ATLAS эксперимент

Научная сессия ученого совета ОФВЭ ПИЯФ

24-27 декабря 2012 года

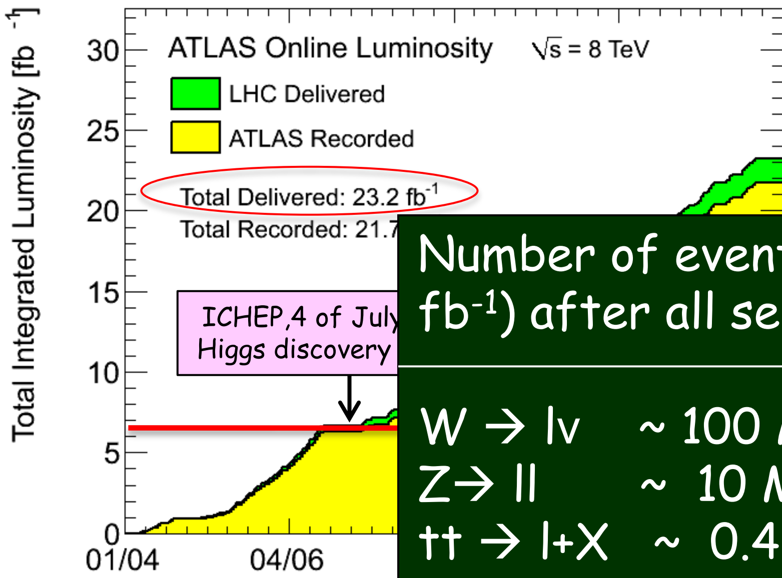
Олег Федин

Содержание

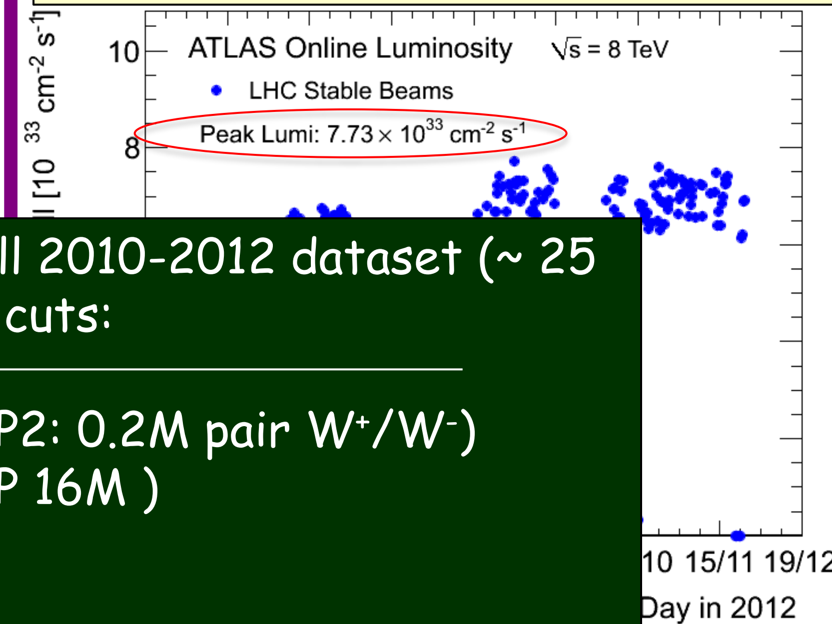
- Status of the ATLAS detector.
- Performance of the ATLAS detector:
  – to highlight the PNPI's participation for the further improvement and control of the ATLAS performance.
- PNPI participation in ATLAS:
  – physics program;
  – detector development;
  – TDAQ/DCS.
- PNPI plans for ATLAS upgrade.

p-p integrated luminosity vs time

Total integrated luminosity in 2012



Peak luminosity seen by ATLAS: ~ 7.73 x10^{33} cm^{-2} s^{-1}



Number of events in full 2010-2012 dataset (~ 25 fb^{-1}) after all selection cuts:

W → lν ~ 100 M (LEP2: 0.2M pair W^+/W^-)

Z→ ll ~ 10 M (LEP 16M)

tt → l+X ~ 0.4 M

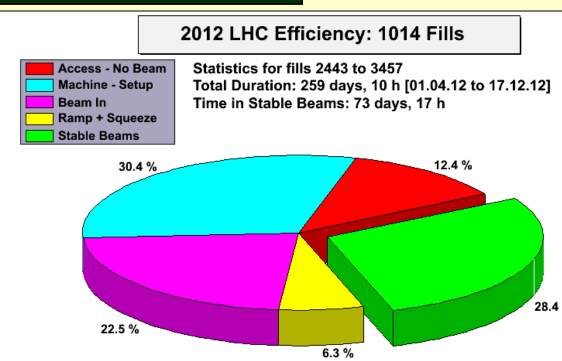
SM Higgs ~ 400

[~1 H→ γγ (~1 H→ 4l) produced every 50' (14h) at 7x 10^{33}]

days of LHC

LHC records in 2012 (in brackets results for 2011)

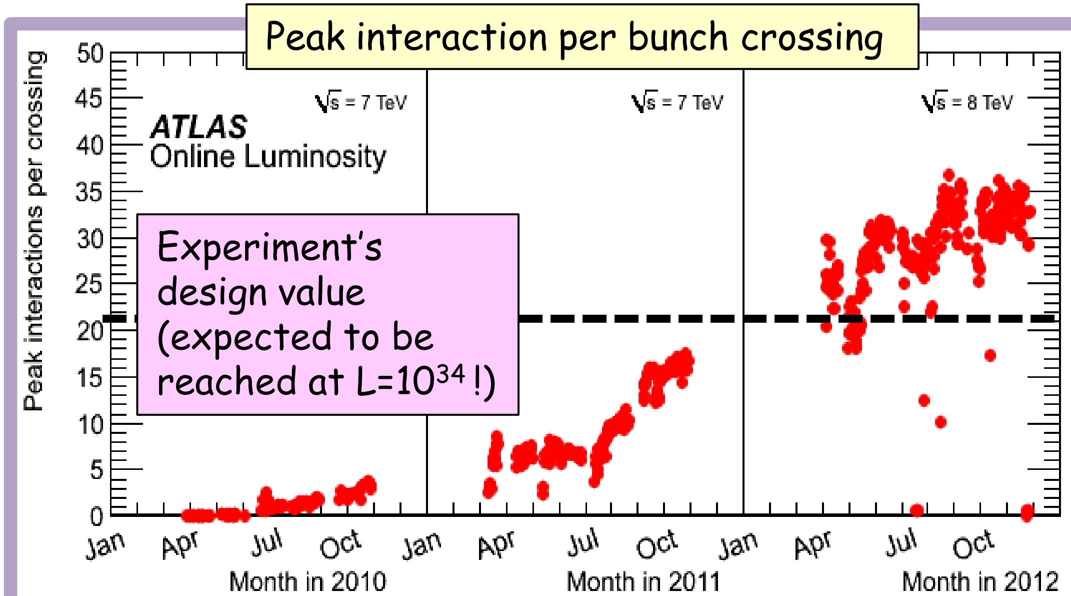
- Maximum luminosity delivered in one fill 237.32 pb^{-1} (122.44)
- Maximum luminosity delivered in one day 286.33 pb^{-1} (135.45)
- Maximum colliding bunches (design 2808) 1380 (1854)
- Maximum bunch population (design 1.15 10^{11}) ~2.0 10^{11} (1. 10^{11})
- Bunch spacing (design 25 ns) 50 ns
- Maximum peak events per bunch crossing 71.55 (33.96)
- Longest time in stable beam foe one fill 22.8 hours (26)

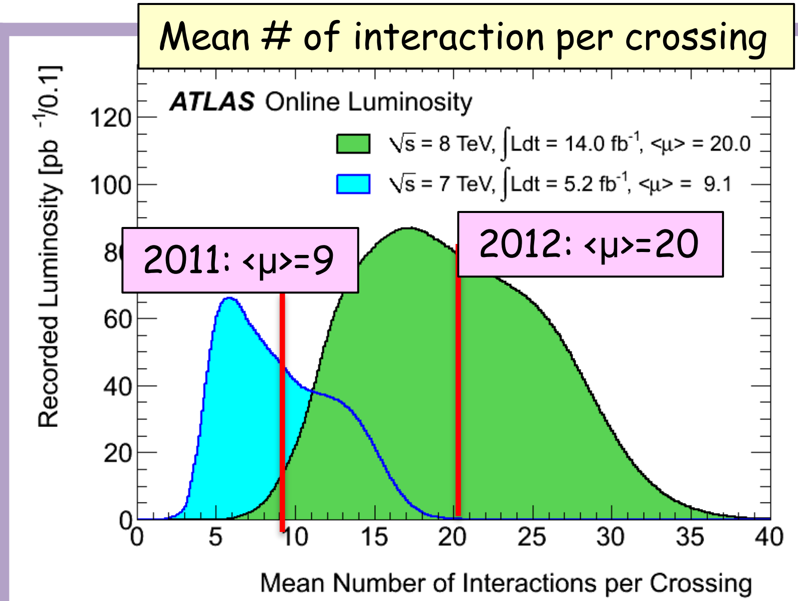


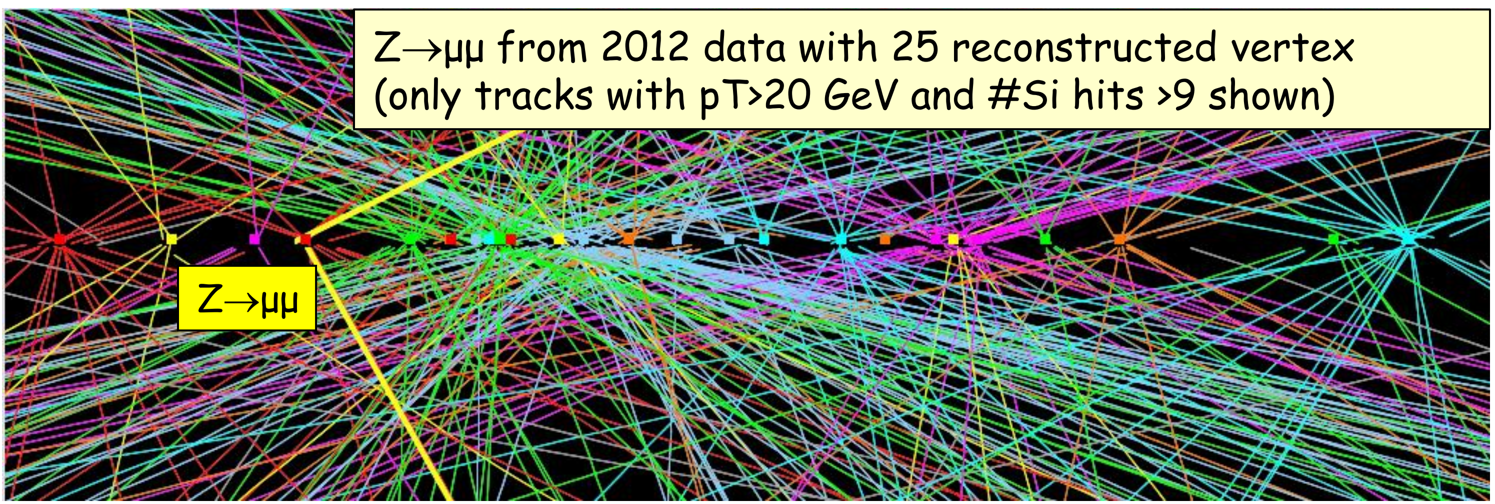
Multiple pp-collisions per bunch crossing

