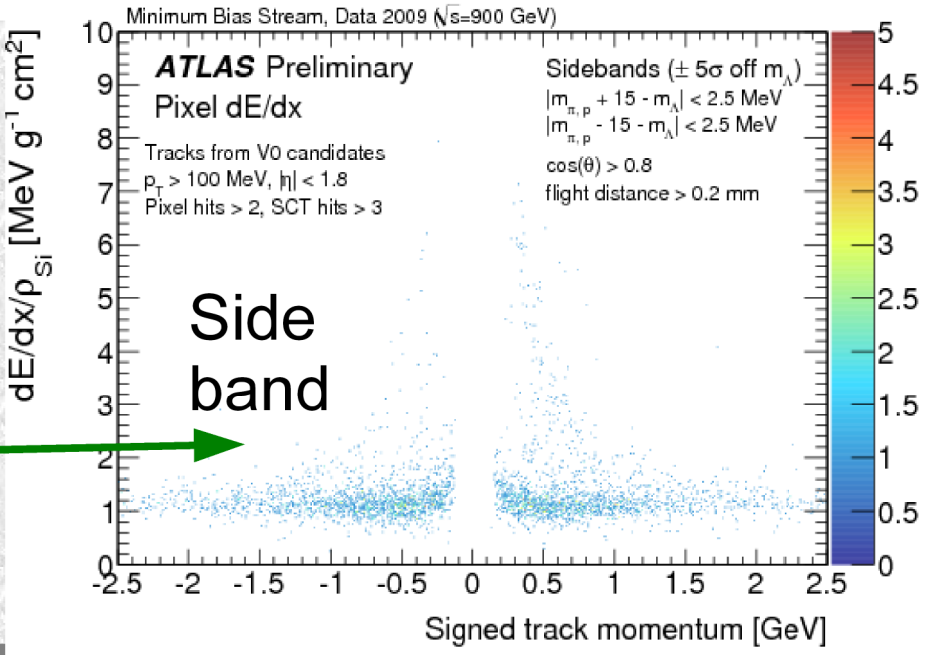


Λ peak



P dedx: Here

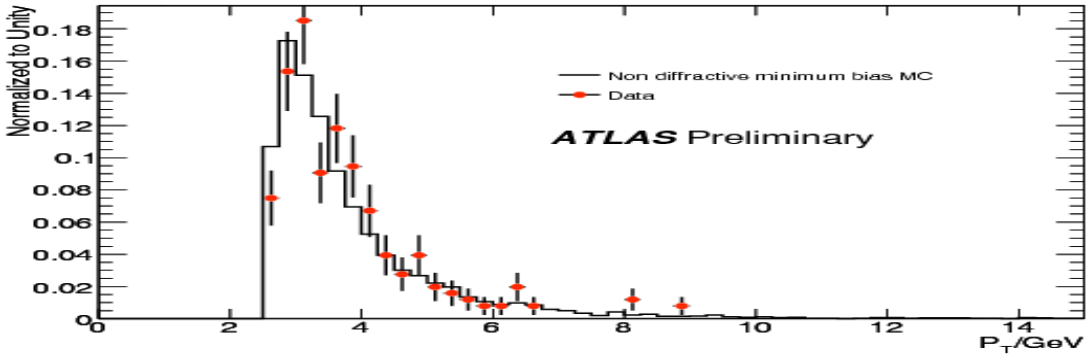
But not here



Electron / photon performance

Hundreds of candidates in 900GeV minimum bias
Many tests of the detector have been made

Photon p_T



Candidates have 3 or 4 GeV – very soft

2010 data will *trigger* photons at 20GeV

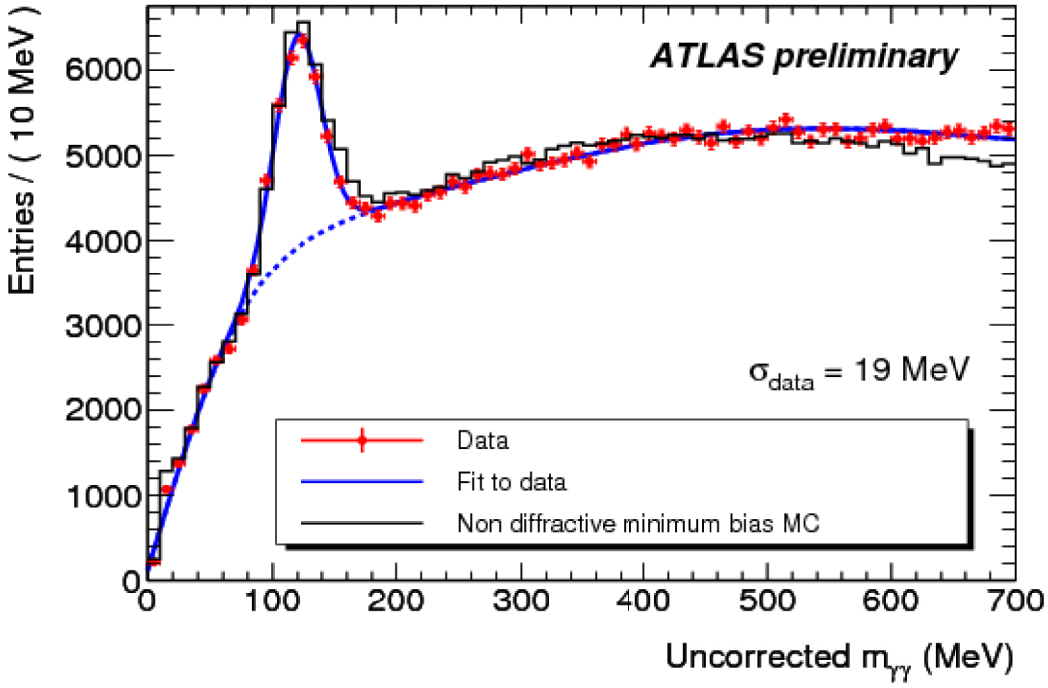
MC says mostly π^0 decays

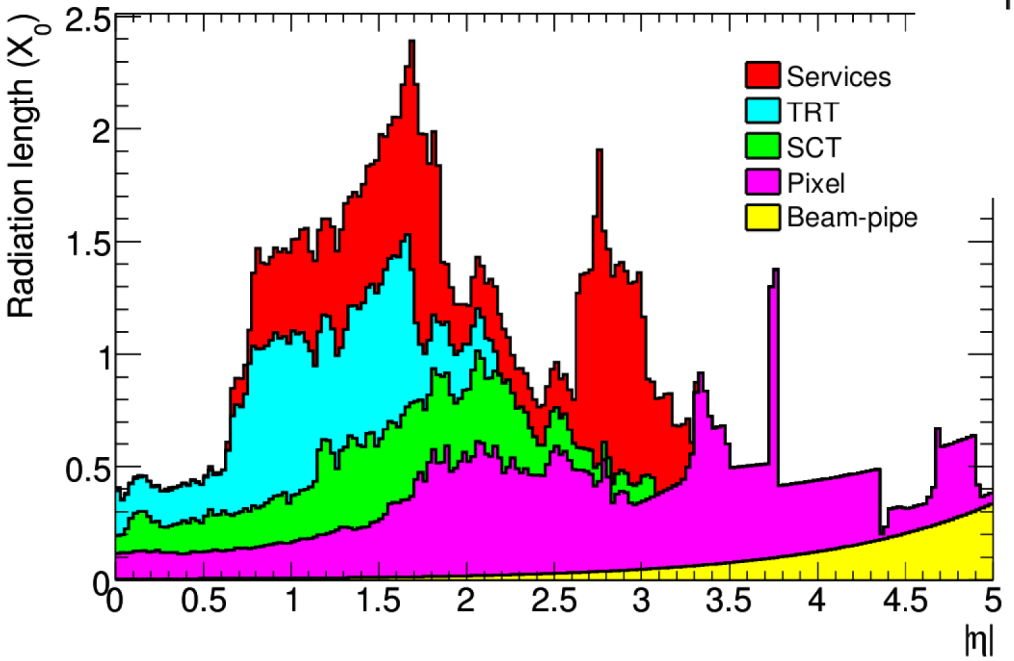
Spectrum is well reproduced

π^0 Observation

Rather soft particles
ECAL scale:
- Known to be <3%
- Found to be 1%!

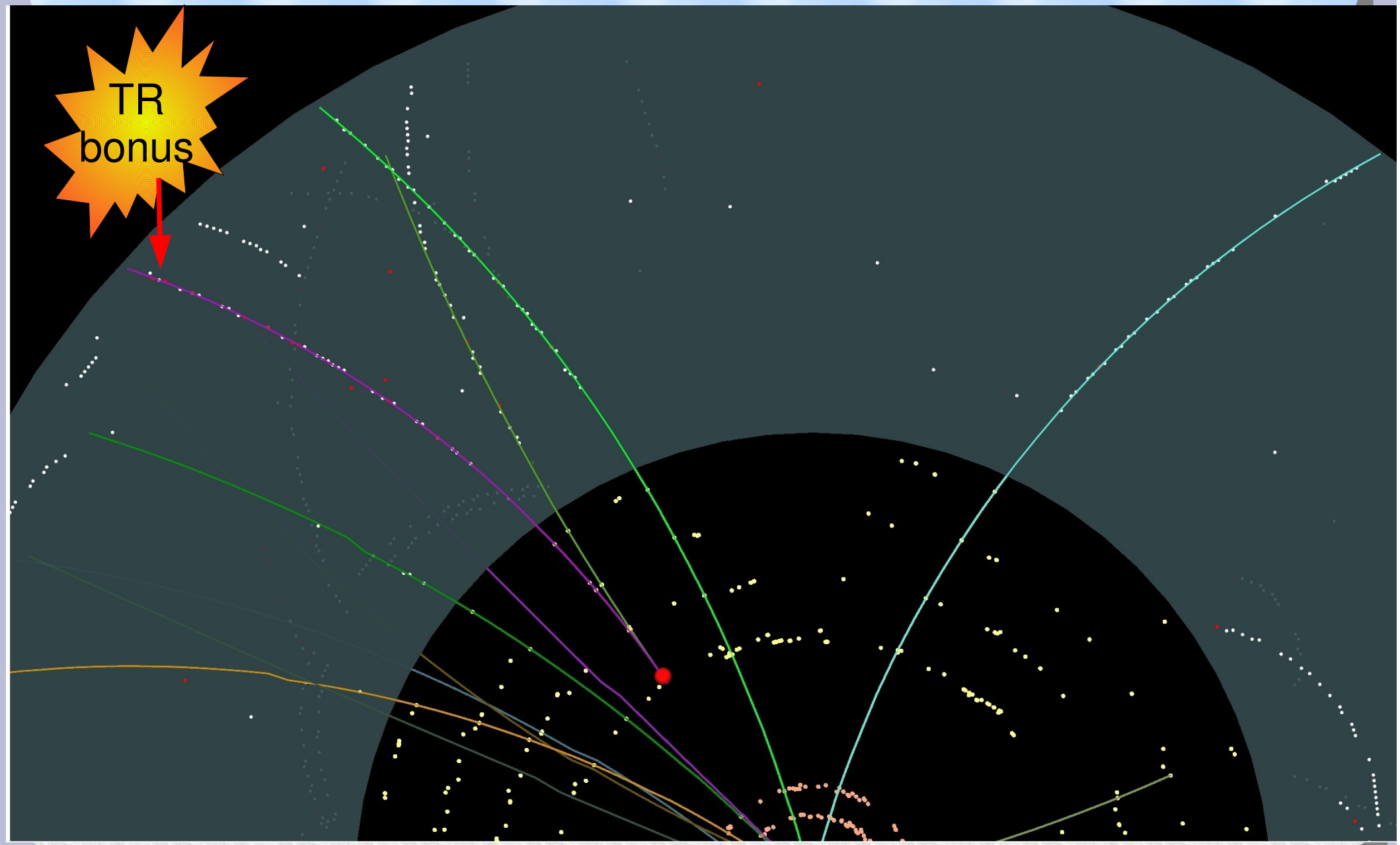
Excellent start





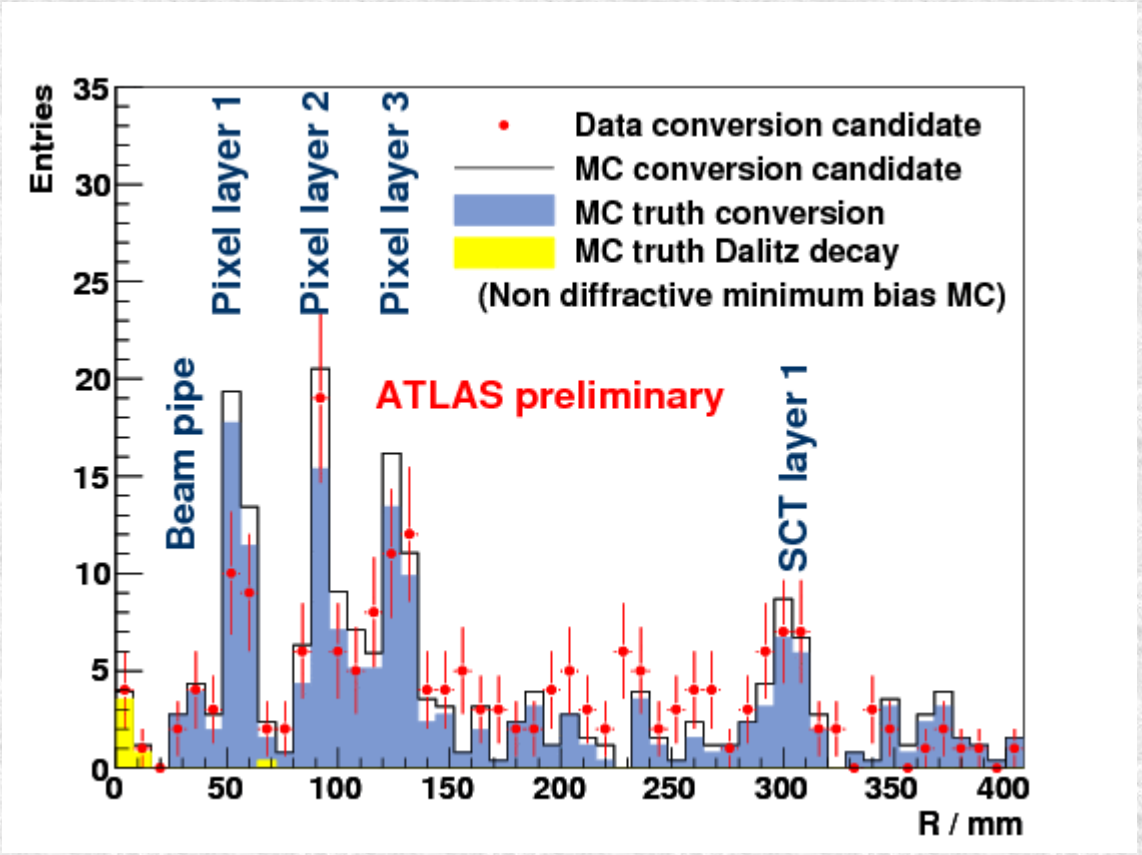
Material 0.5-1.5X^0
MEASURE it using
- ECAL cluster widths
- Conversion positions
- K^0 mass v radius

Photon Conversions



Photon conversion radius

- Photons convert in material
- Measured rate with radius gives the material distⁿ.
- Radial distribution well modelled
  - Consistent with MC



Can even see evidence for Dalitz decays

Electron E/p

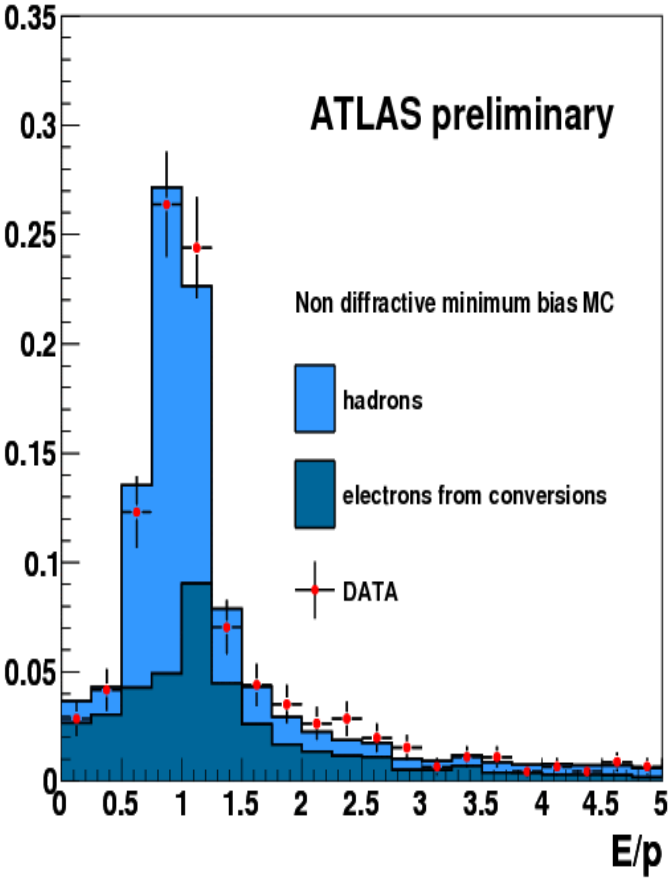
Electron candidates

E/p is a tool to select electrons

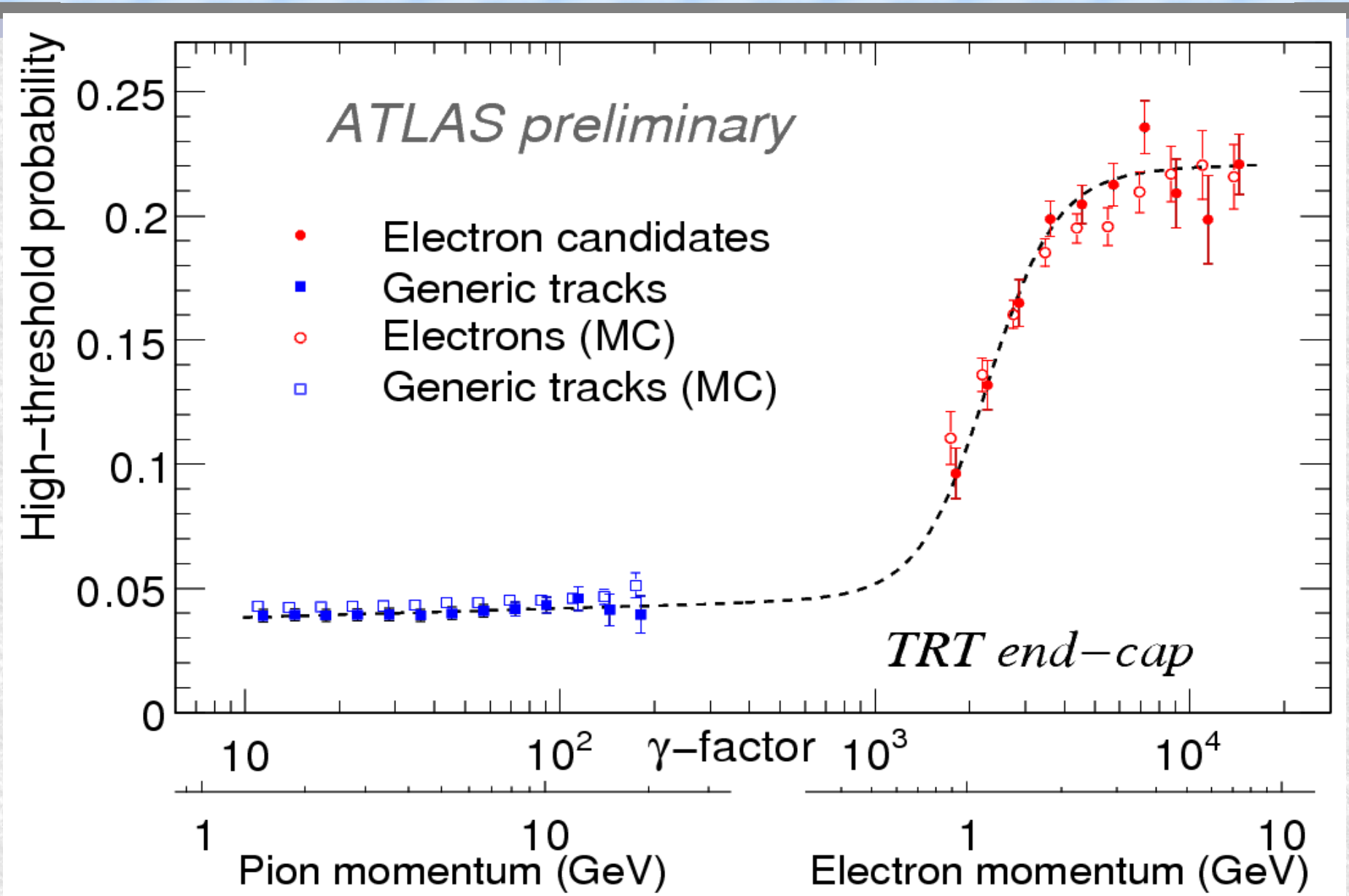
test scale of energy/momentum

Signal to background not good as p_T is low

Agreement with simulation is excellent.



Transition Radiation Tracker



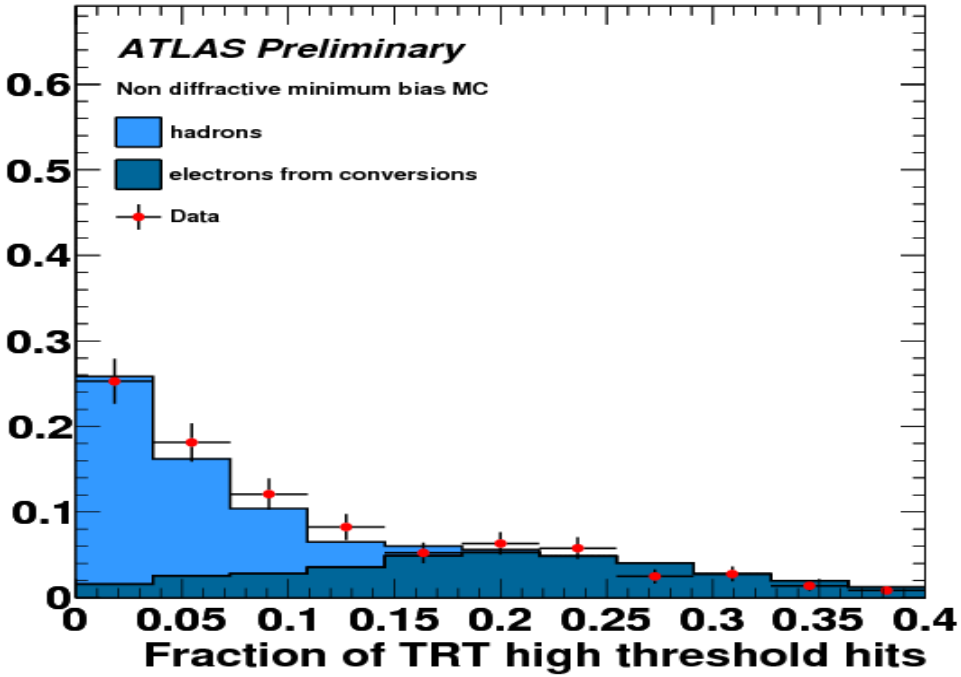
Enhancing Electrons

Loose electron candidates

Electrons give high threshold hits

We have huge s/b enhancement possible

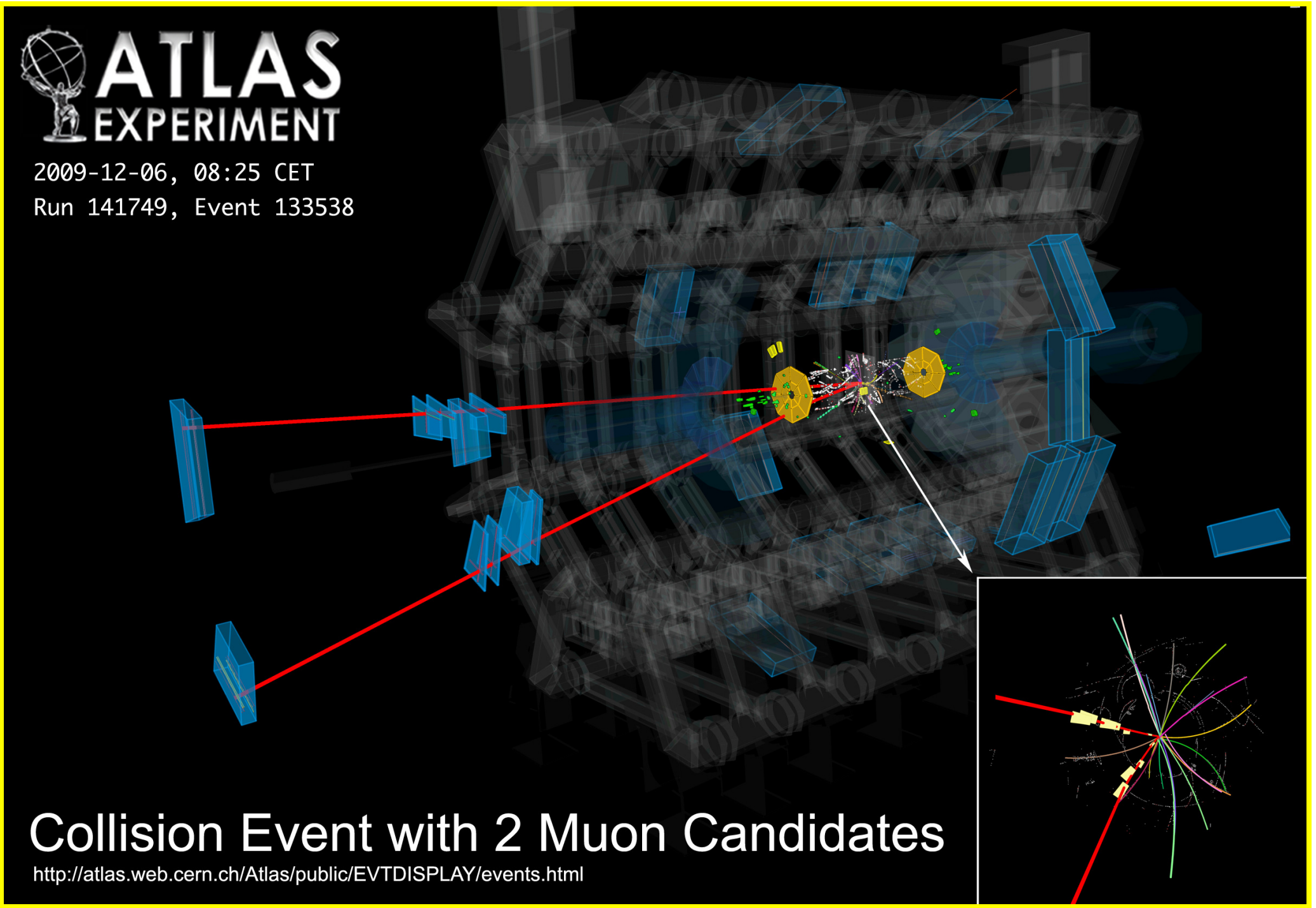
A TRT which works



Muon System

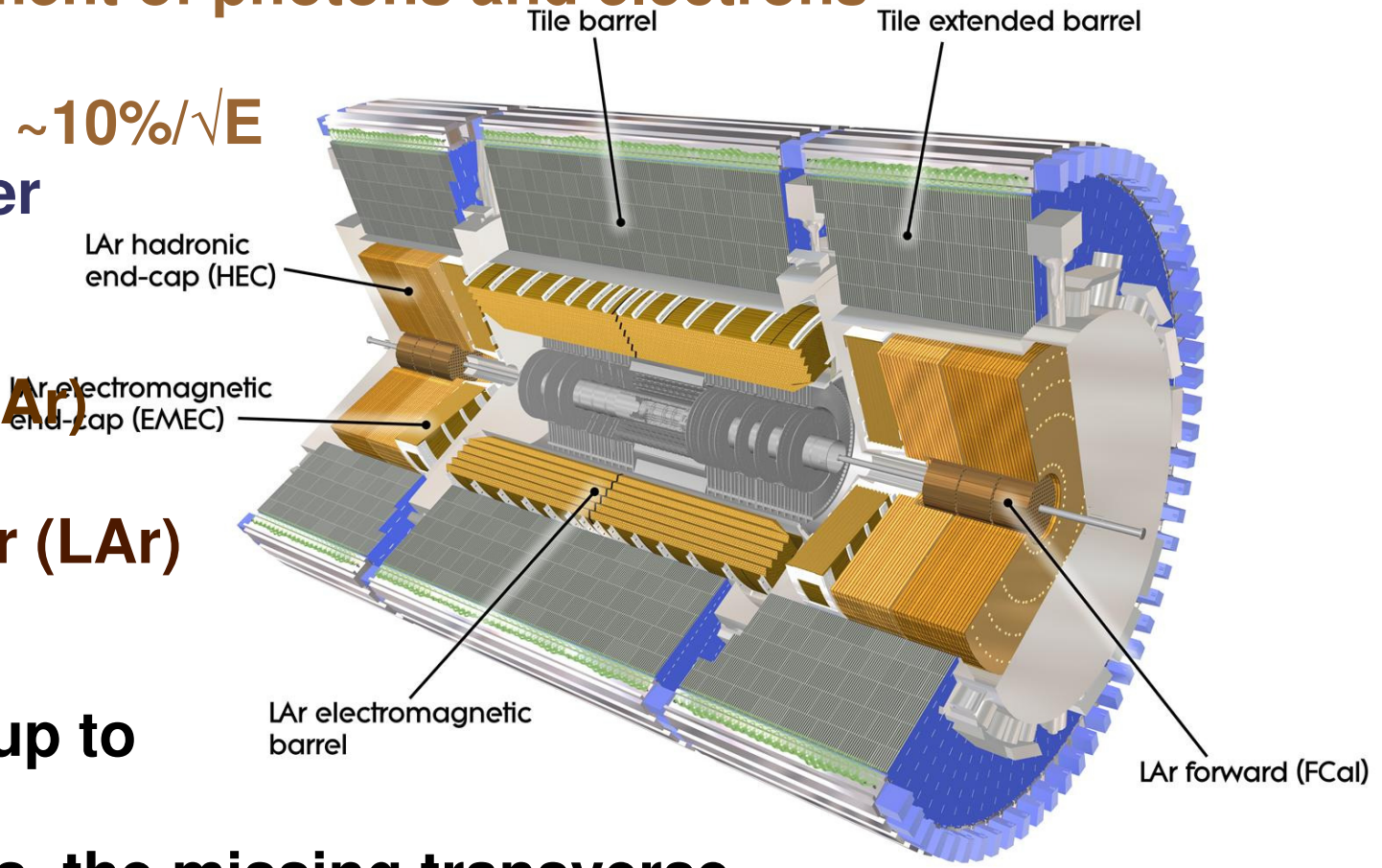
A major part of ATLAS
One of the strengths of the experiment

Well-commissioned with cosmics
But not many muons from beam yet


ATLAS
EXPERIMENT
2009-12-06, 08:25 CET
Run 141749, Event 133538
Collision Event with 2 Muon Candidates
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Jets and missing energy

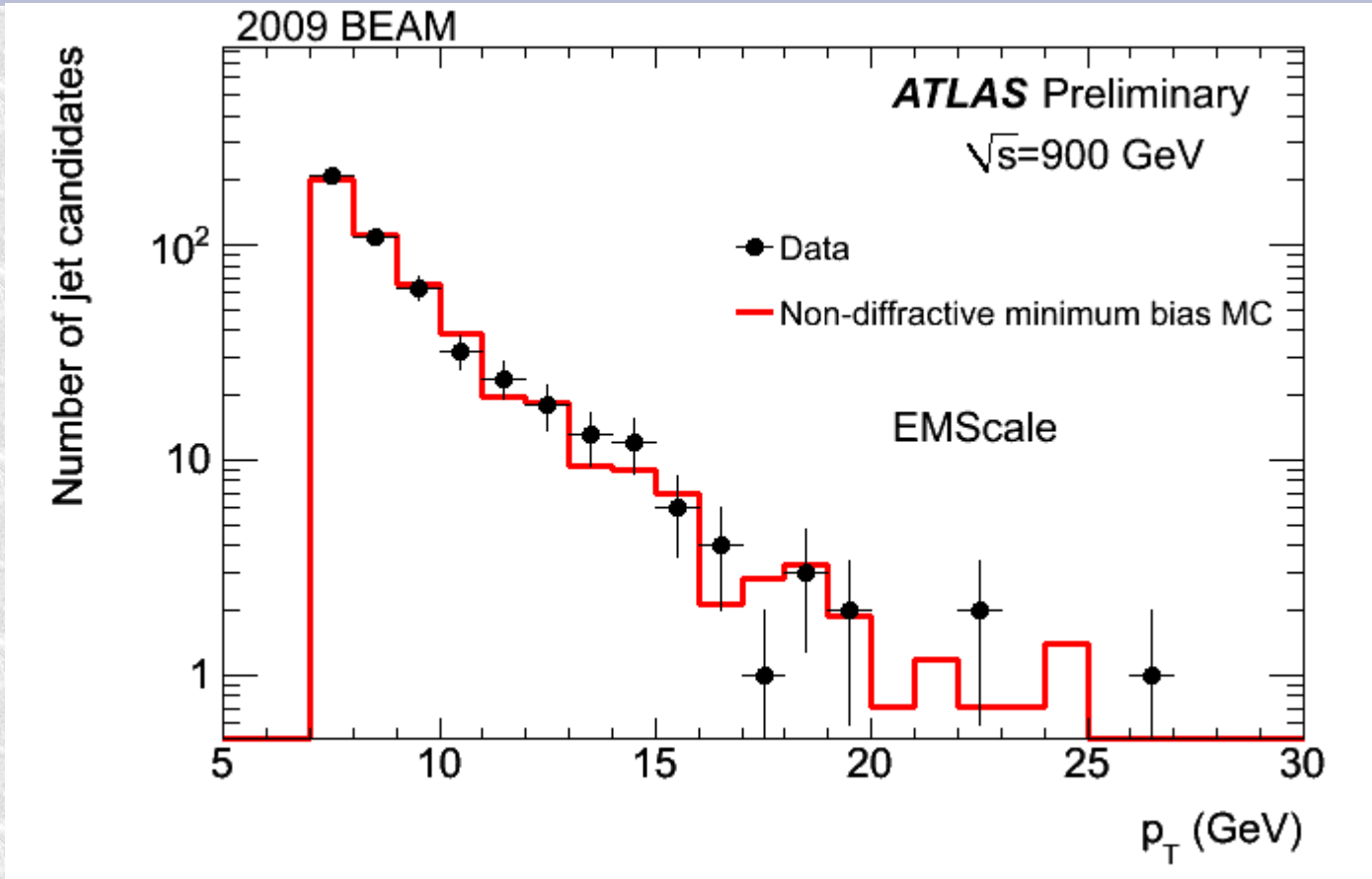
Electromagnetic accordion calorimeter (LAr)
Precision measurement of photons and electrons
|η|<3.2
Intrinisic resolution ~10%/√E
Hadronic calorimeter
Scintillator Tile calorimeter |η|<1.7
Hadronic endcap (LAr)
1.5<|η|<3.2
Forward calorimeter (LAr)
3.2<|η|<4.9



hermetic coverage up to |η|<4.9
Essential for the jets, the missing transverse momentum and for the trigger