The BIG challenge in 2012: PILE-UP

$$\mu = L_{bunch} \times \sigma_{inel} / f_r$$

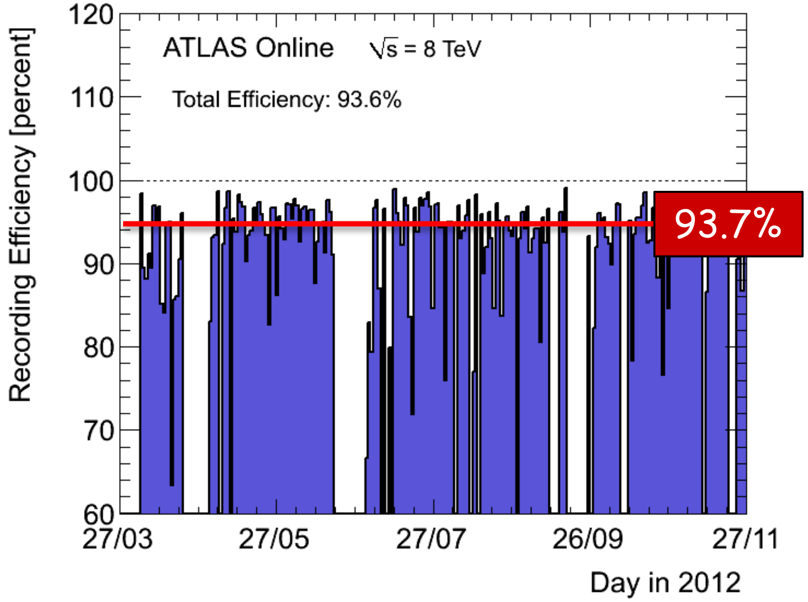






Detectors operation

Data-taking efficiency = (recorded lumi)/(delivered lumi): 93.7% (2011 -93.5%)



Fraction of non-operational detector channels: (depends on the sub-detector) few permil to 3.5%

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	98.3%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	100%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	96.0%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	98.2%

TRT 97.5%

Good-quality data fraction, used for analysis : (depends on the analysis) : 90-96%

ATLAS p-p run: April-Sept. 2012

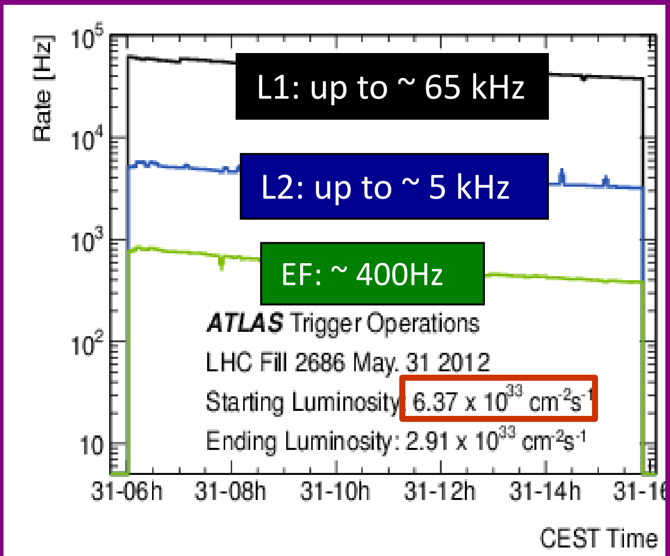
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.3	99.5	97.0	99.6	99.9	99.8	99.9	99.9	99.7	99.2

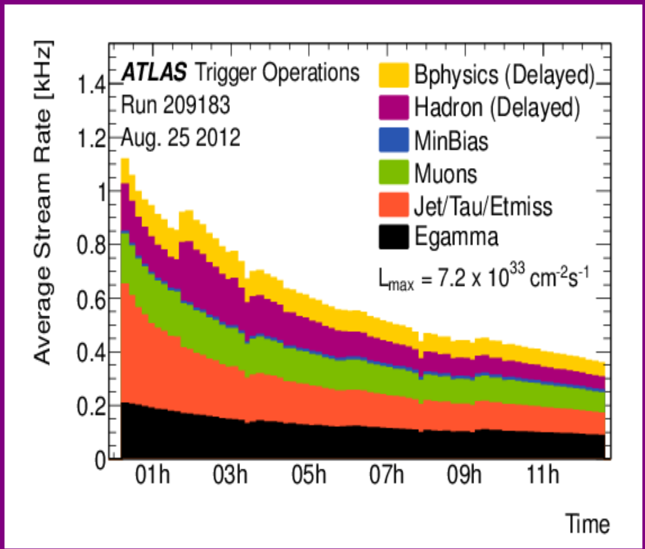
All good for physics: 93.7%

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and September 17th (in %) – corresponding to 14.0 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

Trigger operation

Managed to keep inclusive un-prescaled lepton thresholds within ~ 5 GeV over last two years in spite of the factor ~70 peak luminosity increase





Note > 550 items in trigger menu

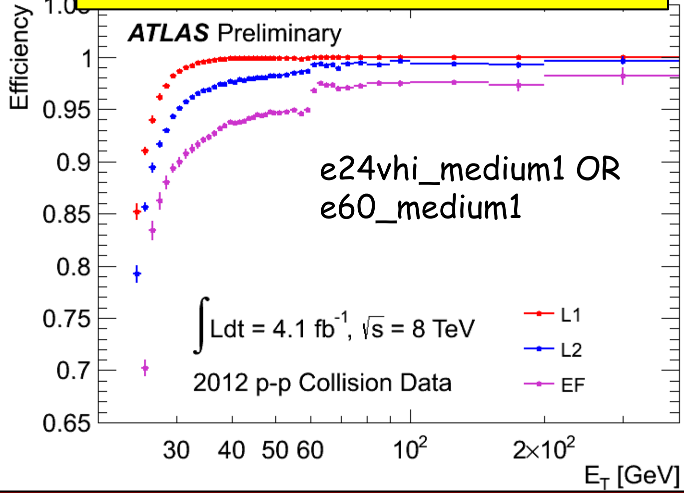
Lowest un-prescaled thresholds
(examples)

Item	p_T threshold (GeV)	Rate (Hz) at 5×10^{33}
Incl. e	25	70
Incl. μ	24	45
ee	12	8
μμ	13	5
ττ	29,20	12
γγ	35,25	10
E_T^{miss}	80	17

- Optimization of selections (e.g. object isolation) to maintain low un-prescaled thresholds (e.g. for inclusive leptons) in spite of x2 higher luminosity and pile-up than in 2011
- Pile-up robust algorithms developed (~flat performance vs pile-up, minimize CPU usage, ...)
- Results from 2012 operation show trigger is coping very well (in terms of rates, efficiencies, robustness, ..) with harsh conditions while meeting physics requirements

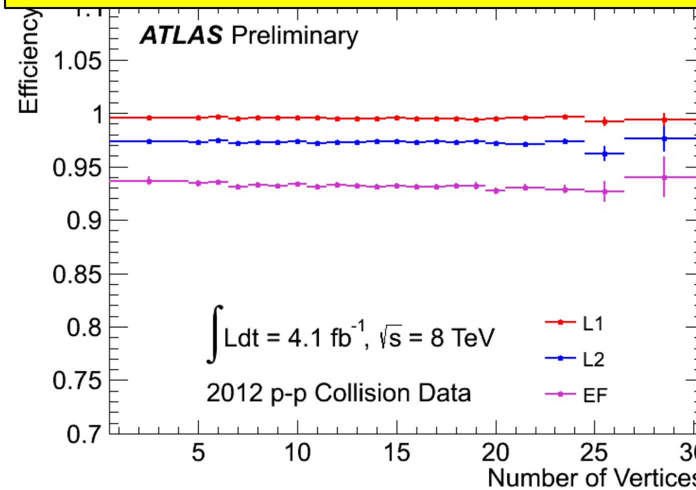
Electrons

Efficiency of inclusive electron trigger as a function of E_T

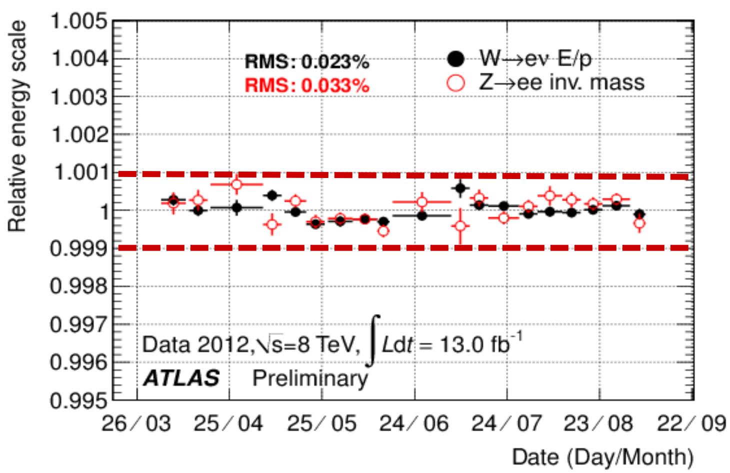


From Z→ ee events

Efficiency of inclusive electron trigger (E_T thresholds as low as 24) as a function of "pile-up"