Calorimeter Jet Selection

Anti-kT
D=0.4

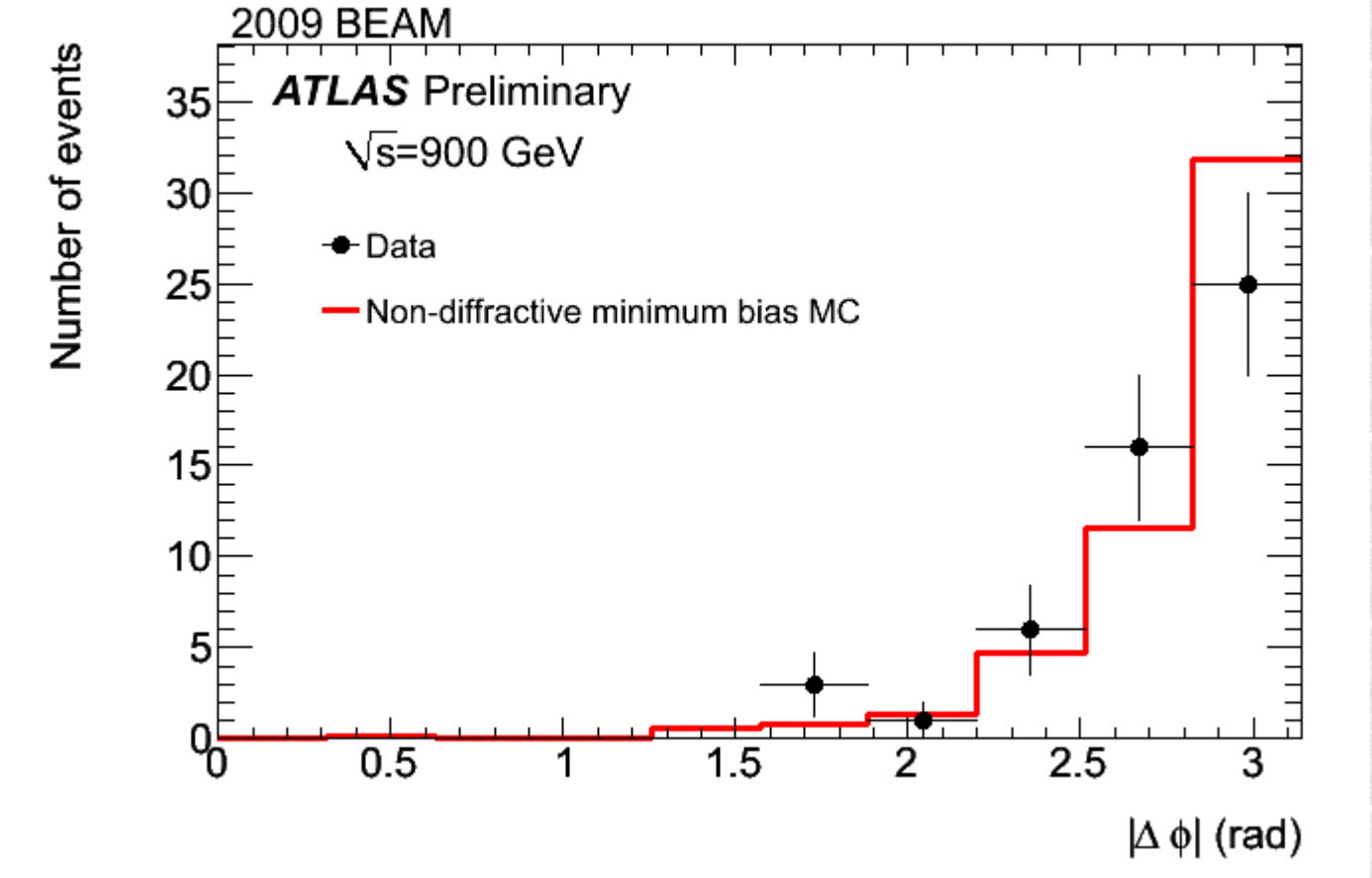


Jet p_T spectrum at EM scale

EM scale: energy left by electron in calo, no material

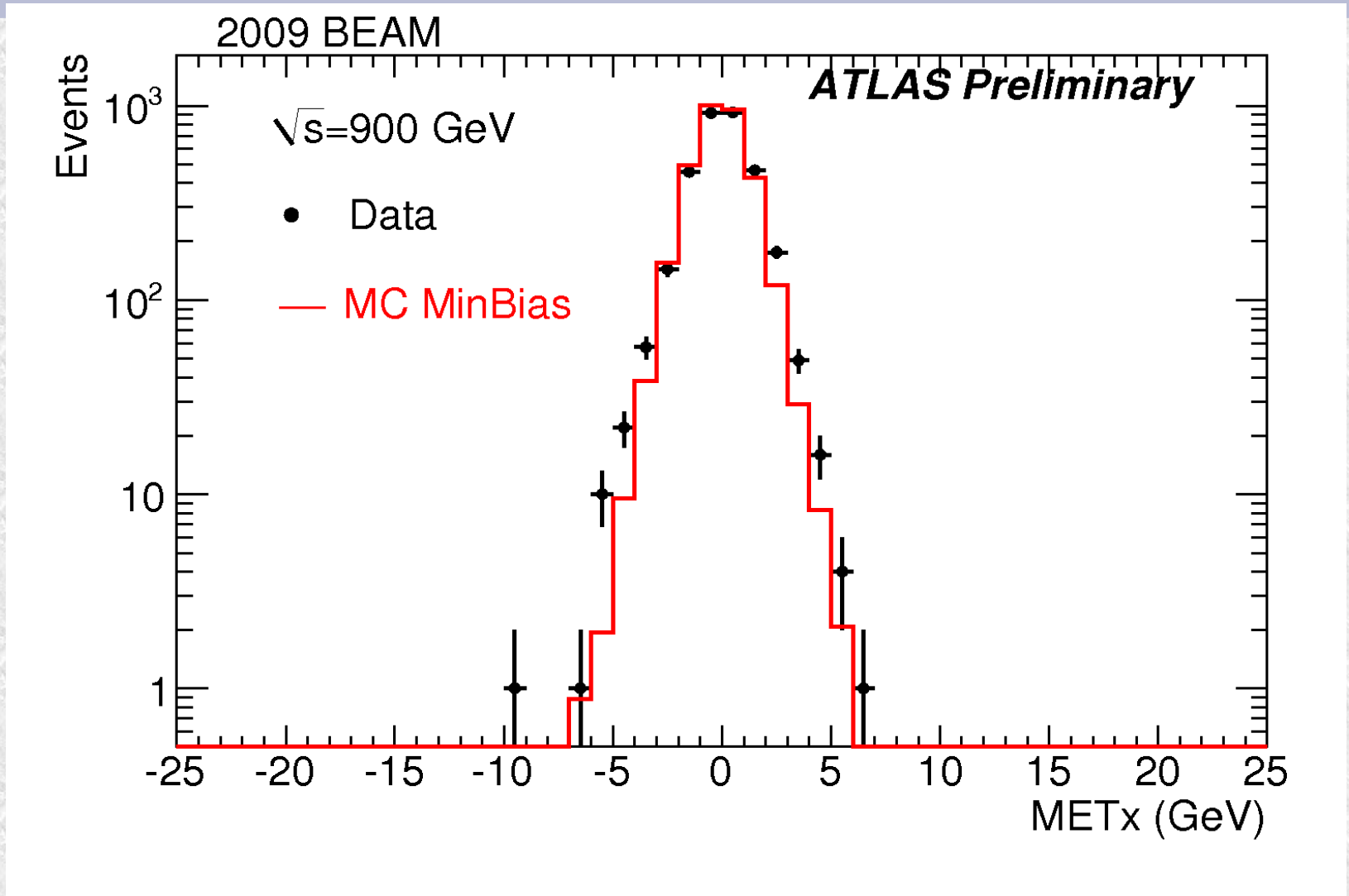
Very nice agreement simulation

Jet acolinearity



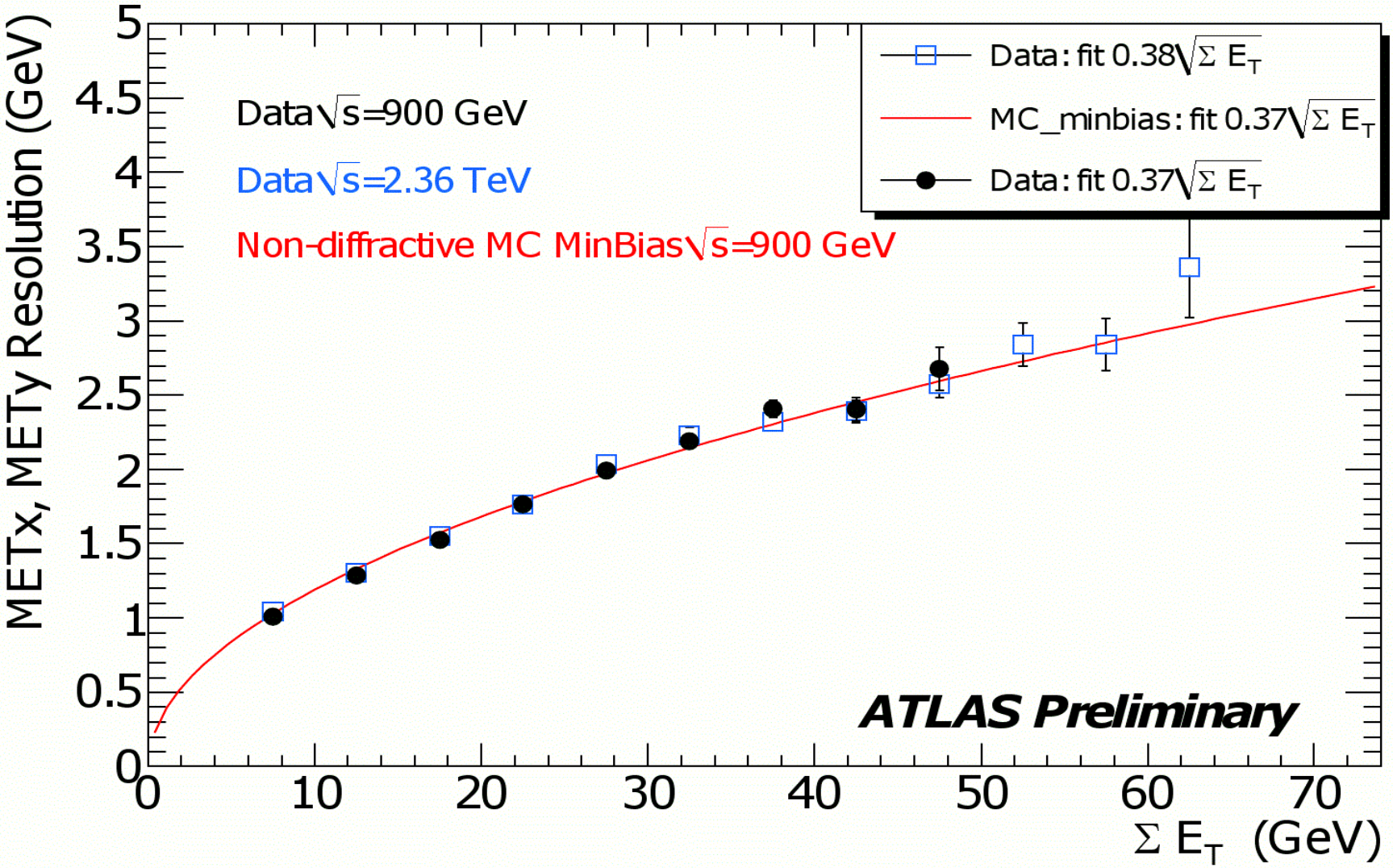
Di-jet events with 7GeV at EM scale
Back to back jets →momentum conservation!

Missing energy: x component



Some noise has been suppressed

Missing energy resolution



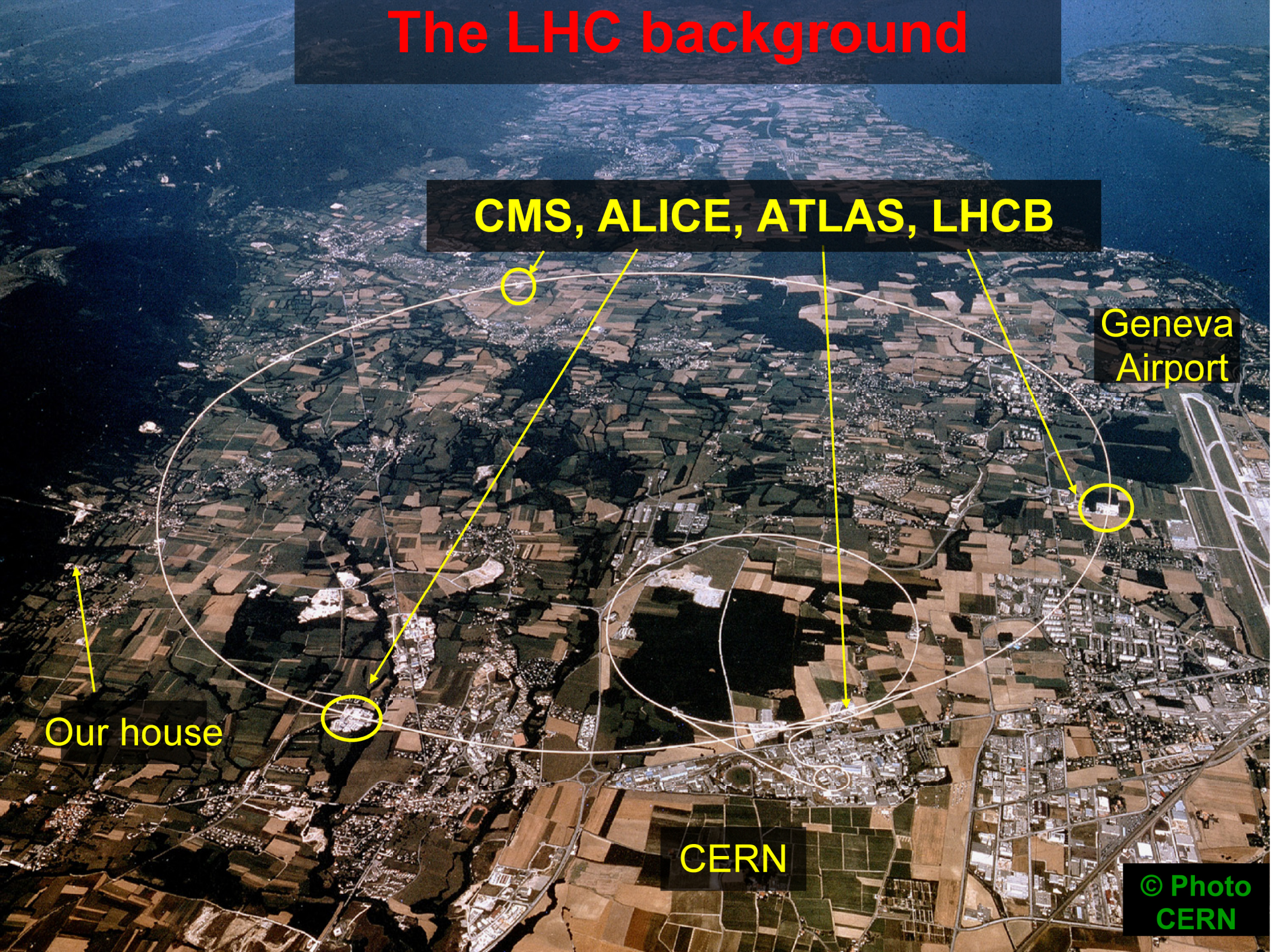
Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.9%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM Calorimeter	170 k	98.8%
Tile calorimeter	9800	99.2%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Trigger	370 k	98.5%
TGC Endcap Muon Trigger	320 k	99.4%
LVL1 Calo trigger	7160	99.8%

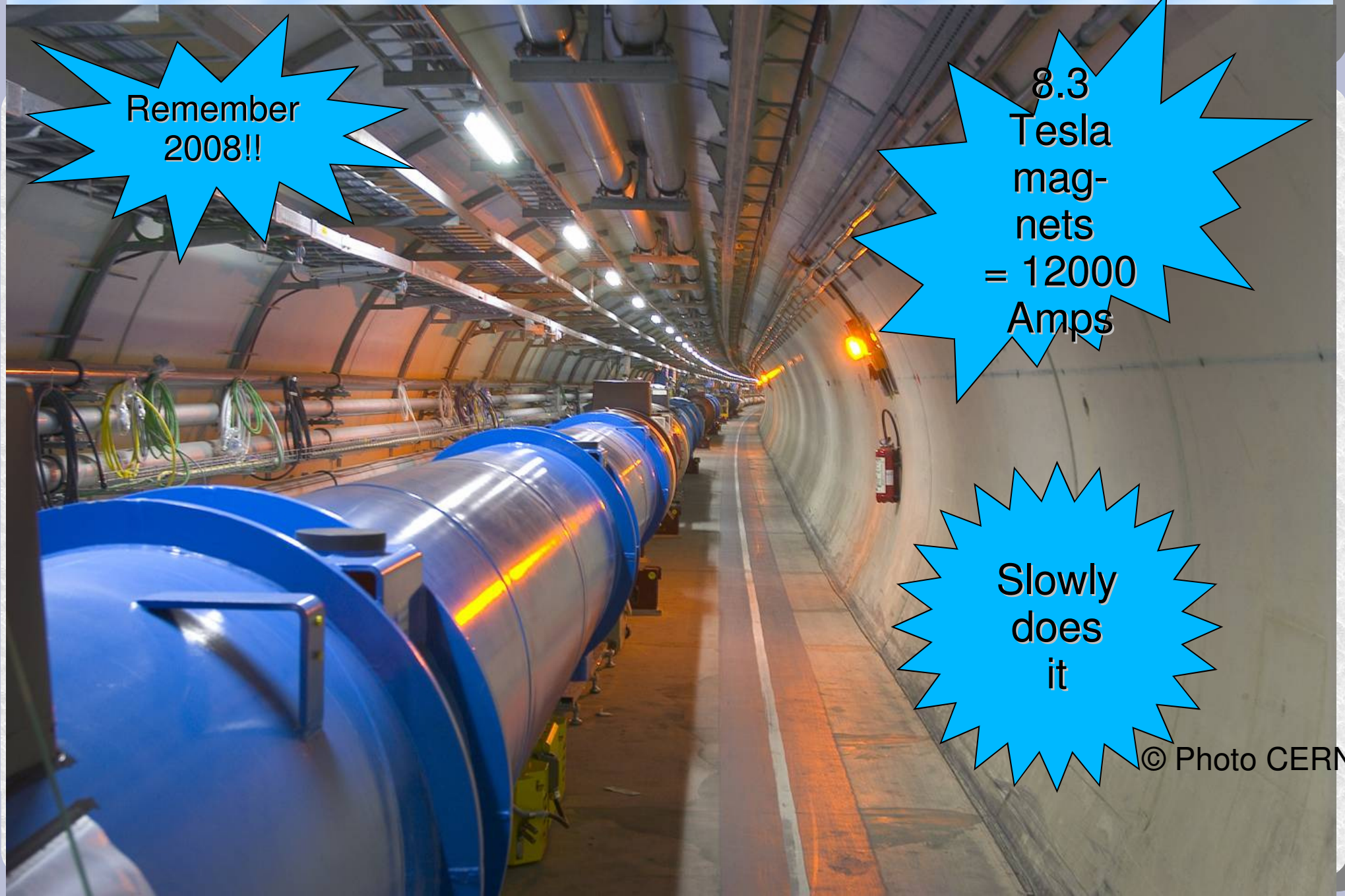

≥2010

2010

- LHC
  - The run plan
  - Crystal ball gazing luminosity
- The Physics
  - SM
  - SUSY
  - Z', W'
  - Higgs
- Discovery v lumi / time