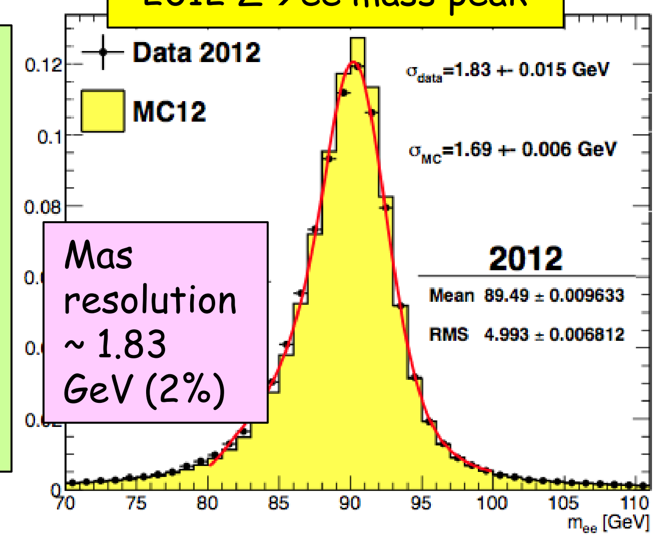
Stability of EM calorimeter response vs time (and pile-up) during full 2012 run better than 0.1%



Present understanding of calorimeter E response (from Z, J/ψ → ee, W→ eν data and MC):

- E-scale at m_Z known to ~ 0.3%
- Linearity better than 1% (few-100 GeV)
- "Uniformity" (constant term of resolution): ~ 1% (2.5% for 1.37<|η|<1.8)

2012 Z→ee mass peak



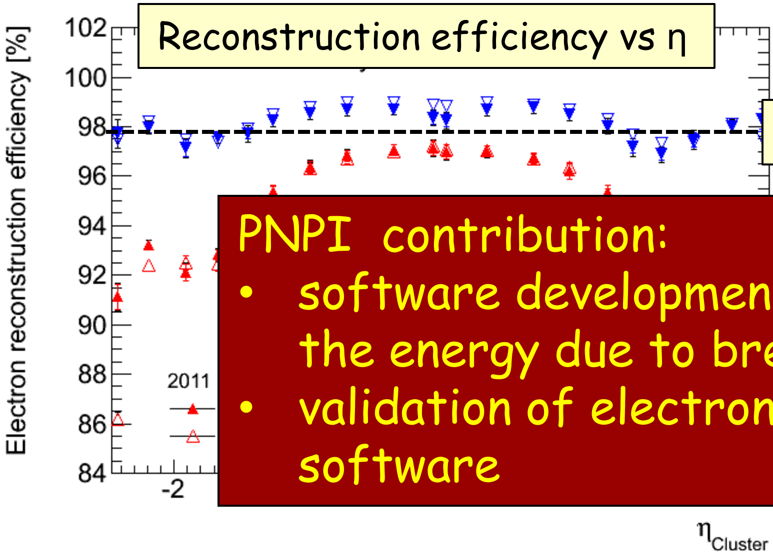
Mas resolution ~ 1.83 GeV (2%)

Electrons

High efficiency for low-p_T electrons (affected by material) crucial for H→ 4e, 2μ2e

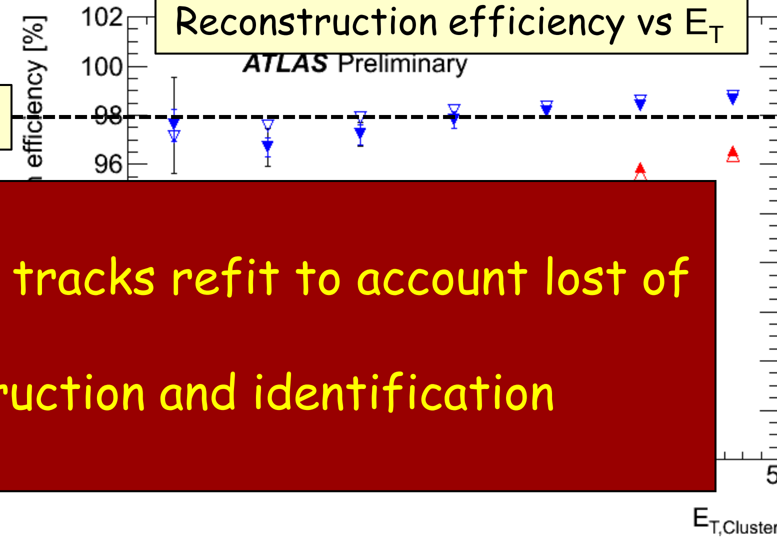
Improved track reconstruction and fitting to recover $e^{\pm}$ undergoing hard Brem→ achieved ~ 98% reconstruction efficiency, flatter vs η and E_T

Reconstruction efficiency vs η



<ε>~98%

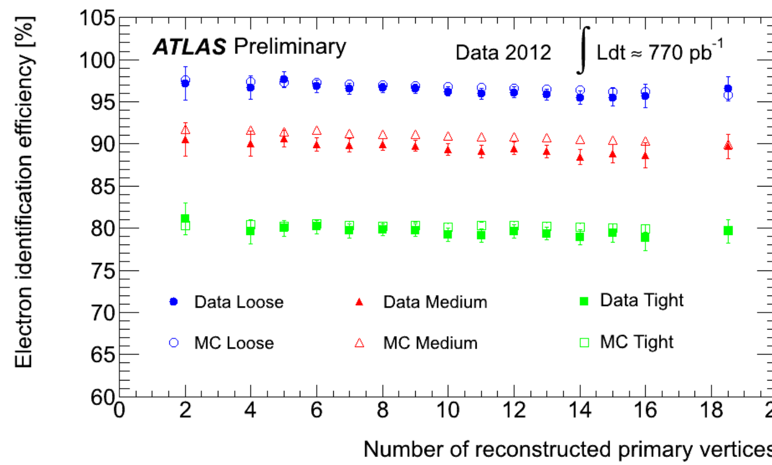
Reconstruction efficiency vs E_T



PNPI contribution:

- software development for the tracks refit to account lost of the energy due to brem
- validation of electron reconstruction and identification software

Re-optimized $e^{\pm}$ identification using pile-up robust variables (e.g. Transition Radiation, calorimeter strips) → achieved ~ 95% identification efficiency, ~ flat vs pile-up; higher rejections of fakes

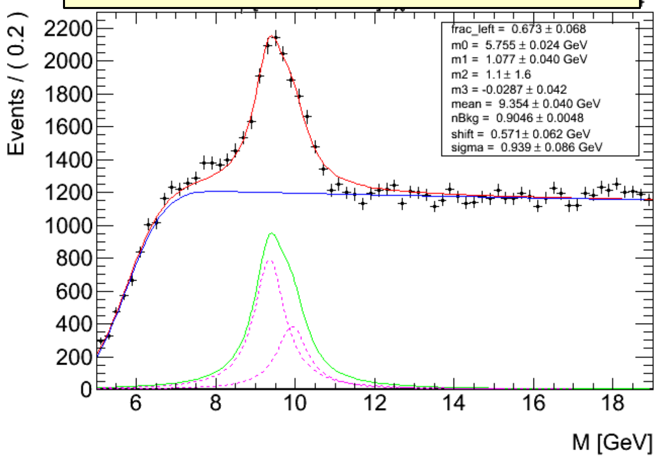


Results are from Z→ ee data and MC tag-and-probe

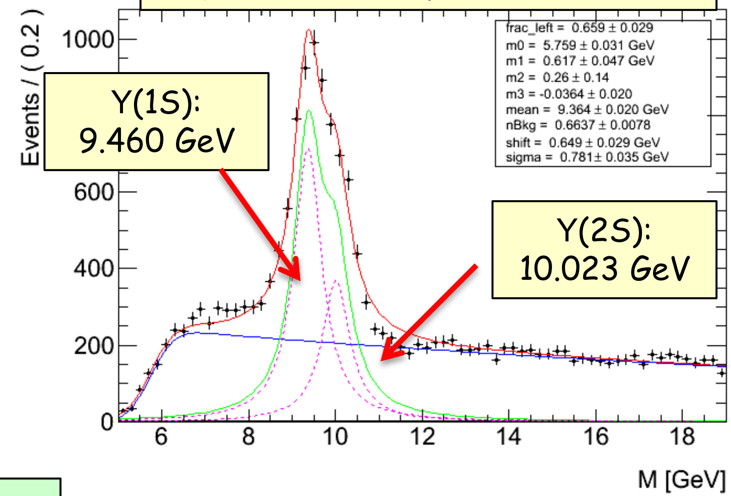
Electrons

PNPI contribution: A measurement of the electron identification efficiency using $\Upsilon \to e^+e^-$ decays by tag&probe method.
Work is supported by RFBR grant in 2012-2013

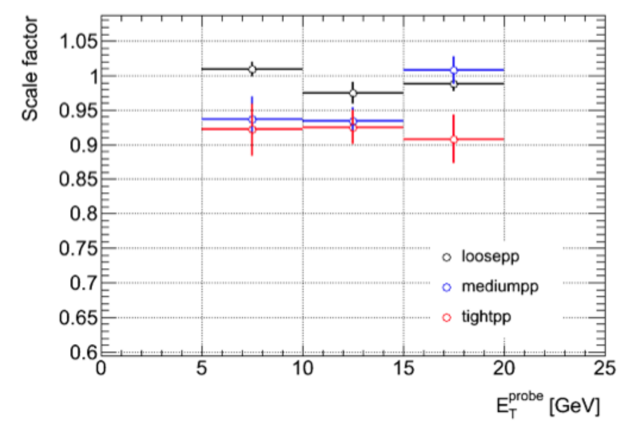
2 electron invariant mass (no ID requirements for probe electrons)