The LHC background
CMS, ALICE, ATLAS, LHCB
Geneva Airport
Our house
CERN
© Photo CERN

The LHC


Remember 2008!!
8.3 Tesla mag-nets = 12000 Amps
Slowly does it
© Photo CERN

Danger of Stored Power

Full bear
This Briti
knots
Steered t
hole

The mag
fields is 1

This American aircraft carrier at 32 knots

Luminosity Steps (S. Myers)

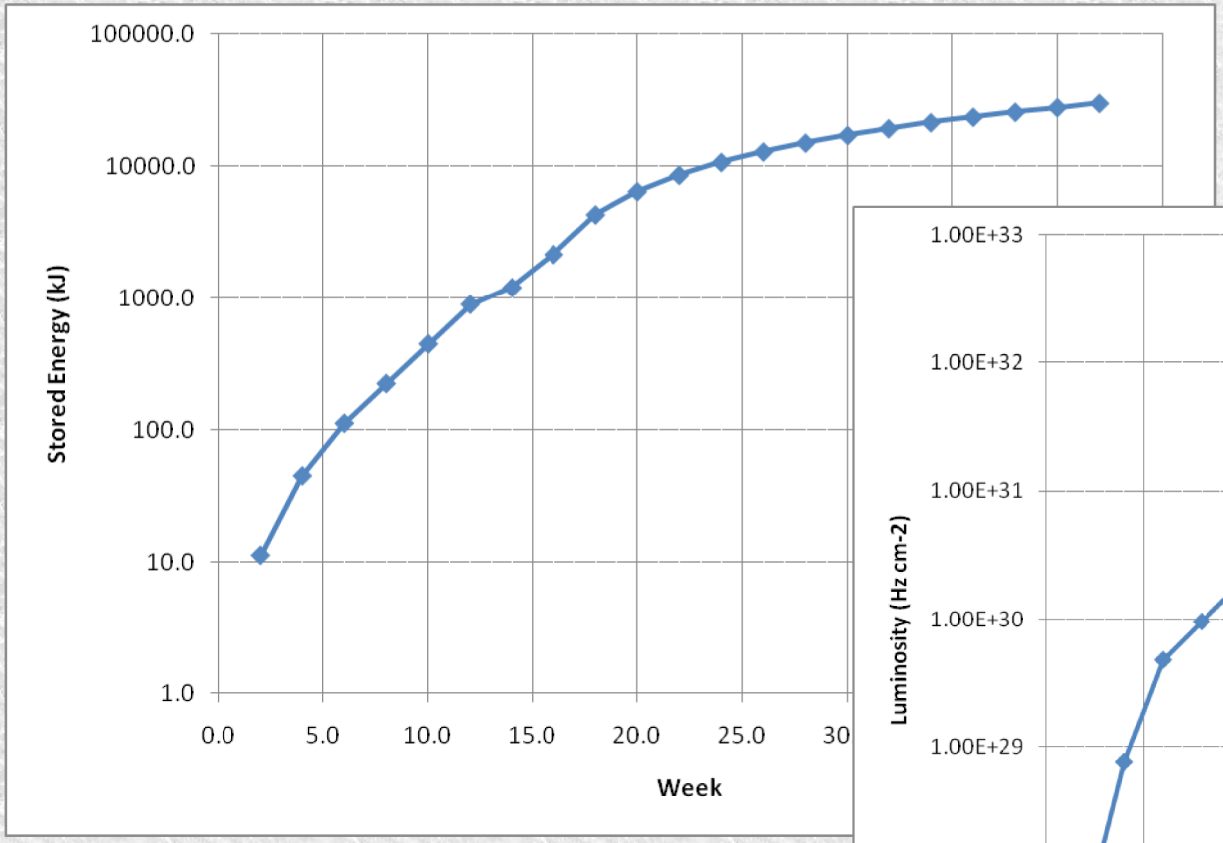
Stage	Ib (protons)	Nb	Stored E (kJ)	Stored E step	Peak L (Hz cm-2)
4 pilots	0.5×10^{10}	4	11.2	1.00	4.77×10^{27}
4 bunches	2.0×10^{10}	4	44.8	4.00	7.63×10^{28}
4 bunches	5.0×10^{10}	4	112.0	2.50	4.77×10^{29}
8 bunches	5.0×10^{10}	8	224.0	2.00	9.54×10^{29}
4x4 bunches	5.0×10^{10}	16	448.0	2.00	1.91×10^{30}
8x4 bunches	5.0×10^{10}	32	896.0	2.00	3.81×10^{30}
43x43	5.0×10^{10}	43	1204.0	1.34	5.13×10^{30}
8 trains of 6 b	8.0×10^{10}	48	2150.4	1.79	1.33×10^{31}
50 ns trains	8.0×10^{10}	96	4300.8	2.00	2.67×10^{31}

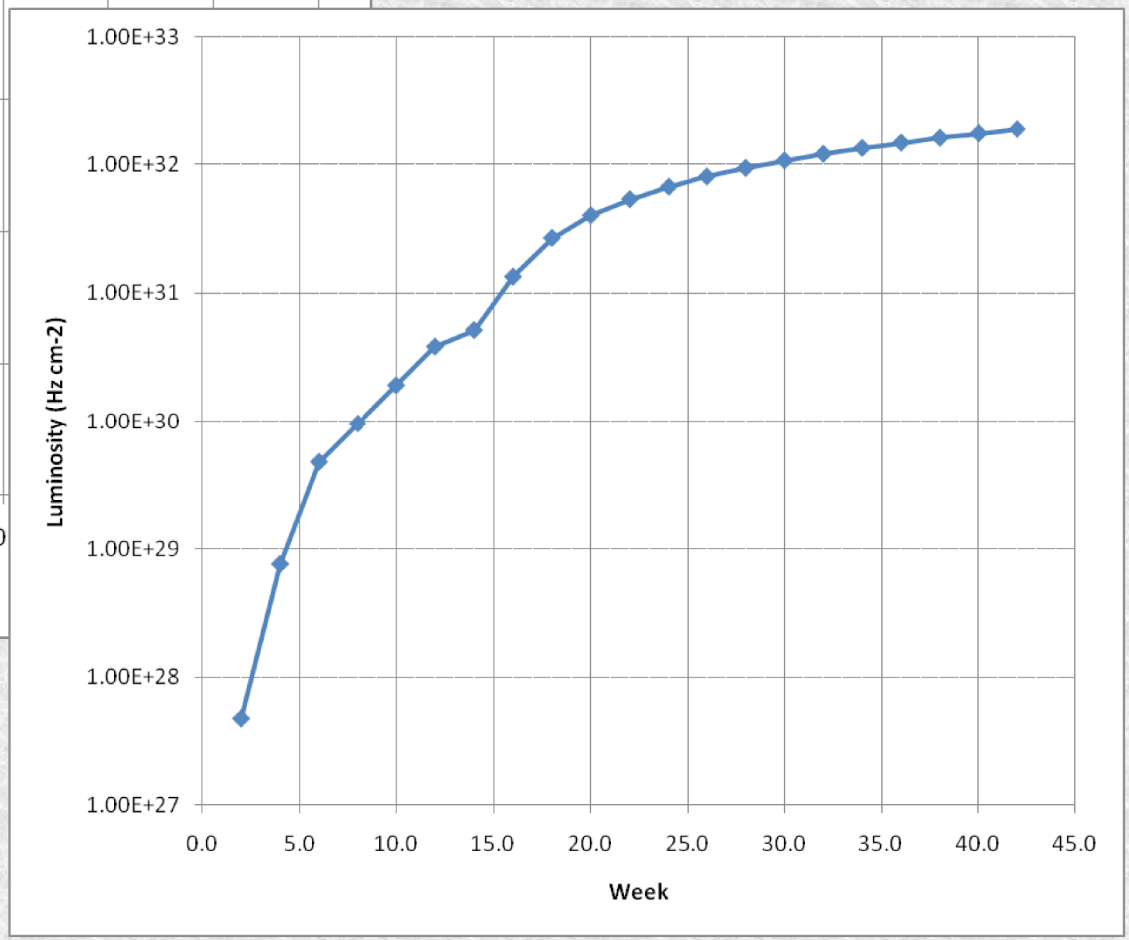
$\beta^* = 2$ m, nominal emittance

2 weeks between energy steps = 10 days + margin for MD, access etc

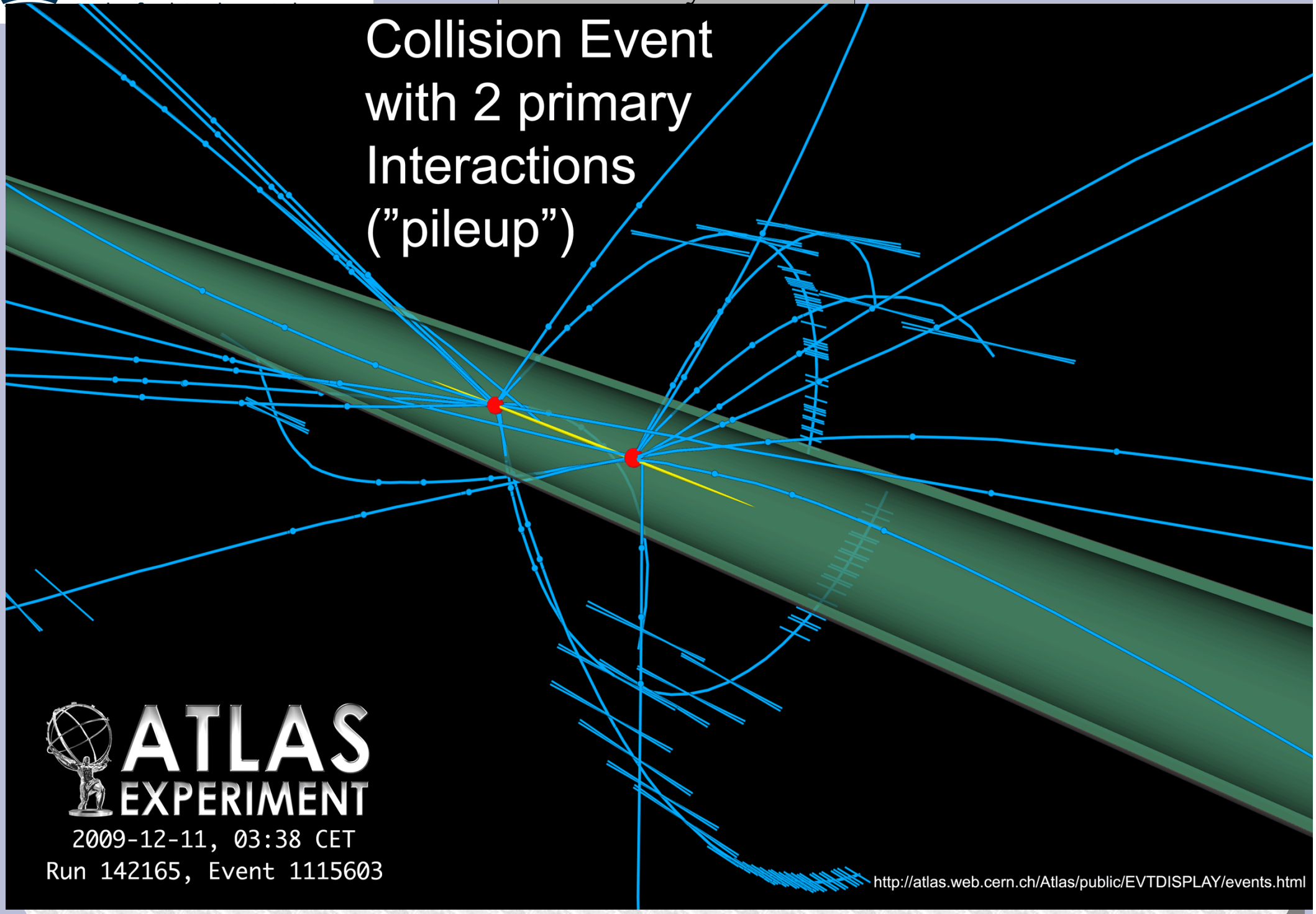
4343

Luminosity v time (S. Myers)





Pileup of order 1.3 events for second half


Collision Event
with 2 primary
Interactions
("pileup")
ATLAS
EXPERIMENT
2009-12-11, 03:38 CET
Run 142165, Event 1115603
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Luminosity Summary

2x10^{32}cm^{-2}s^{-1} in 2010 there must be a rapid progression in stored beam energy in parallel t

es, with the potential to cause damage !

ime.

nce in MPS.

S. Myers

Summary 2011

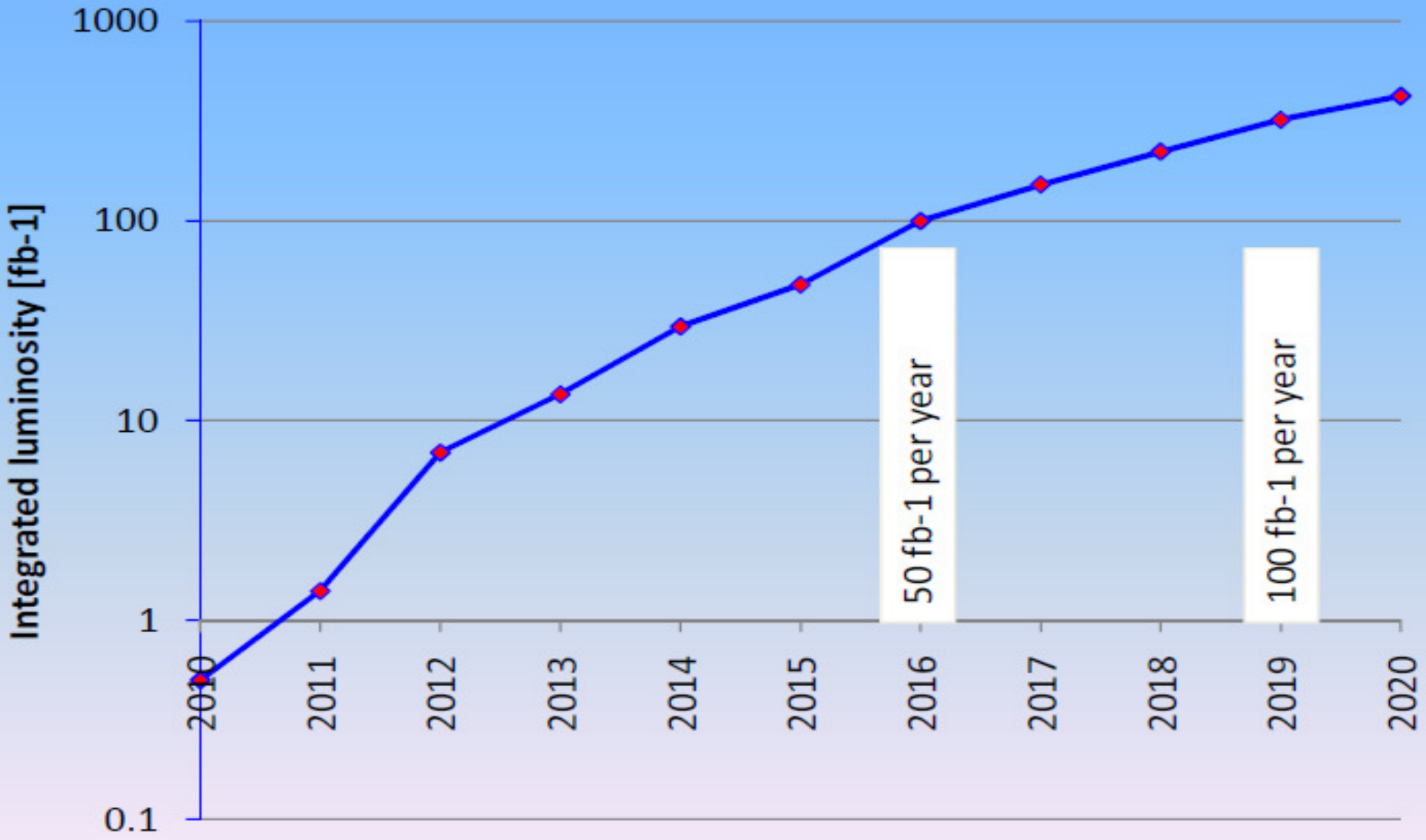
3.5 TeV: run flat out at ~100 pb^{-1} per month

	No. bunches	ppb	Total Intensity	Beam Stored Energy (MJ)	beta*	Peak Lumi	Int Lumi per month [pb-1]
50 ns	432	7 e10	3 e13	17	2	1.3 e32	~ 85
Pushing intensity limit	720	7 e10	5.1 e13	28.2	2	2.2 e32	~ 140
Pushing bunch current limit	432	11 e10	4.8 e13	26.6	2	3.3 e32	~ 209

With these parameters we should be able to deliver 1 fb^{-1}

And to ultimate (no LHC upgrade)

Assuming 60% machine availability
Assuming 4h turn around time



ATLAS physics

Rough Expectations:

Summer conferences: 10pb^{-1}

Winter Conferences 200pb^{-1}

End of run: 1000pb^{-1}

Following results use crude estimates made for 'Chamonix 2009'

- We often have internal studies confirming them
- Studies shown are a few examples from many.

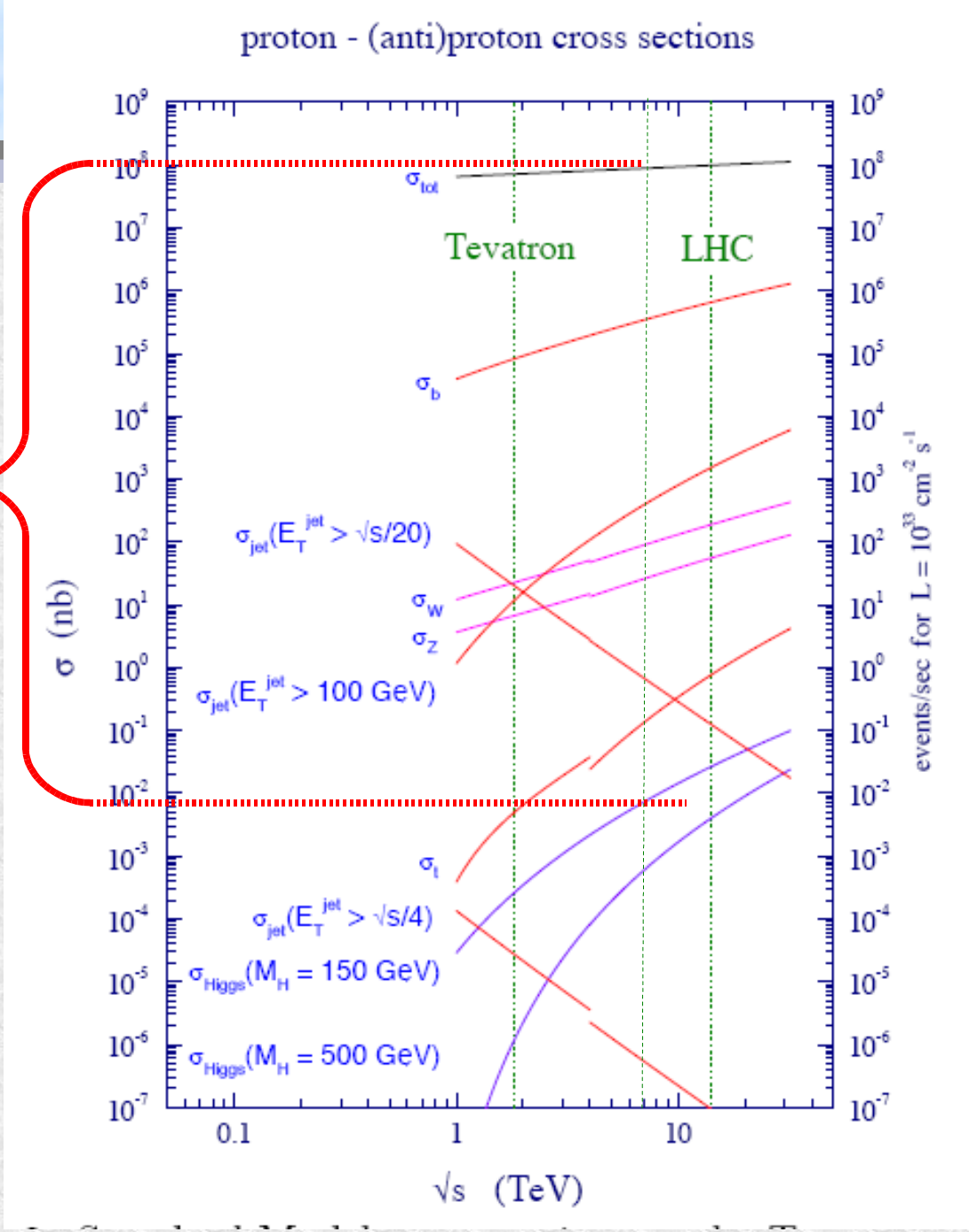
Cross-section

LHC backgrounds!

10^{10}

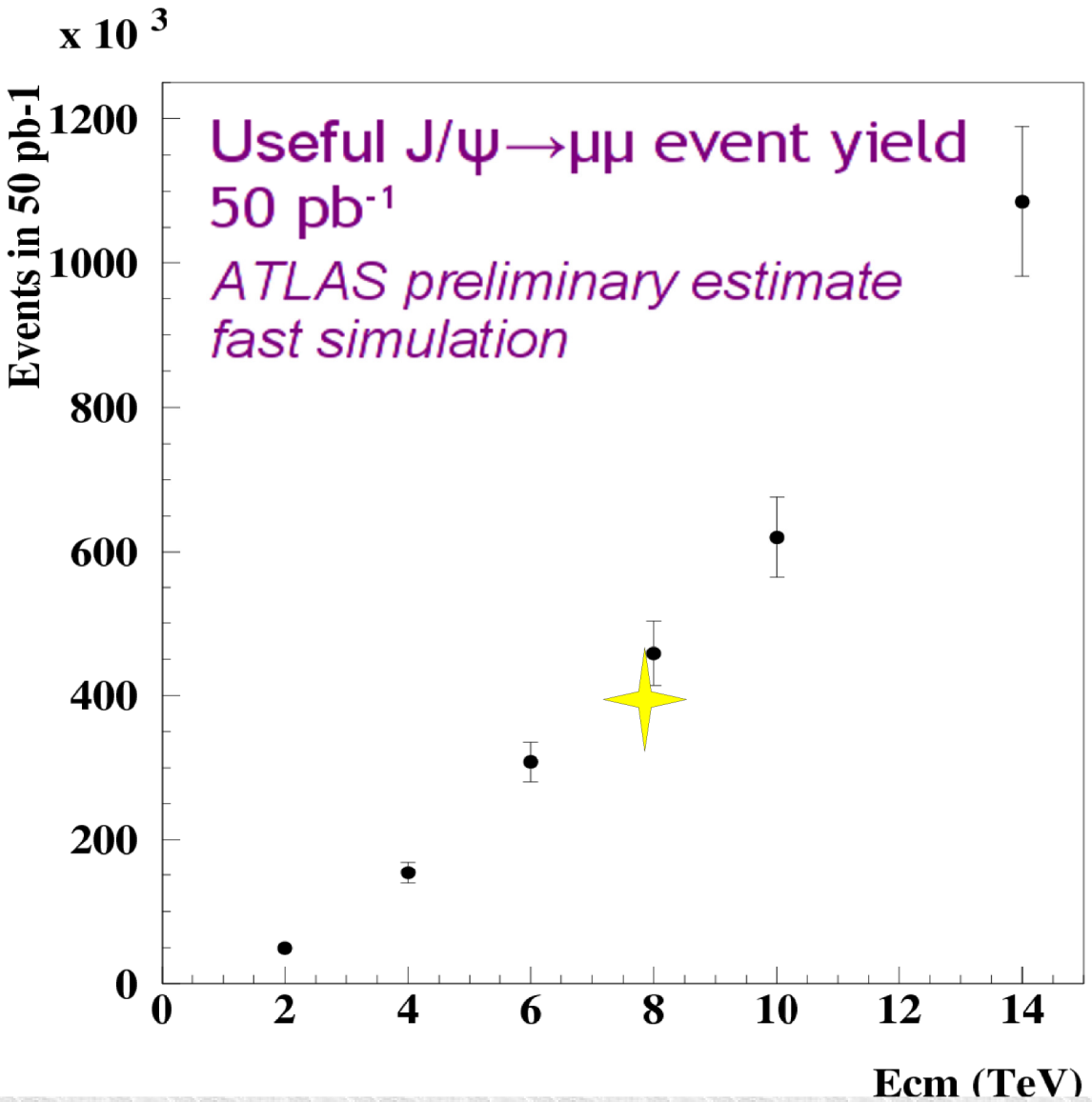
Every event at a lepton collider is physics; every event at a hadron collider is background

Sam Ting



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

- J/ψ will be rapidly produced
- A great calibration point for the muon system
  - Inc. ID tracks
- 80,000 useful for summer?
- Millions from run



J/ψ physics

Several measurements envisaged:

- Cross-section
- Prompt fraction
- Polarization

Soon leads into

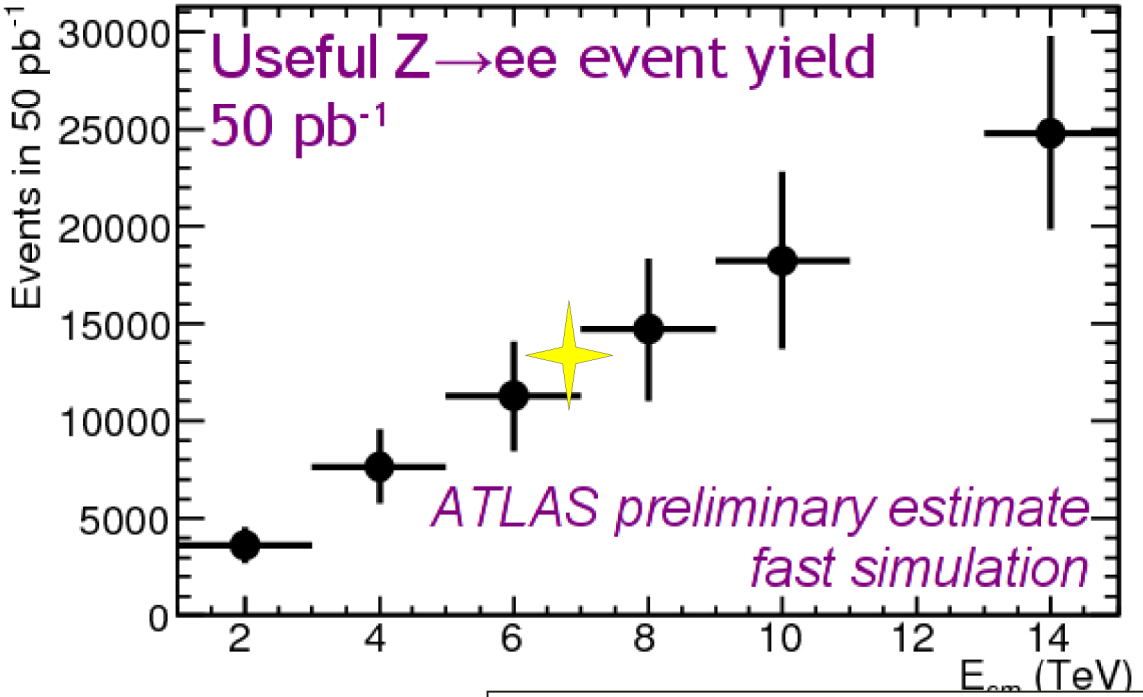
- upsilon studies
- J/ψ K_s B decays
- Bs→μμ
- Etc,