2 electron invariant mass (loose ID requirements for probe electrons)

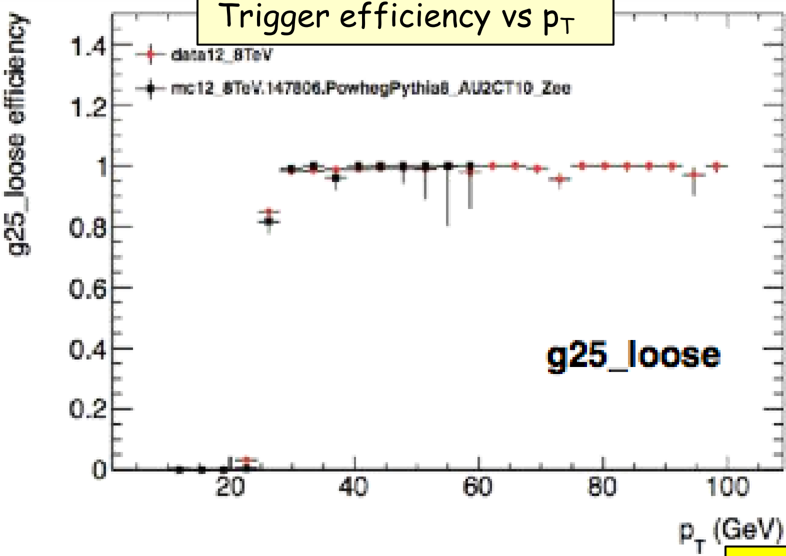


- Special trigger was developed to register decays of the $\Upsilon \to e^+e^-$: 2 legs L1 EM clusters, one high-pT (E_T>16 GeV), one at low pT (E_T>6 GeV), tight ID for high pT cluster and no requirement for track matched to low pT cluster, invariant mass of two electrons between 6 and 20 GeV.
- For the tag electrons applied tight ID selection.
- Efficiency of probe electrons measured in the data and MC.
- Scale Factors defined as $\varepsilon_{date}/\varepsilon_{MC}$ and used to correct MC prediction



Photon

Trigger efficiency vs p_T

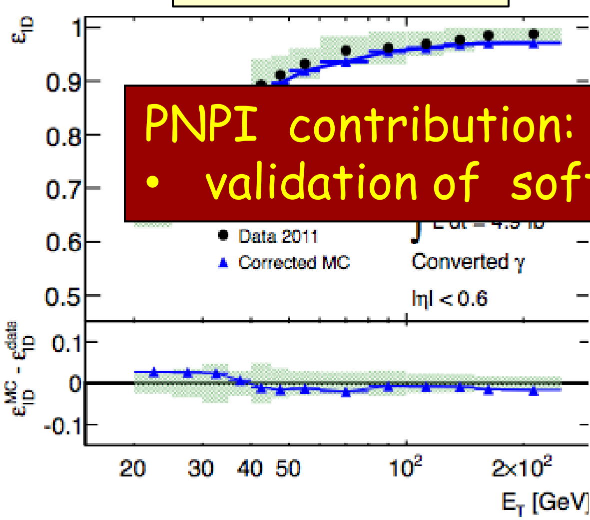


2012 unprescaled photon triggers

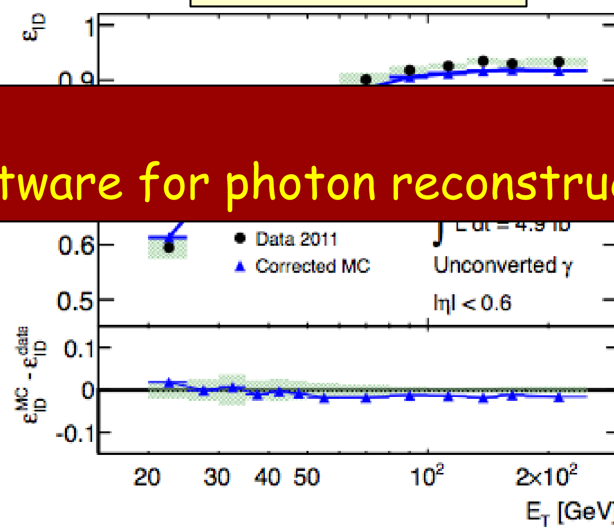
Trigger	Physics use	Rate (Hz) at $7x10^{33}$
1γ: E_T>120 GeV, ID-loose	Multi	12
2γ:ET>35(25) GeV, ID loose	Higgs	14
2γ: E_T>20 GeV, ID-medium	SM	5
3γ:ET>15 GeV, ID loose	SM tri-booson	1

From Z→ eeγ events

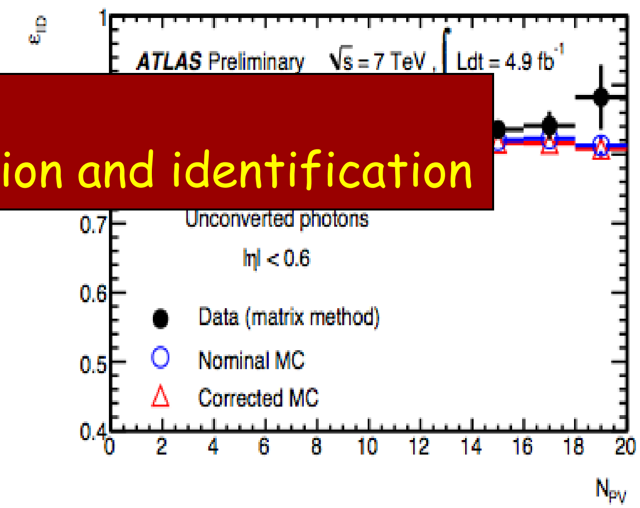
ID efficiency vs E_T
Converted γ



ID efficiency vs E_T
Unconverted γ



ID efficiency vs "pileup"
Unconverted γ



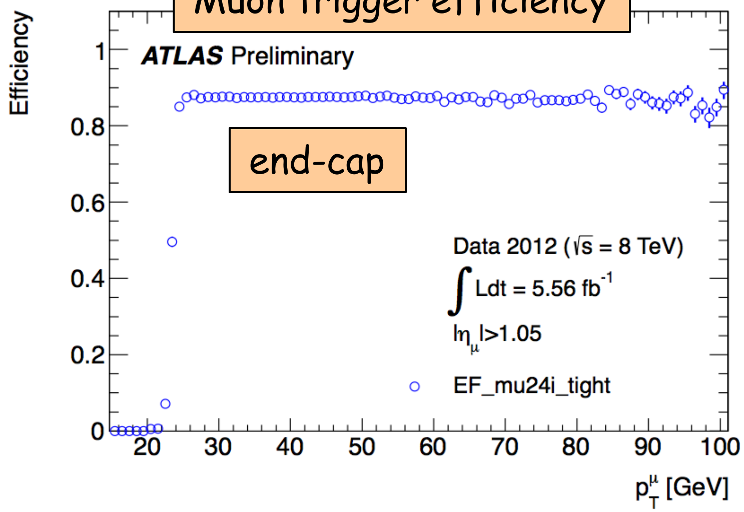
PNPI contribution:

- validation of software for photon reconstruction and identification

Muons

Muon trigger efficiency

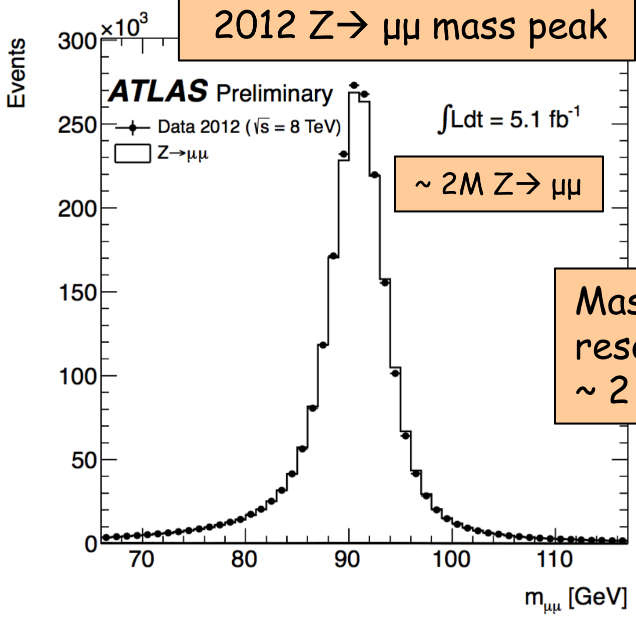
end-cap



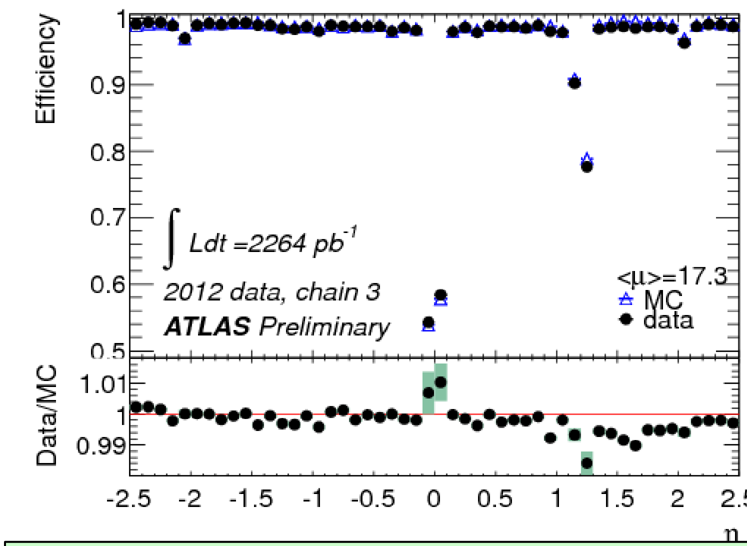
2012 Z→ μμ mass peak

~ 2M Z→ μμ

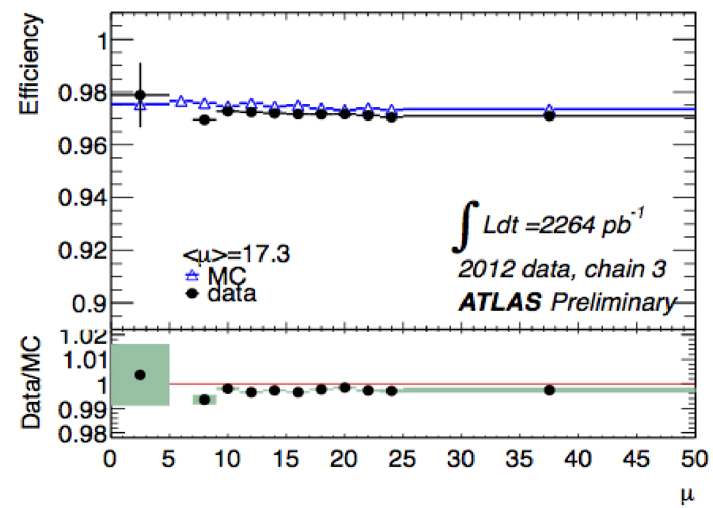
Mass resolution ~ 2 GeV



Reconstruction efficiency ~ 97%, ~ flat down to p_T ~ 6 GeV and over |η|~2.7



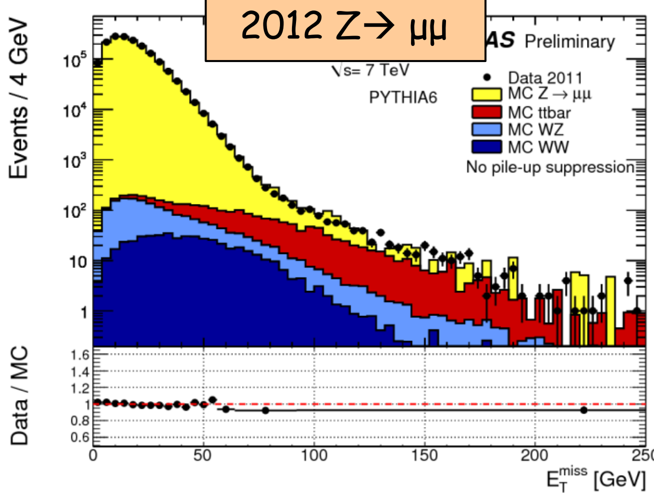
Reconstruction efficiency stable to pile-up



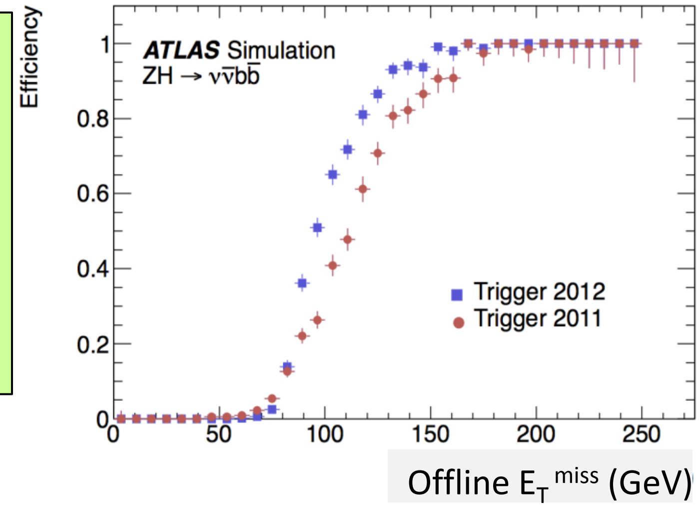
Missing E_T

Understanding of E_t^{miss} (most sensitive to pile-up) is crucial for $H \to WW^{(*)} \to l\nu l\nu$, $W/ZH \to W/Zbb$, $H \to \tau\tau$

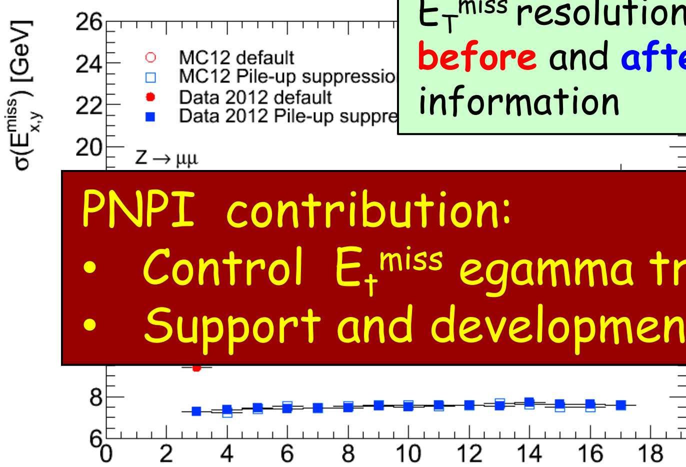
2012 $Z \to \mu\mu$



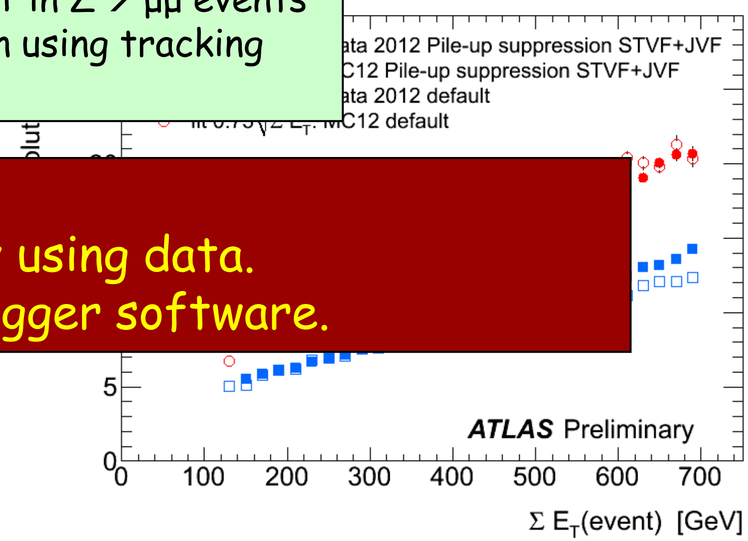
Many improvements in E_T^{miss} trigger: e.g. pile-up suppression, L2 fast front-end board sums instead of L1 only → same threshold as in 2011, sharper turn-on curve



E_T^{miss} resolution vs pile-up and vs ΣET in $Z \to \mu\mu$ events **before** and ***after*** pile-up suppression using tracking information



Number of reconstructed primary vertices

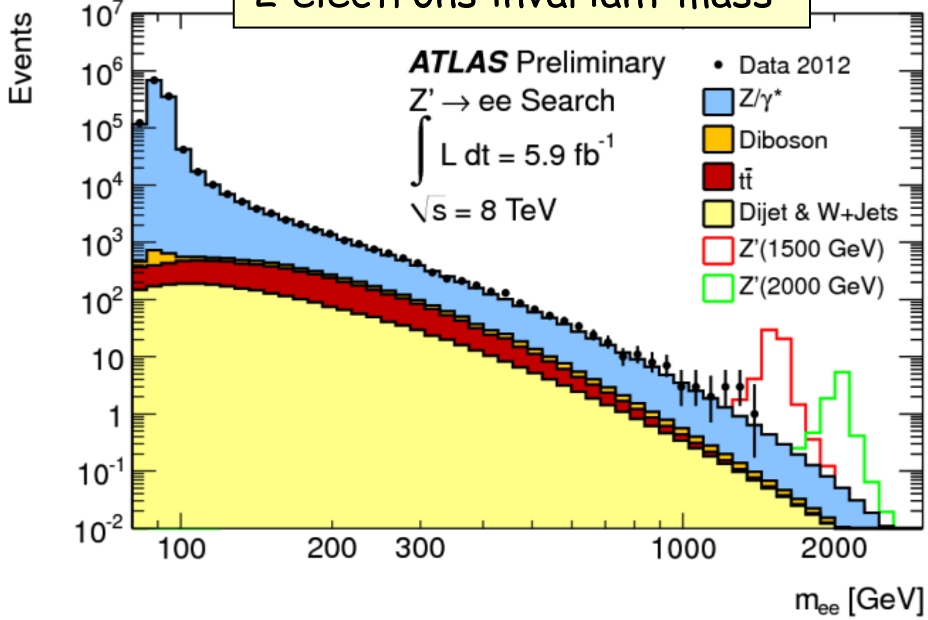


PNPI contribution:

- Control E_t^{miss} egamma trigger efficiency using data.
- Support and development of the HLT trigger software.