Z → ee studies

Essential standard candle

Used to check calorimeter scale

Also 'tag and probe' electron efficiency studies



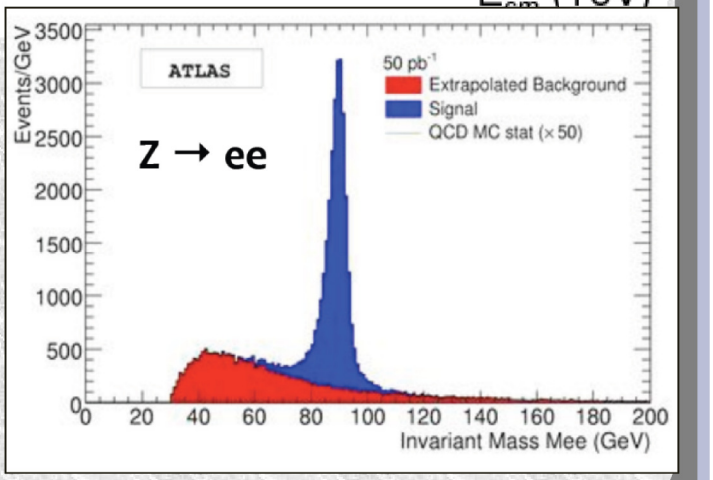
Selected cross-section: ~260pb^{-1}

Thousands of events by summer

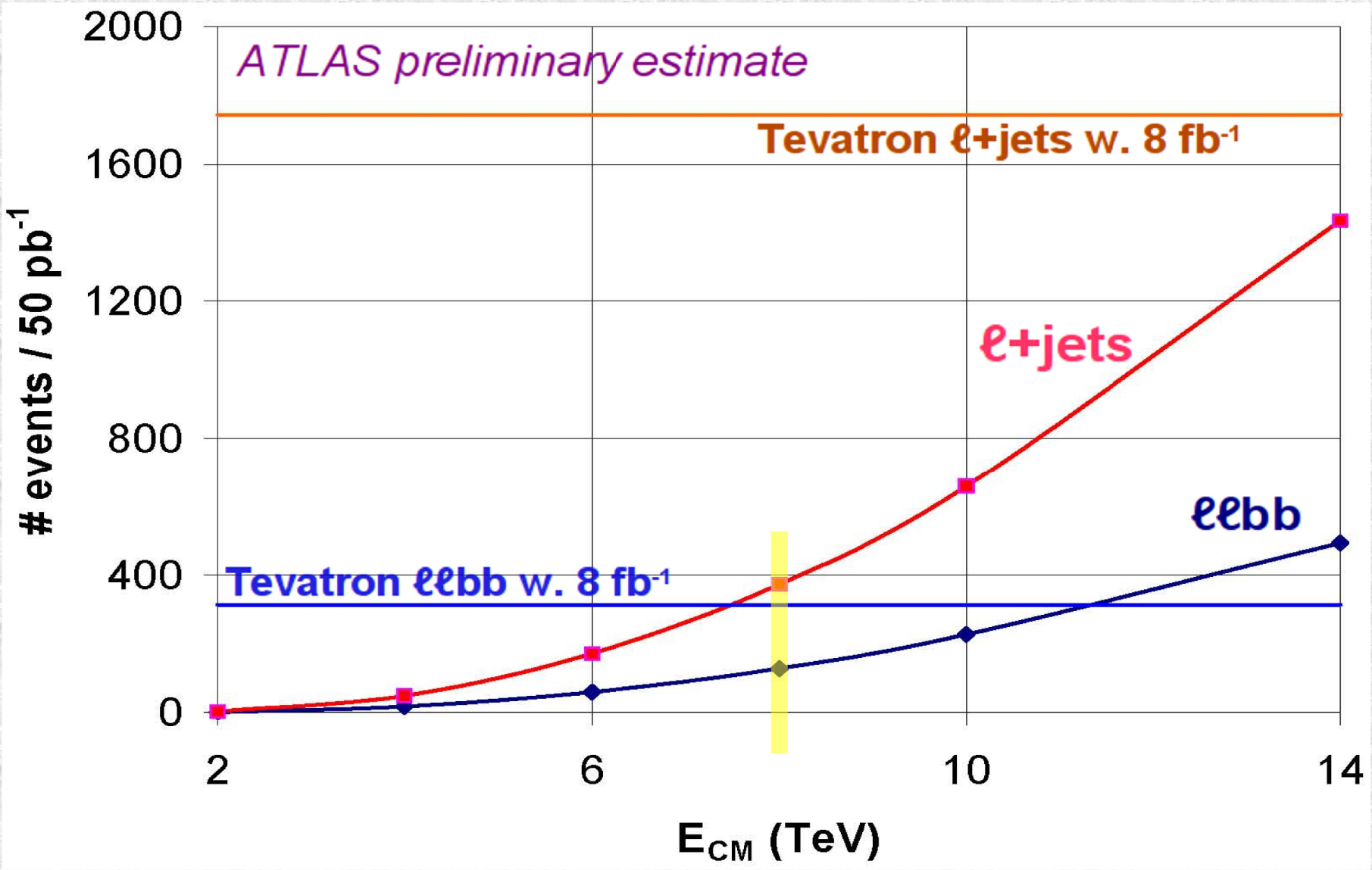
Hundreds of thousands from run

There are 10 times as many W's

Allows detailed Z+jets studies



Top Quark pairs

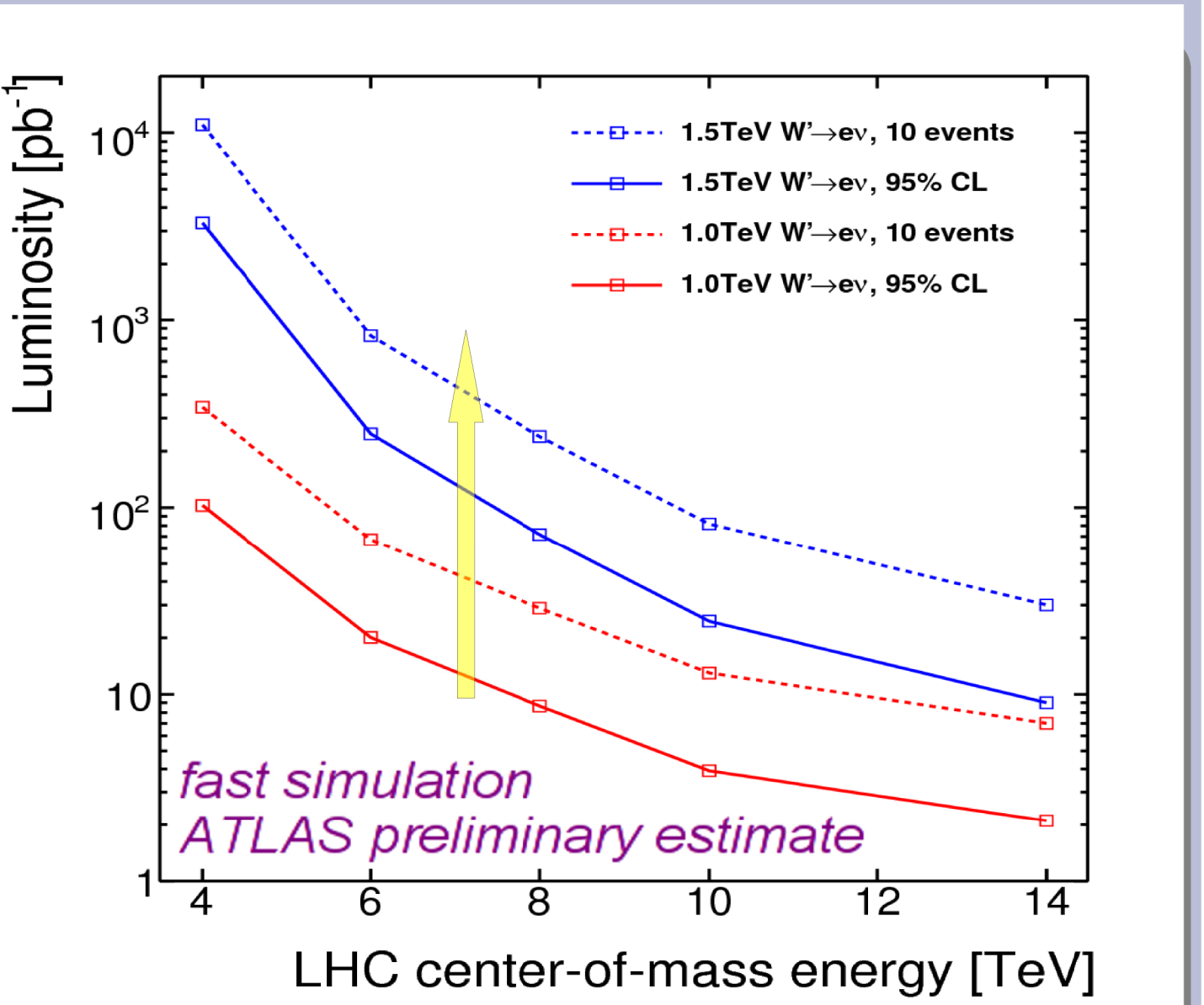


Top statistics

- 10pb^{-1} at 7TeV analyses select:
  - 30 lvblvb events?
  - 100 jjblvb events?
- These analyses have no b-tagging
  - Robust for early data; s/b acceptable
    - But b tag works already
    - Maybe we can relax other cuts??
- 'Discovery' of top for Summer 2009 will be hard
- 1fb^{-1} will give top samples 5 times TeVatron
  - With better s/b
  - LHC will start its role as a top factory

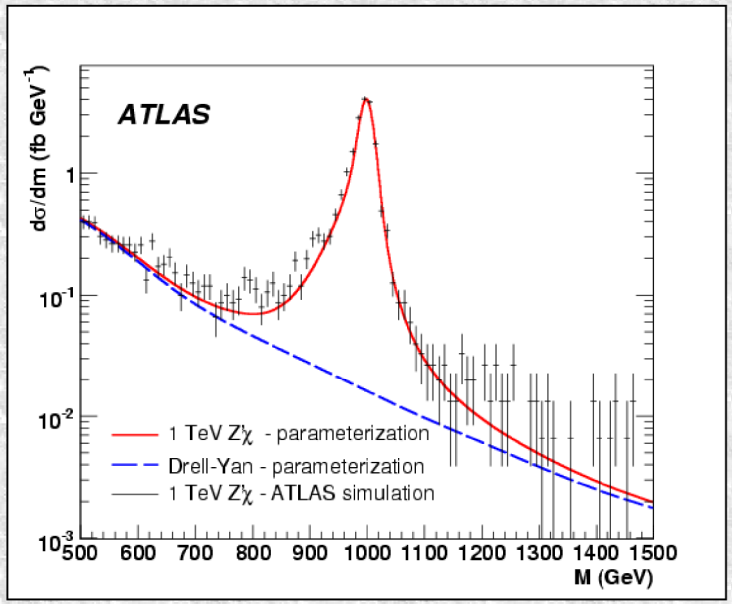
W' sensitivity in ev

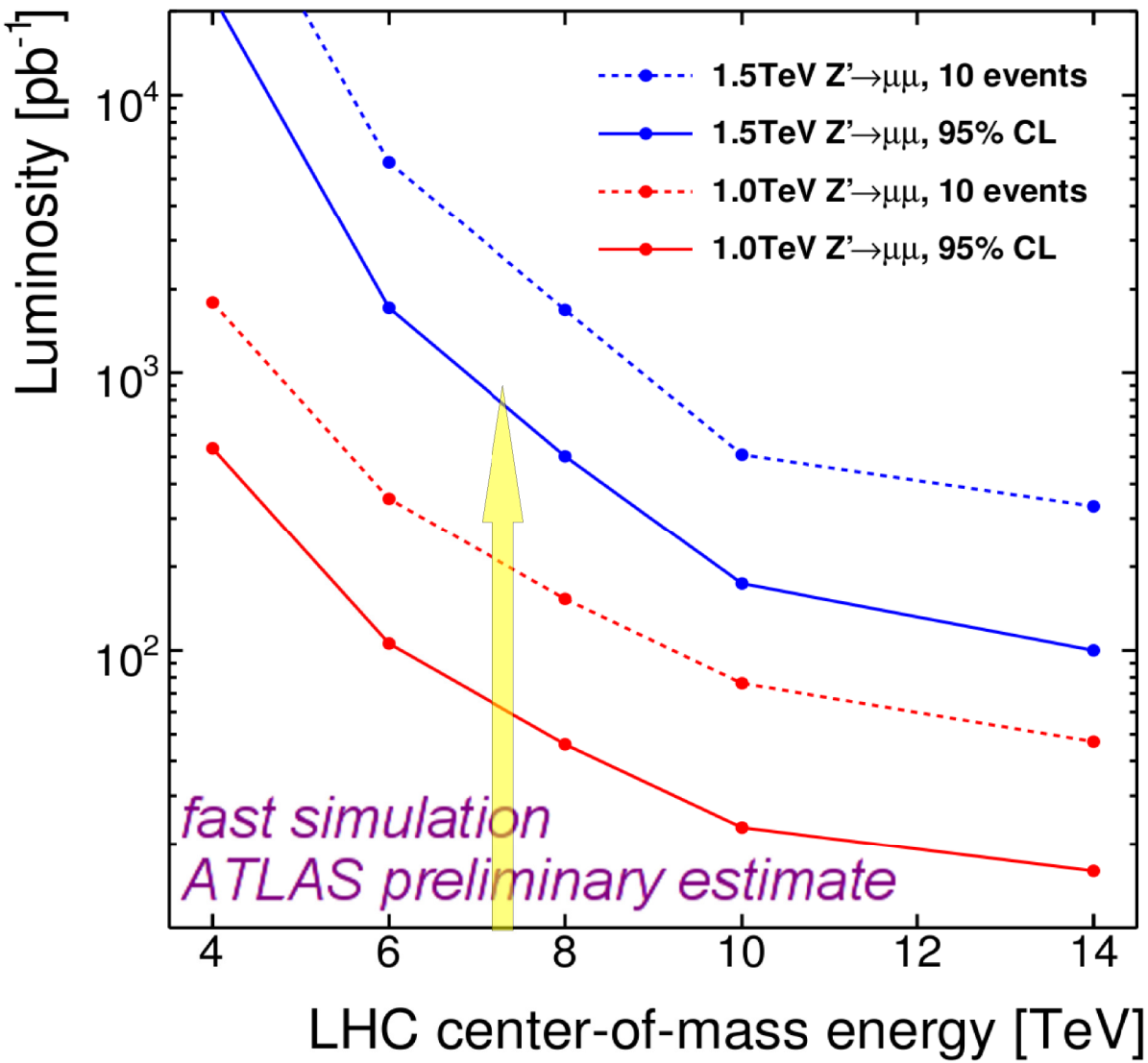
- Arrow shows $10pb^{-1}$ to $1fb^{-1}$
- Sensitivity approaching 1TeV by summer
  - systematics must be controlled
  - Also μν channel
- CDF 788GeV limit



Z' sensitivity in $\mu^-\mu^+$

Rarer decay mode than W
But sensitive to 1.5TeV from this run



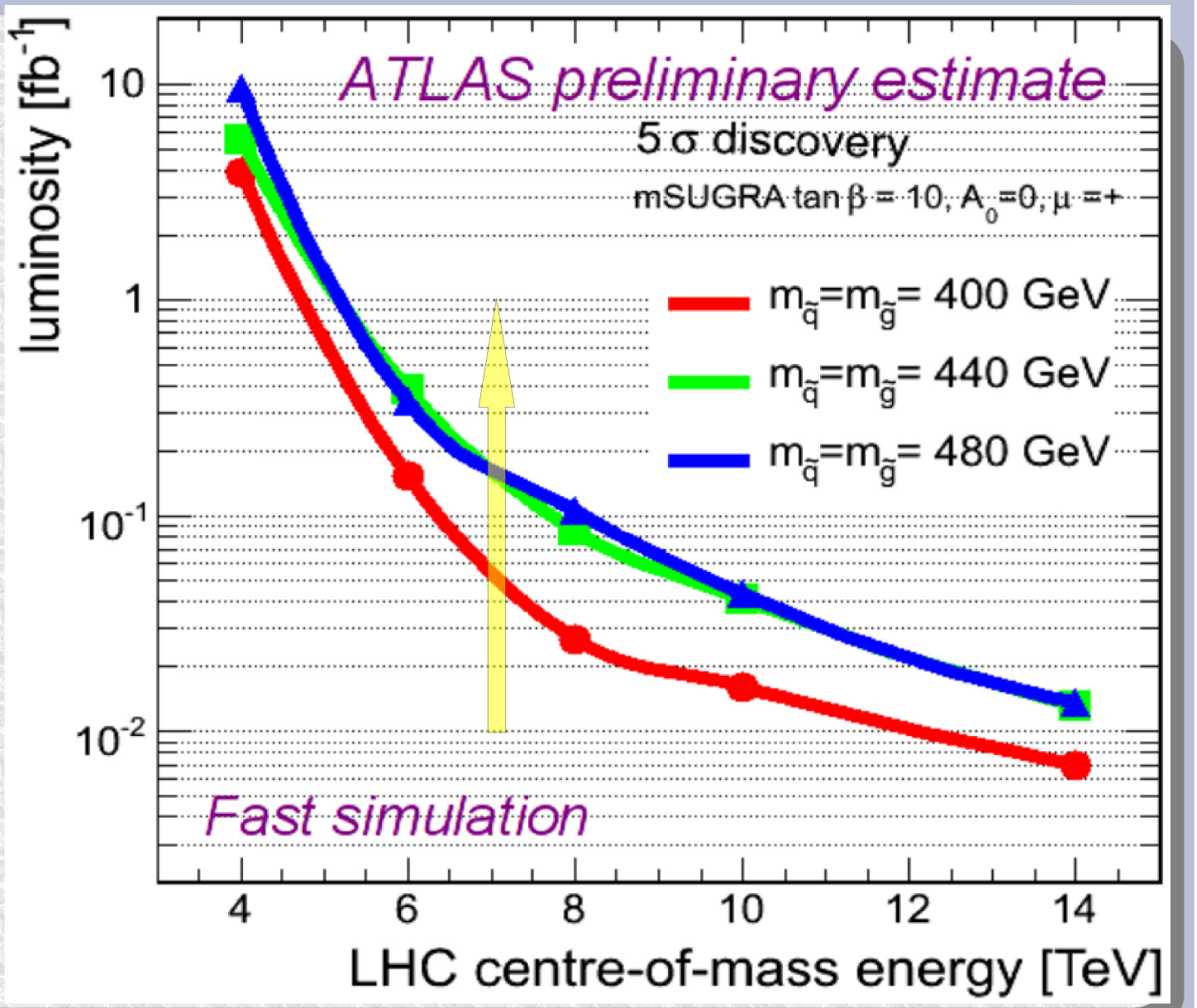


Supersymmetry

Pawel Bruckman will discuss this after lunch

D0 limits
- 308 gluino
- 380 squark

Overtaken by Christmas



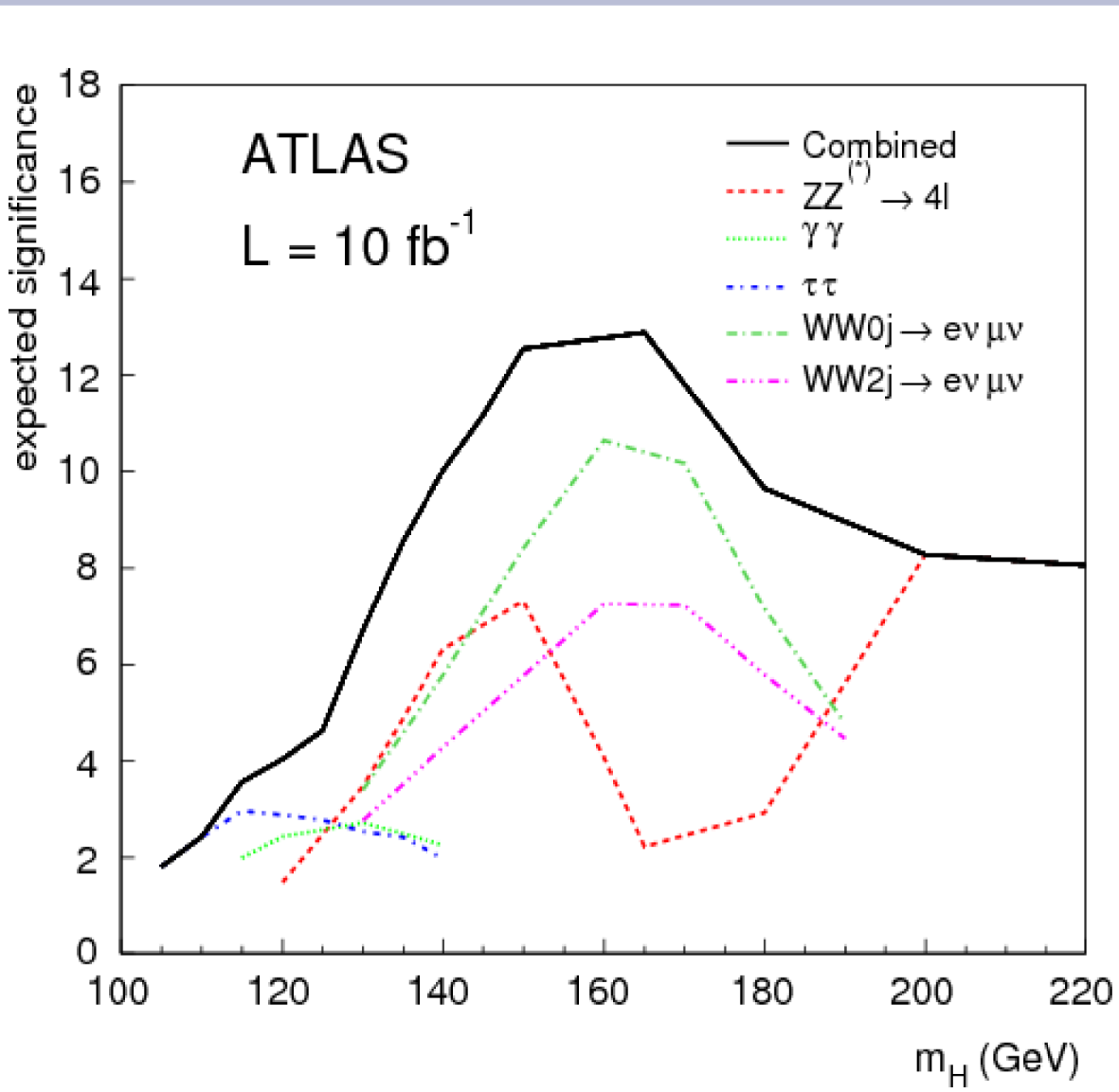
Higgs

Higgs combination at 14TeV

At full energy, $10fb^{-1}$ gives good discovery sensitivity
- Except below 130GeV

What can 7TeV do??