Search for high-mass resonances decaying to dileptons

2 electrons invariant mass



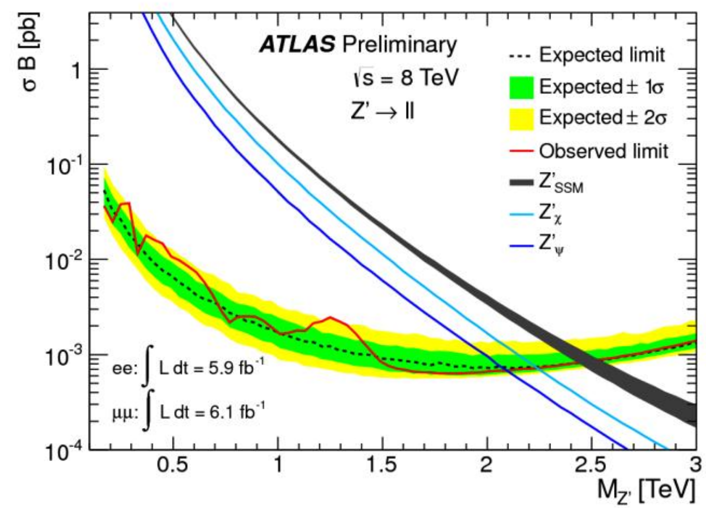
Several models predict new resonances decaying to pairs of charged leptons or into lepton:

- Spin-1 benchmarks: Z' in Sequential Standard Model or E6 grand unified symmetry
- Spin-2 benchmark: Graviton in Randall-Sundrum models
- Chiral spin-1 bosons (M.V.Chizov Phys. Atom. Nucl. 71, 2096 (2008))

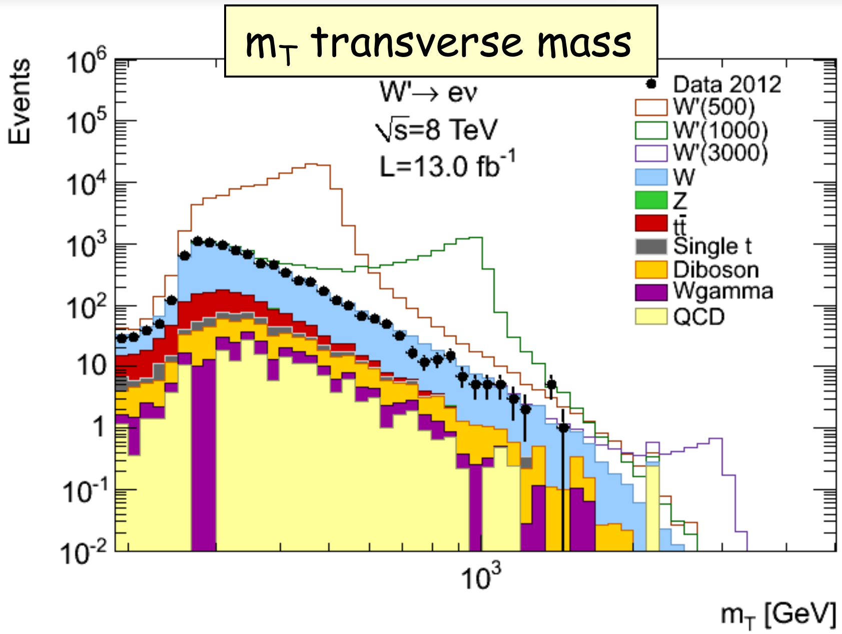
Expect very high-pT electrons from this signal

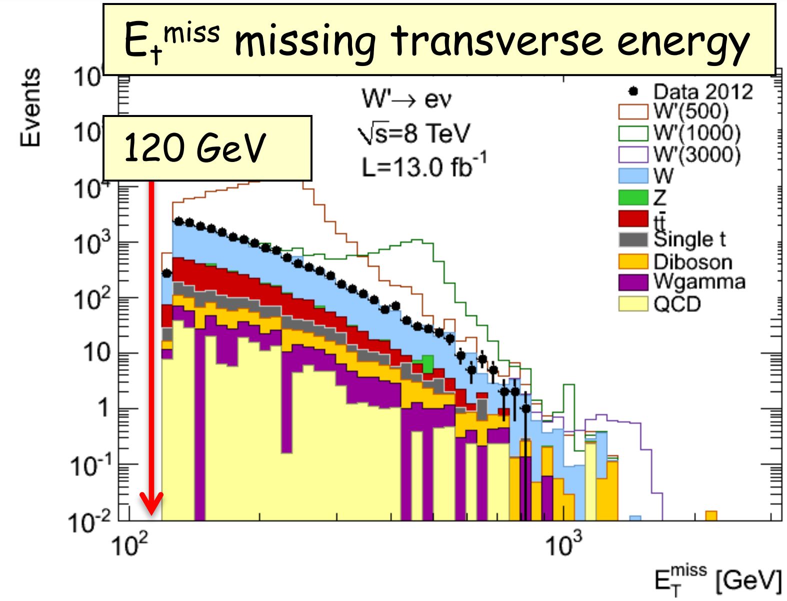
- E_T>25 GeV $|\eta|$ < 2.47, excluding crack 1.37<$|\eta|$< 1.52
- Cuts on shower shape and track matching
- A hit in the first layer of the pixel detector is required if to suppress background from photon conversions
- Higher E_T must be isolated requiring ΣE_T (ΔR < 0.2) < 7 GeV – to supress QCD background

- No statistically significant excess above the Standard Model expectation is observed;
- Upper limits are set at the 95% CL on the cross section times branching fraction of Z' resonances decaying into ℓ+ℓ− pairs as a function of the resonance mass.
- As a result, Z' bosons of the Sequential Standard Model with masses less than 2.47 TeV are excluded at 95% CL.
- Z* bosons with masses less than 2.20 TeV are excluded at 95% CL (only 2011 data)

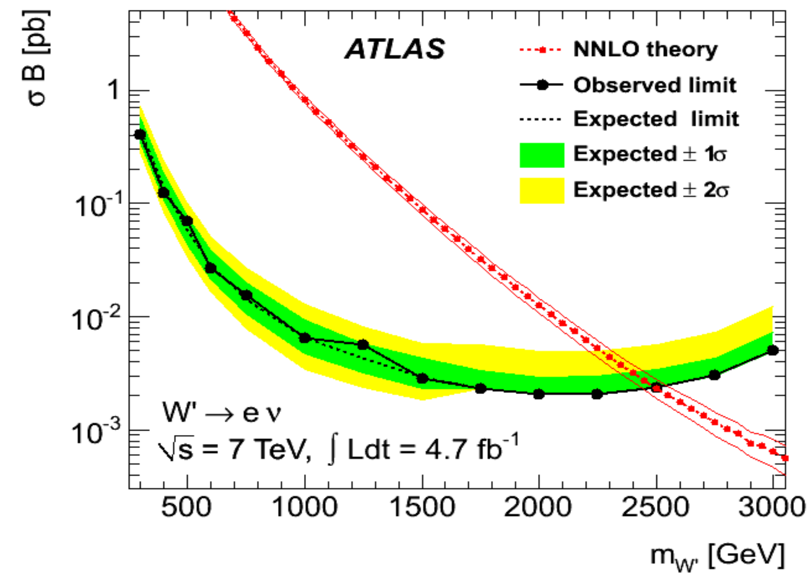


Search for high-mass resonances decaying to lepton and neutrino

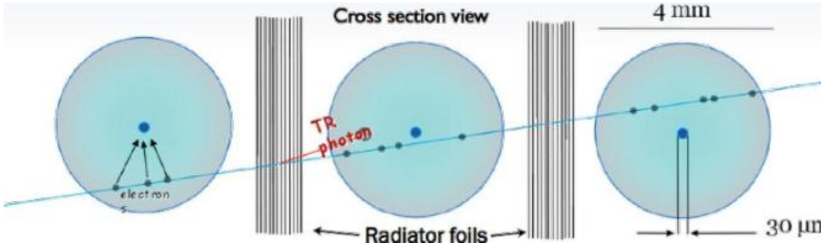


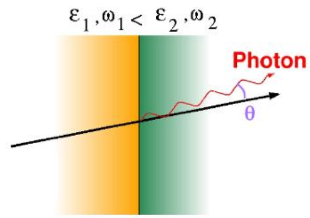


- No yet new limits are set in 2012 data.
- In 2011 data no statistically significant excess above the Standard Model expectation is observed;
- Upper limits are set at the 95% CL on the cross section times branching fraction of W′ resonances decaying into ℓ+ℓ− pairs as a function of the resonance mass.
- As a result, W′ bosons of the Sequential Standard Model with masses less than 2.5 TeV are excluded at 95% CL.
- W* bosons with masses less than 2.38 TeV are excluded at 95% CL.

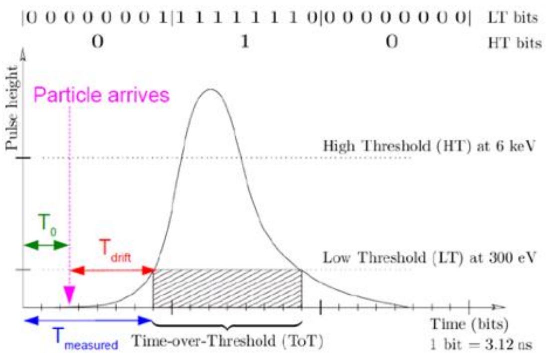


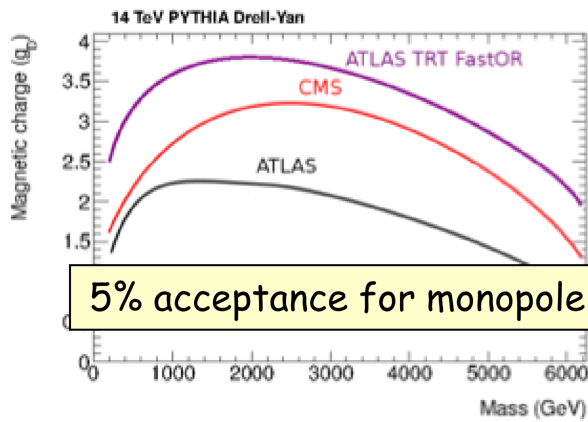
TRT eFastOR trigger



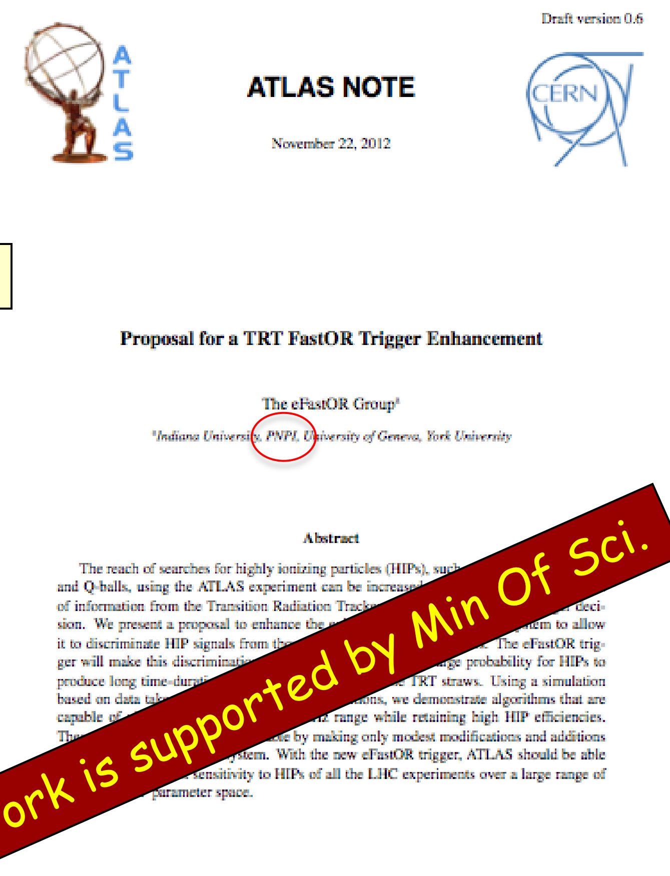


TR: photon (soft X-ray emitted by a charge particle when traversing the boundary between materials with different dielectric constants





5% acceptance for monopole


Draft version 0.6

ATLAS NOTE

November 22, 2012

CERN

Proposal for a TRT FastOR Trigger Enhancement

The eFastOR Group[a]

[a]Indiana University, PNPI, University of Geneva, York University

Abstract

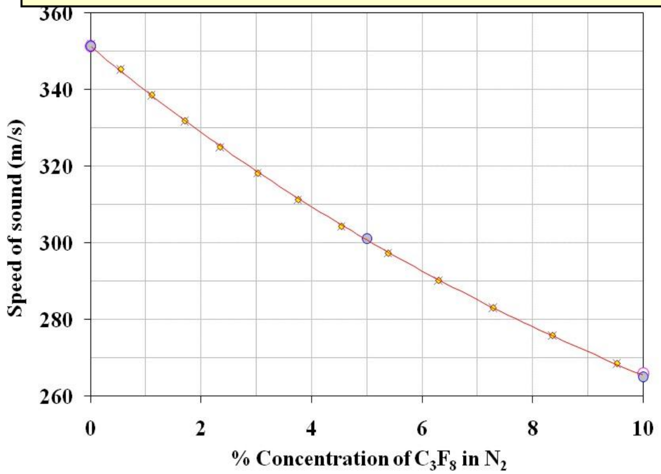
The reach of searches for highly ionizing particles (HIPs), such [illegible] and Q-balls, using the ATLAS experiment can be increased [illegible] of information from the Transition Radiation Track[illegible] deci-sion. We present a proposal to enhance the [illegible] stem to allow it to discriminate HIP signals from th[illegible]. The eFastOR trig-ger will make this discriminati[illegible] arge probability for HIPs to produce long time-durati[illegible] e TRT straws. Using a simulation based on data tak[illegible] ions, we demonstrate algorithms that are capable of [illegible] range while retaining high HIP efficiencies. The[illegible] e by making only modest modifications and additions [illegible] ystem. With the new eFastOR trigger, ATLAS should be able [illegible] sensitivity to HIPs of all the LHC experiments over a large range of [illegible] parameter space.

Work is supported by Min Of Sci.

- Goal is to build an enhancement to the current TRT FastOR Level-1 Trigger system that will significantly increase ATLAS sensitivity to highly ionizing particles (HIPs), such as magnetic monopoles and Q-balls.
- Trigger should run within ATLAS Level-1 trigger.
- eFastOR trigger takes advantage of differences in High Threshold (HT) signals from the TRT produced by known particles compared to those produced by HIPs.

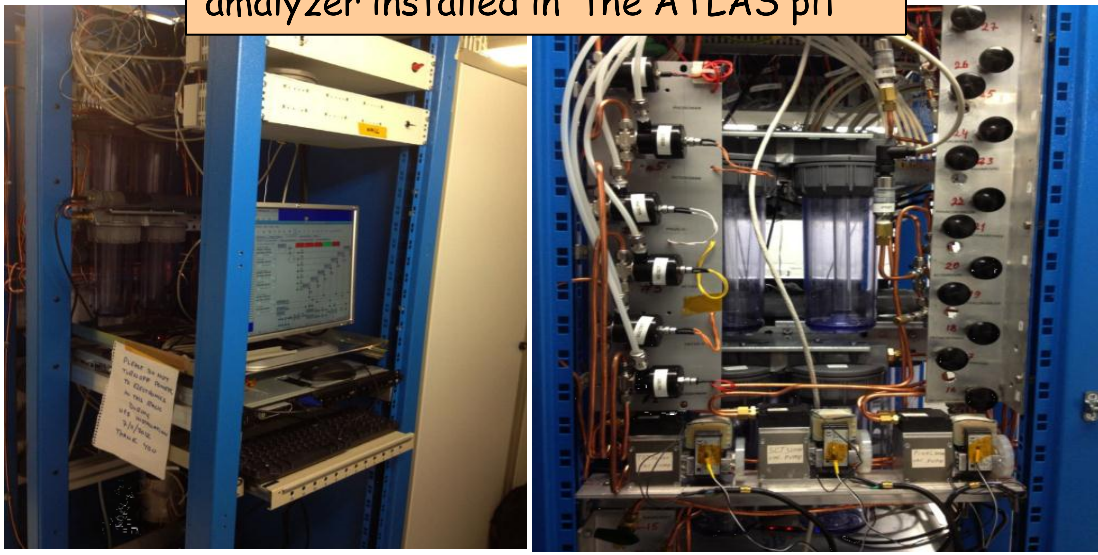
Ultrasonic vapour analyzer/flowmeter for the ATLAS silicon tracker

Sound velocity vs % concentration of C_3F_8/N_2 mixture



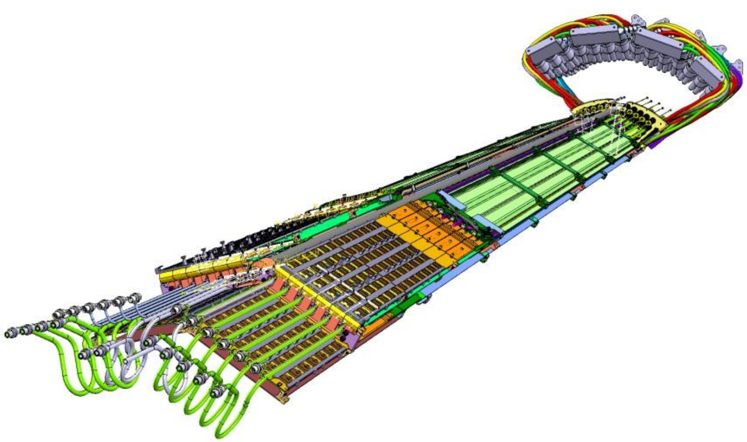
- The vapour flow rate is calculated from the sound transit times measured parallel, t_{down}, and anti-parallel, t_{up}, to the flow direction, according to the following algorithm:
  $c = L/2 * ((t_{up} + t_{down})/ t_{up} * t_{down}$
- Mixture precision:
  - ~0.3% for C3F8/C2F6
  - < 10^{-4} for N2/C3F8
- Flow resolutions of ± 2% F.S. for flows up to 250 l.min-1,
- ± 1.9% F.S. for linear flow velocities up to 15 ms^{-1}

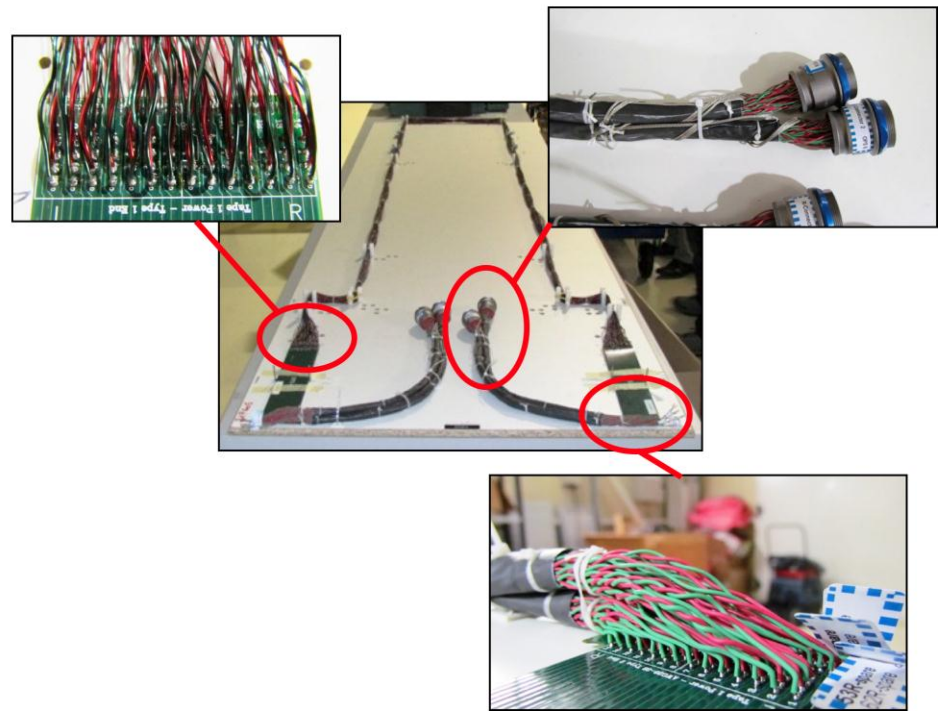
View of the electronics for Utrasonic analyzer installed in the ATLAS pit



Pixel Service Quarter Panels (SQP)

- Transfer services from outside world to pixel detectors
- Problematic opto-couplers on SQP
- To replace these need new infrastructure and electronics
- Mew electronics will allow greater readout bandwidth for > 10^{34} operation
- **PNPI technicians are participating in creation of the SQP**

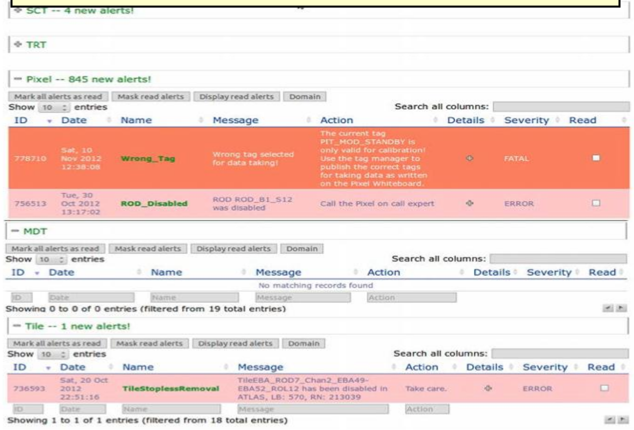




TDAQ/DCS

Отдел информационных технологий проф. Рябов Ю.Ф.