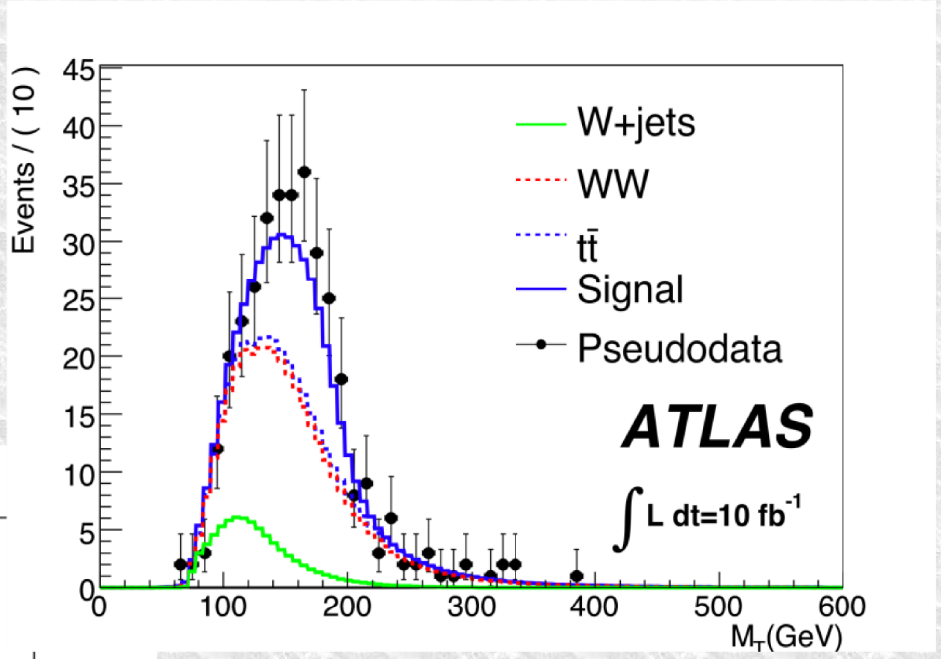
Nb: ZZ channels comparable to WW at 150 and 190GeV

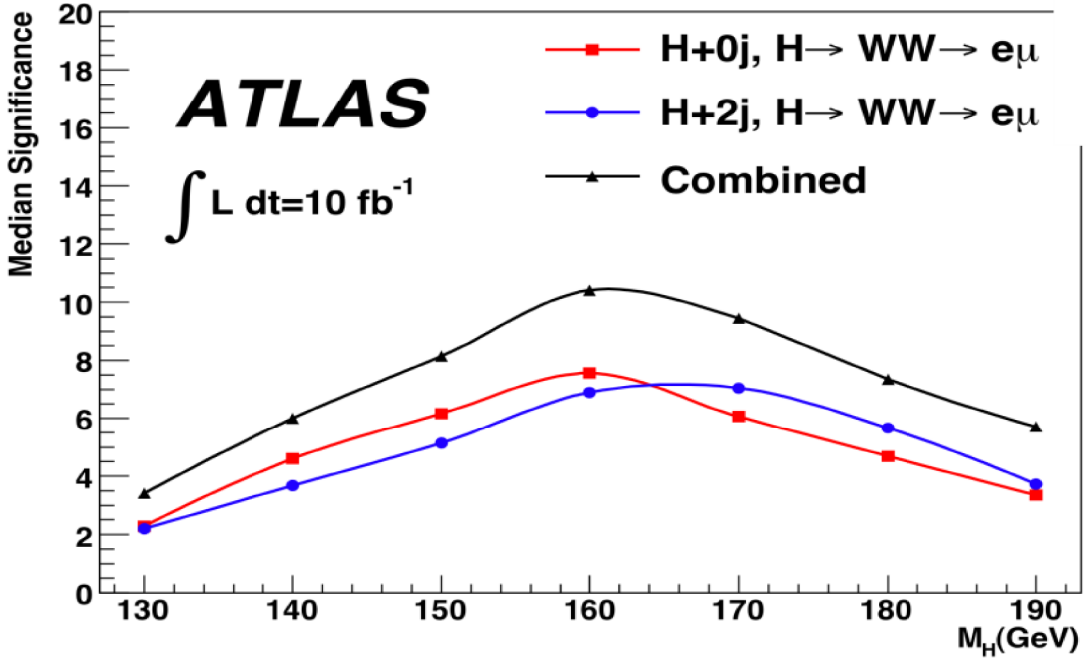


H to WW(*)→lvlv

2 ν; no mass peak
- Analysis needs good background model
- Taken from data

Signal rates large

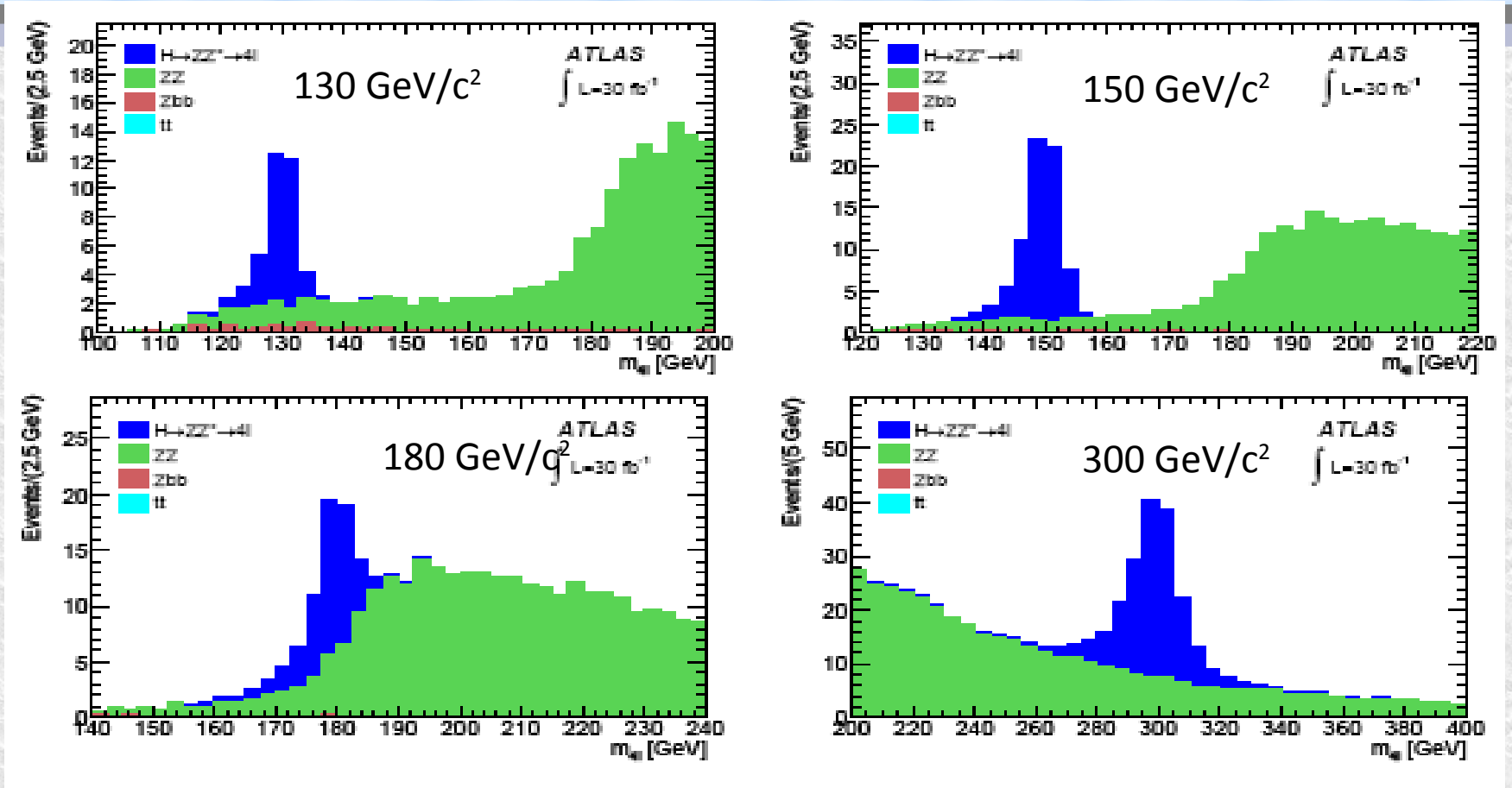




10σ for 160GeV using 10fb^{-1}

VBF and gluon fusion contribute

$H \rightarrow ZZ \rightarrow l^+l^-l^+l^-$



ZZ gives nice peak

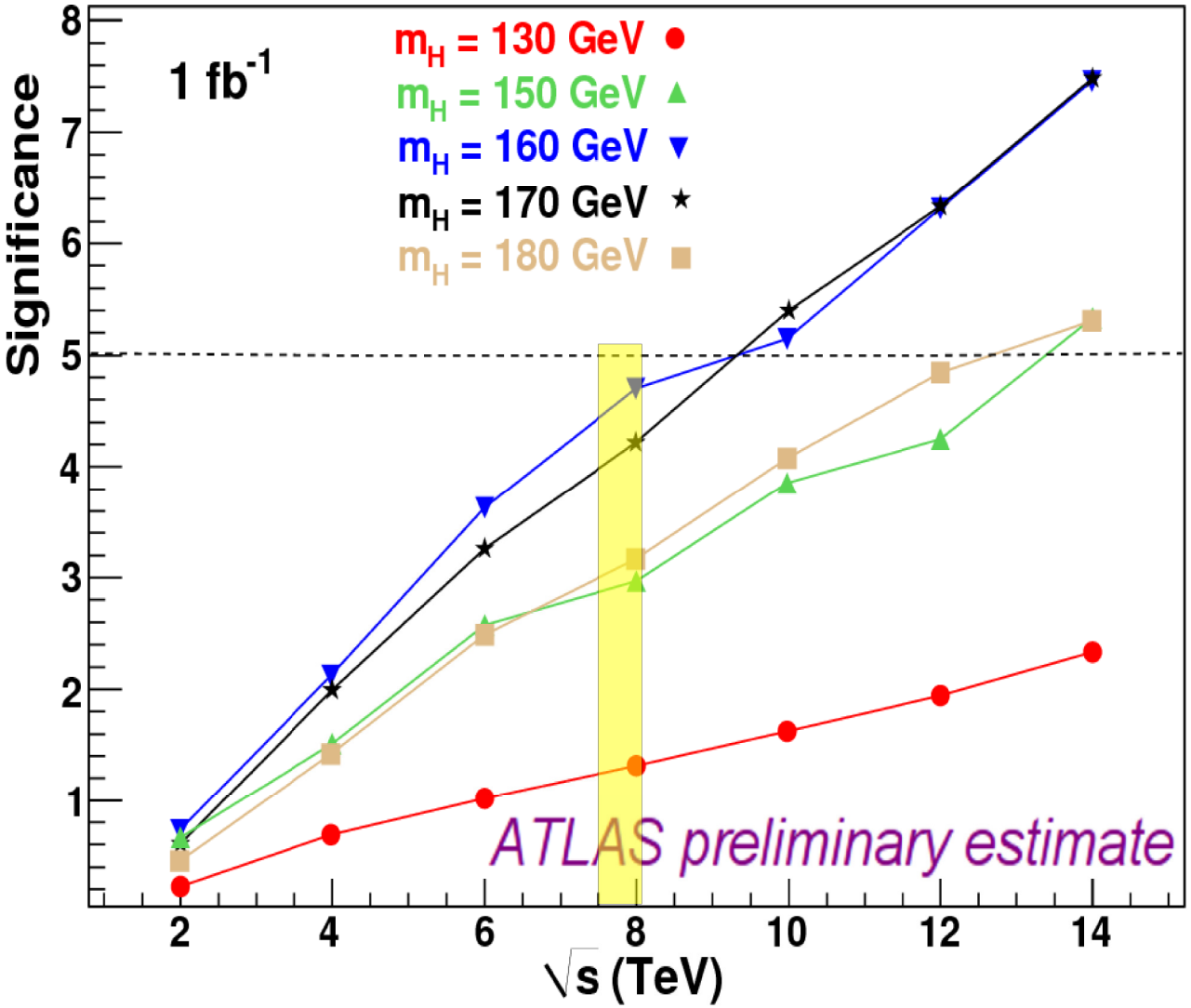
But rate is much lower

Best for 200-400GeV

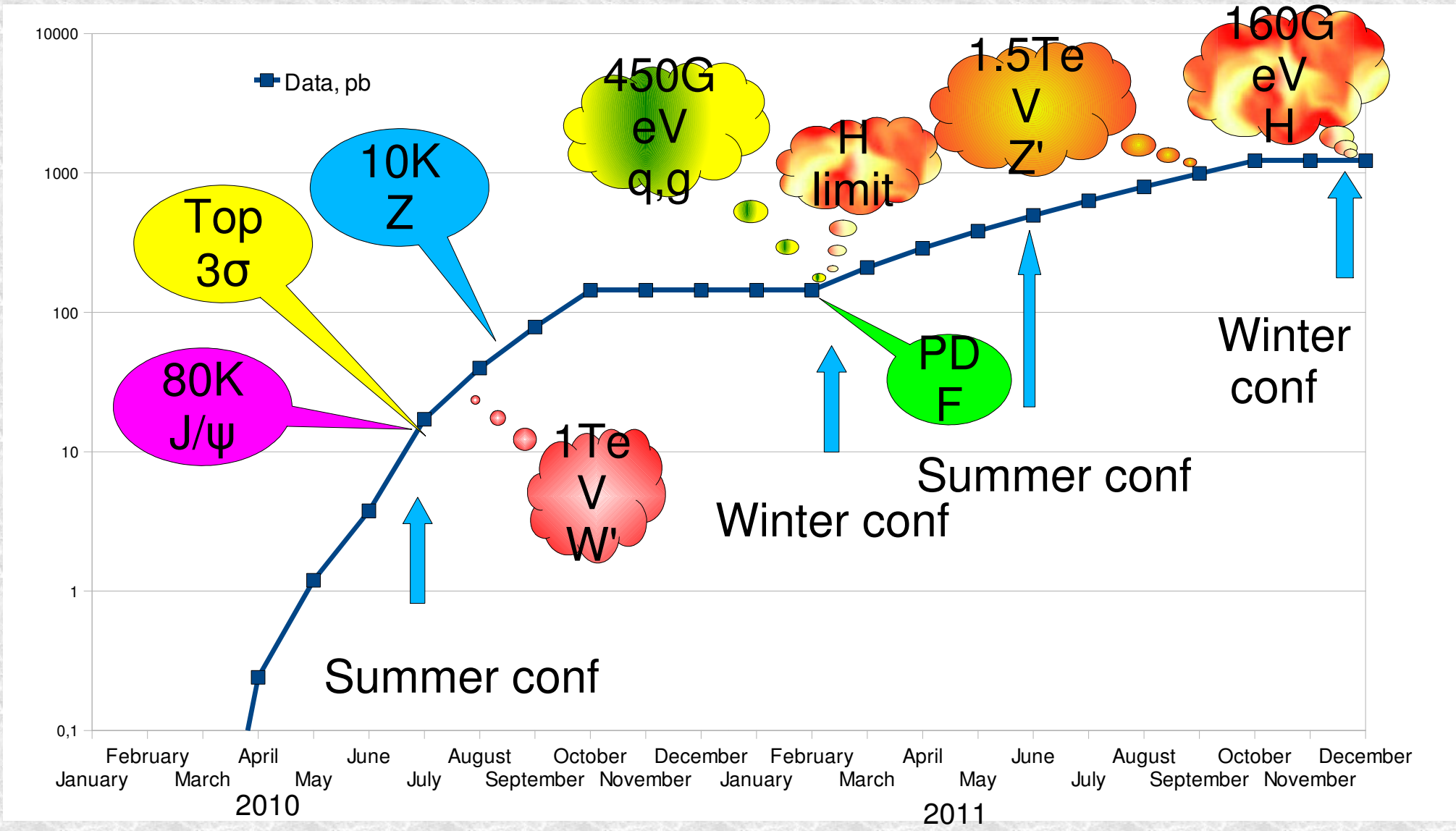
$H \rightarrow W^+W^-$ $1fb^{-1}$ v $\sqrt{s}$

Four sigma for most favoured mass range
- Depends on systematics

One of many Higgs channels
- Will boost 150/180 with ZZ



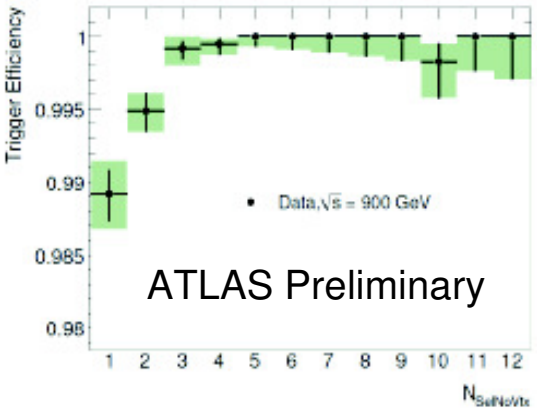
Gazing into the murk



The First Paper

Released 4pm, Thursday...

The Min Bias analysis in a nut shell



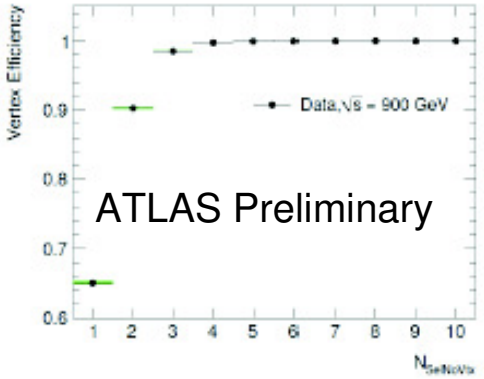
MBTS_1 trigger

efficiency determined from indep. trigger

Background determined from ‚unpaired bunches' ➔ 10^{-4} level

Vertex required (at least three tracks pT > 150 MeV)

Efficiency from data



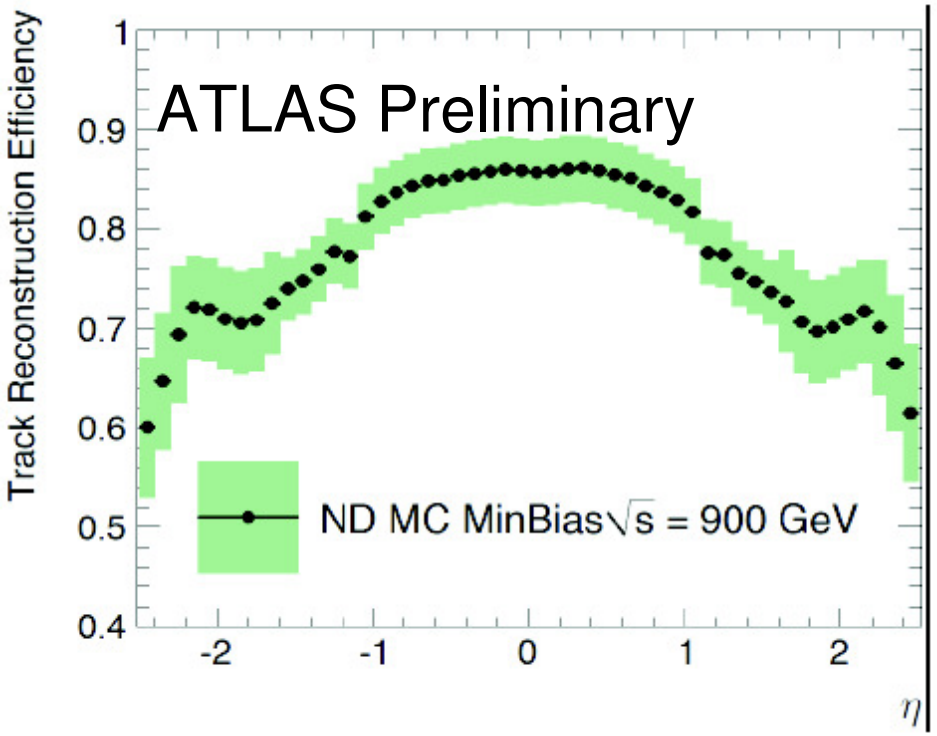
Selection requirement on tracks: d0, z0*sinθ, η < 2.5, pT >500 MeV

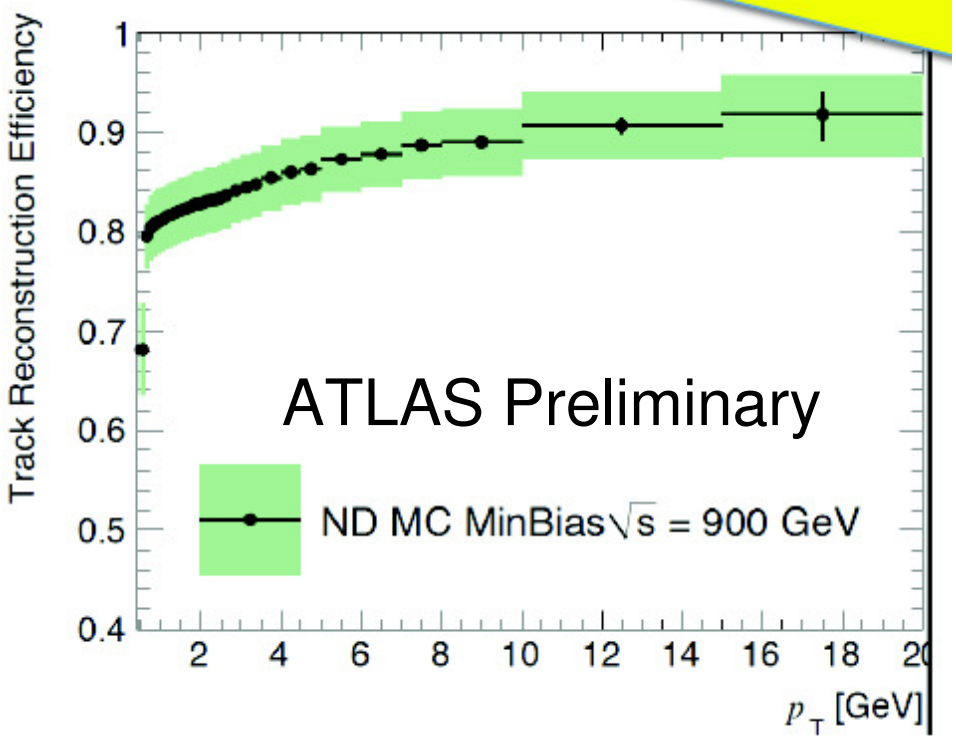
Efficiency determined from simulation with many X-checks in data

Selection requirement on events: data quality + at least 1 selected track

Corrected to ‚hadron level': primary particle inside phase space

Track reconstruction efficiency

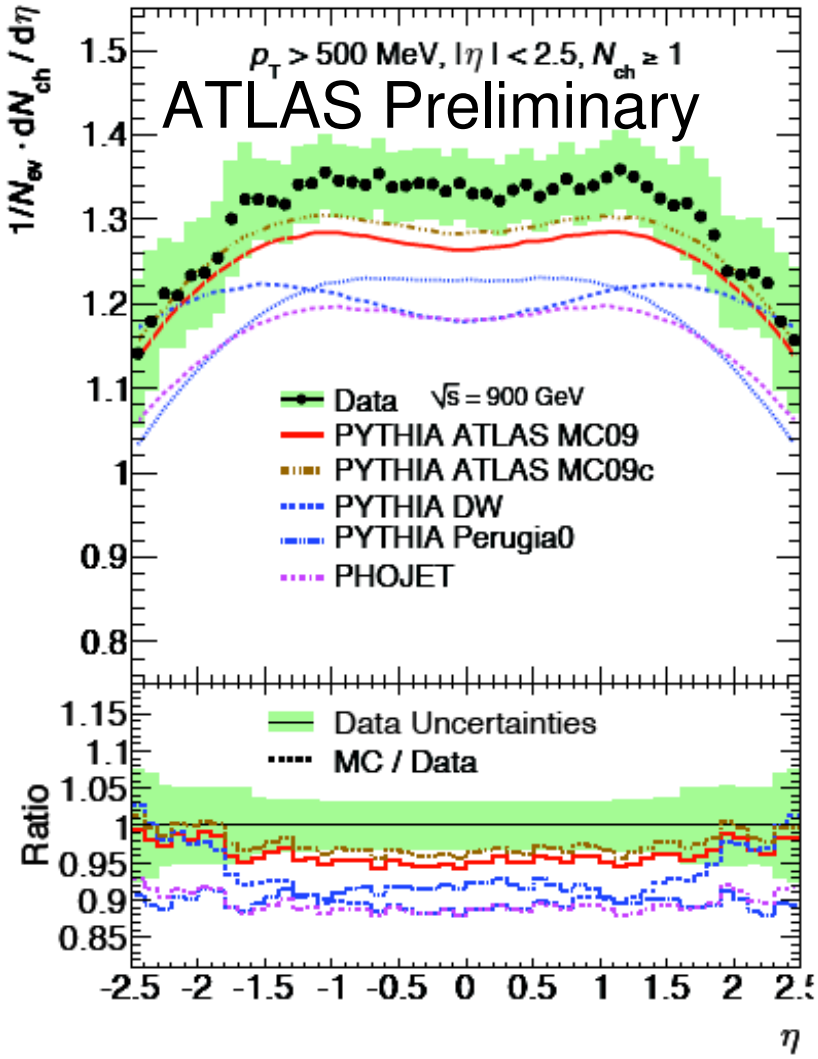


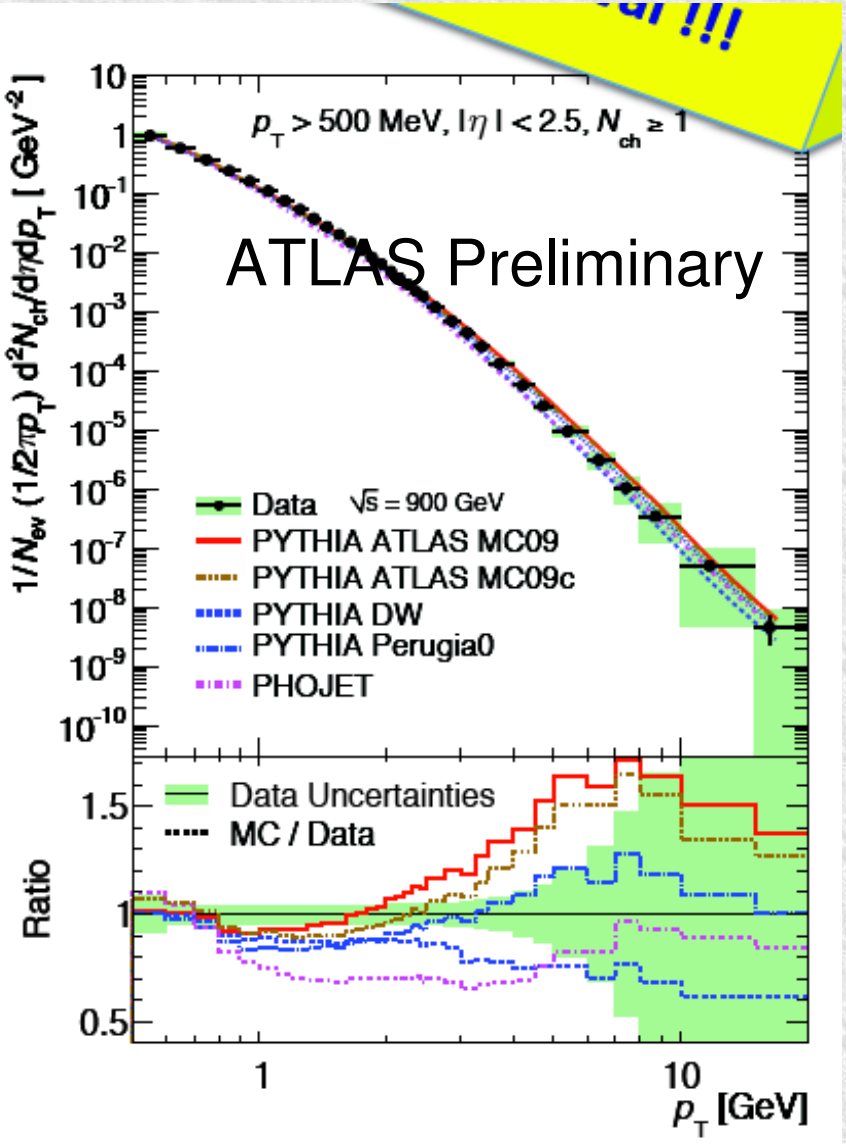


Tracking efficiency is vital for this paper

- Estimated from MC; MANY data comparisons
- 3% systematic

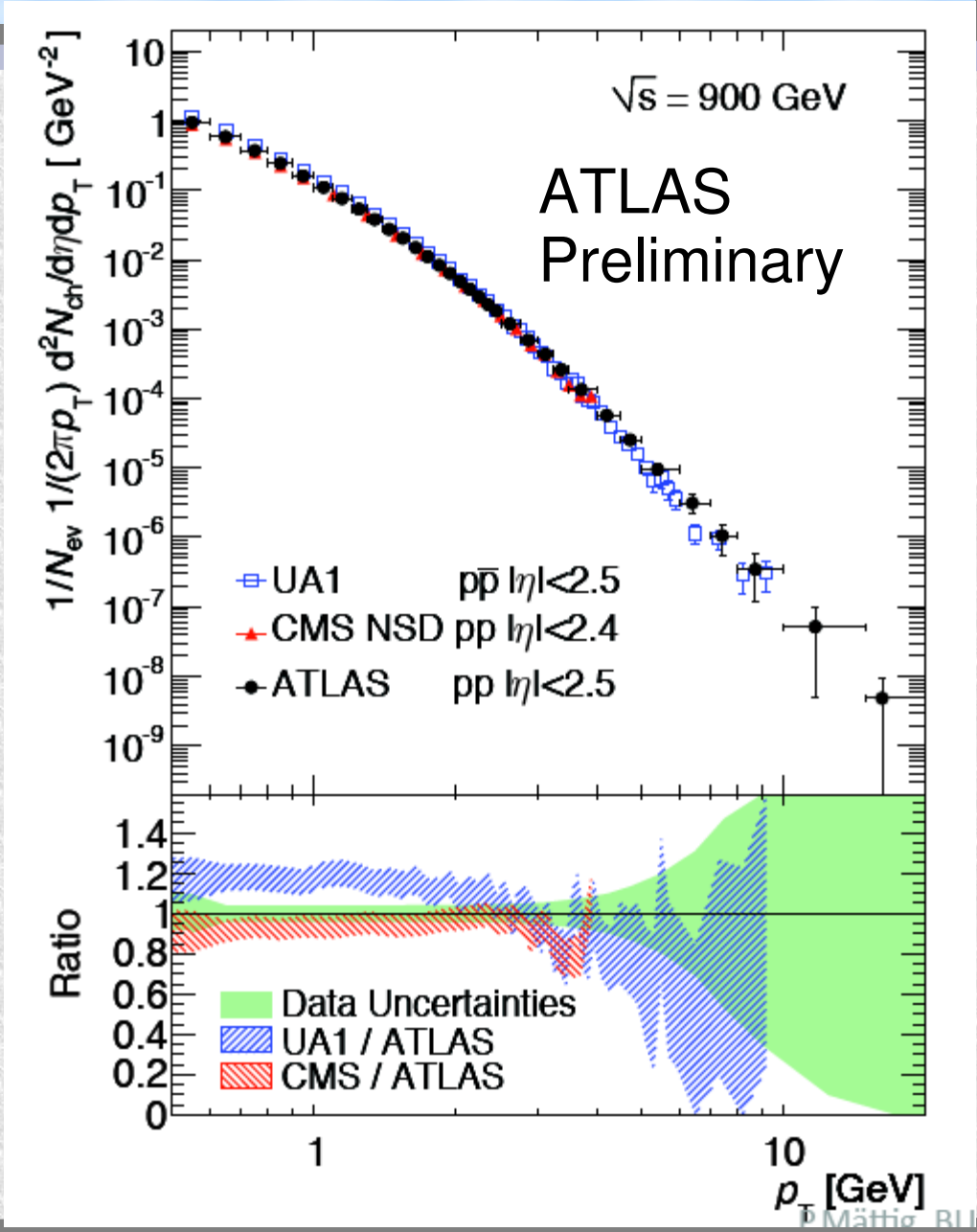
Preliminary Multiplicities





Comparison with UA1/CMS

- Very good agreement with CMS
  - ATLAS extends range
- UA1 has slightly higher rate
  - pp vs pp?
  - Systematics?
- Note uncertainties smaller than UA1 already!



Conclusions

ATLAS is working

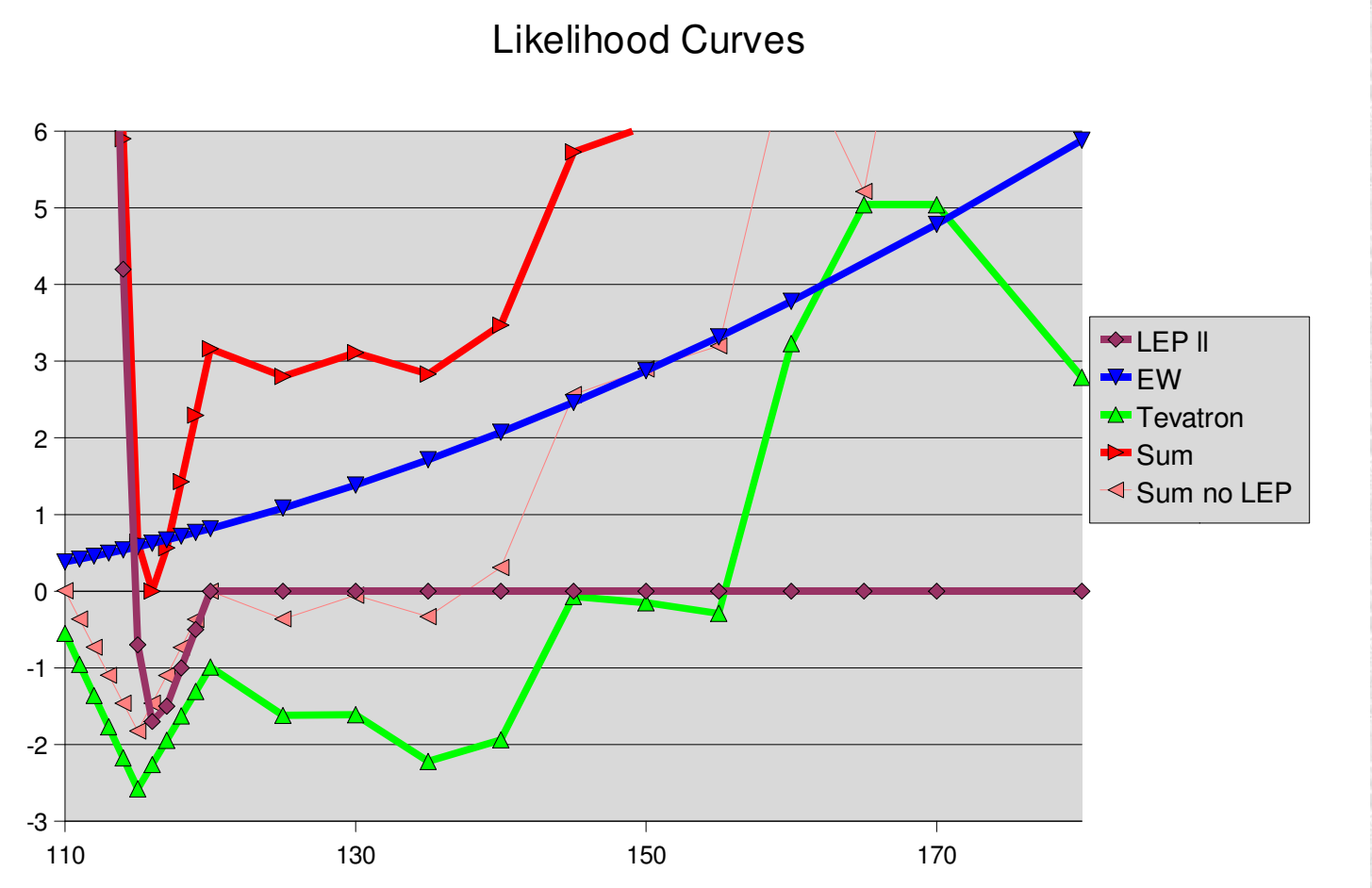
- Fantastic performance
- Agreement with simulation unprecedented
- Physics results already from 20μb

LHC is back

- 0.1-0.2fb^{-1} this year
- 1fb^{-1} expected from run

LHC poised to take over collider physics

Where is the Higgs?



All data point to a low-mass Higgs boson
<140; probably<120GeV