TDAQ Shifter assistance



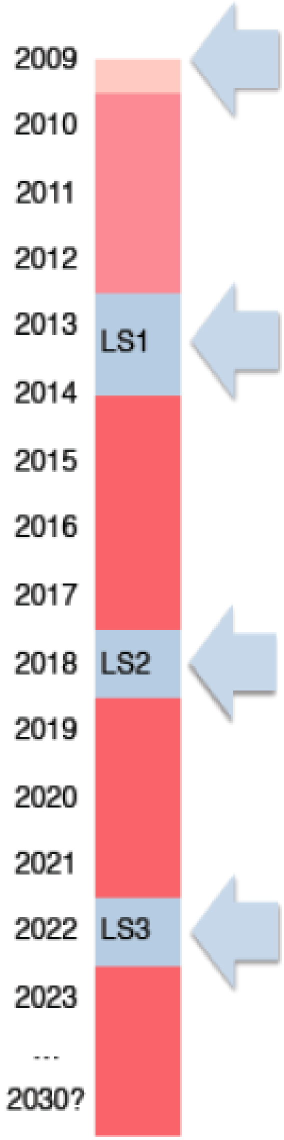
TDAQ PNPI contribution :

- Development and maintenance of the ATLAS data acquisition (TDAQ) system control and monitoring software at Point 1: system configuration, debugging, new features development.
- TDAQ s/w release validation, maintenance (patching), s/w installation at P1, maintenance of TDAQ online infrastructure.
- Development and deployment of a new automation tool "Shifter Assistant" used by TDAQ and ATLAS subdetectors at P1.
- Expert (level 1,2 on-call) support for the running system at P1.
- Shifts at P1: manning the Run Control desk.

DCS PNPI contribution :

- Administering and Technical support of OS Windows on DCS PCs (> 100).
- Support and improvements of:
  - –Rack Control system,
  - –DCS Access Control (including remote access),
  - –ATLAS – LHC Communication Interface
  - –Interface to Condition Database,
  - –CANopen OPC server – Front-end interface used by *all* LHC experiments.
- New development for LHC/ATLAS Upgrade
  - –CANOpen OPC server in advanced standard OPC UA.
- DCS Expert on-call (7/7,24/24) ~25 weeks/year.

Plans for LHC Upgrade



✧ LHC startup, □s = 900 GeV

□s=7~8 TeV, L=6x10^{33} cm^{-2} s^{-1}, bunch spacing 50 ns

Go to design energy, nominal luminosity

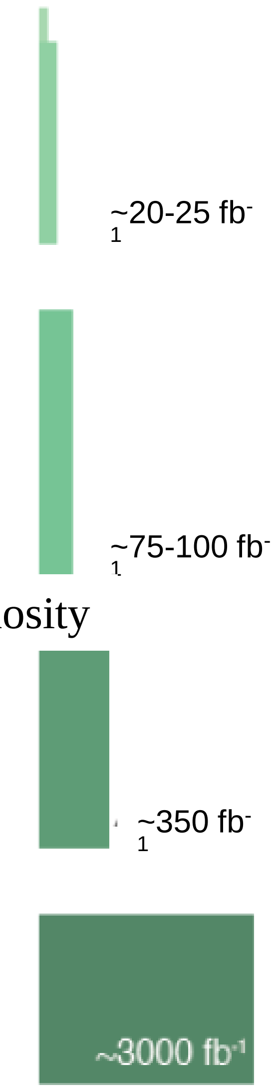
□s=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

Injector and LHC Phase-1 upgrade to ultimate design luminosity

□s=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

HL-LHC Phase-2 upgrade, IR, crab cavities?

□s=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling



Towards to High Energy LHC (HE-LHC) -√s=33 TeV

ATLAS upgrade

Phase 0 Upgrade 2013-2014

New inner pixel layer (IBL) : *Possible new Diamond Beam Monitor (DBM)*
Muon system completion
New neutron shielding
Potential replacement of Minimum Bias Trigger scintillators

Phase I Upgrade 2018

New Muon small wheels
Improved Granularity of Calorimeter trigger at level 1
Trigger and Data Acquisition upgrades including Fast Track Trigger
Under consideration: new pixel detector based on IBL experience

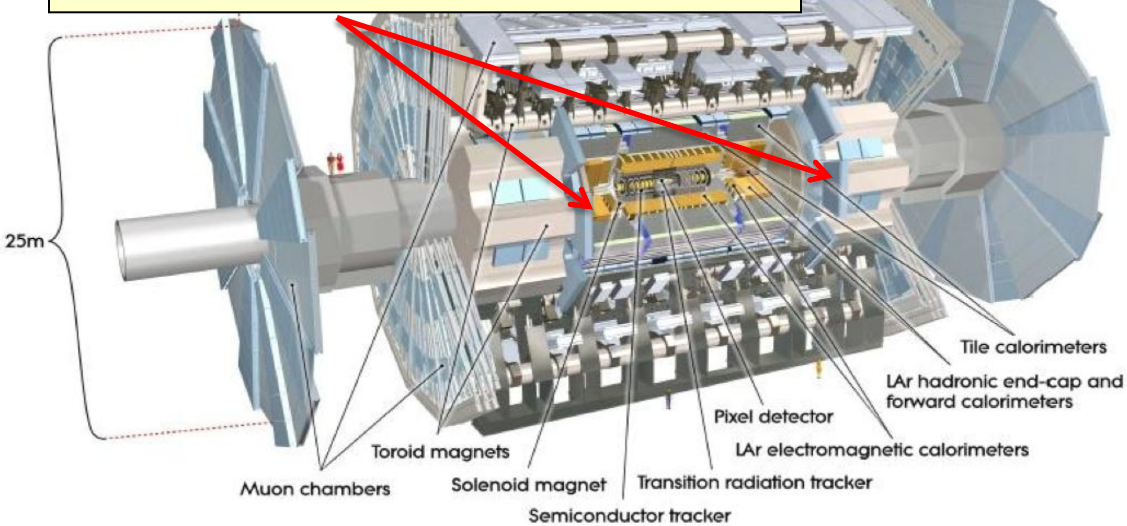
Phase II Upgrade 2022

All new Tracking Detector
New Trigger and Data Acquisition system including Calorimeter electronics upgrades
New detectors for parts of Muon system + more neutron shielding
Possible upgrades for Forward and Hadronic EndCap Calorimeters

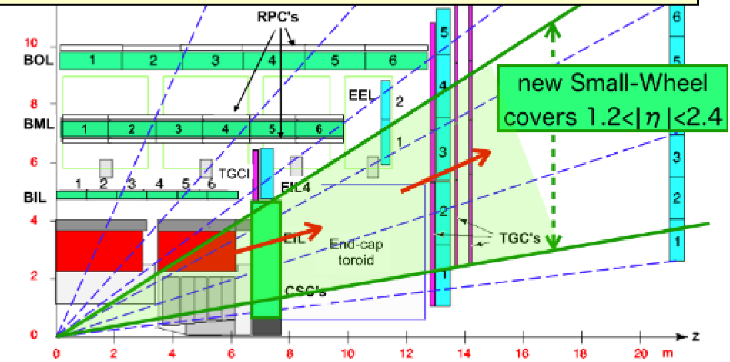
1/11/2012 G. Oakham HEP 2012 Valparaiso Chile

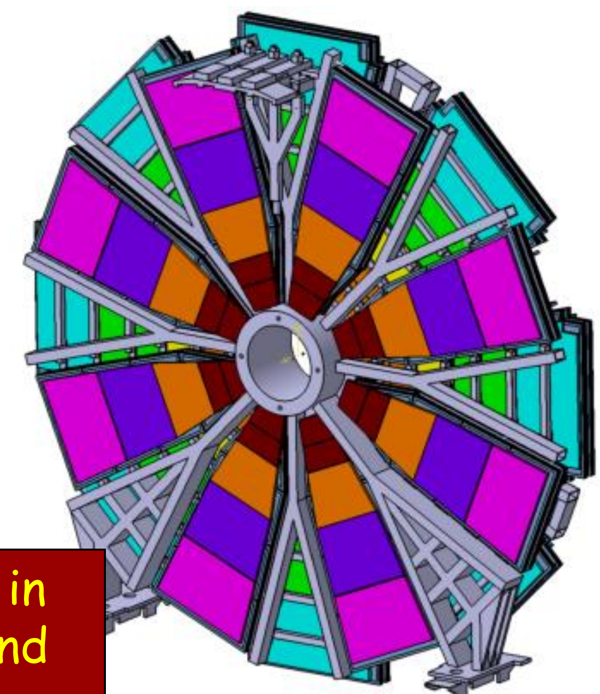
New Muon Small Wheels

Existing Small Muon Wheels: CSC and MDT (Muon Drift Tubes)

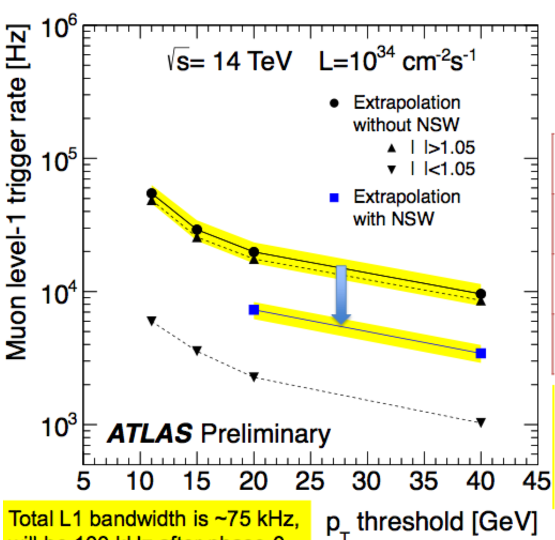


New Small Muon Wheels: sTGS and Micromegas





Extrapolated L1 rate at 14 TeV, 25ns



L1 trigger rate for $L=3\times10^{34}cm^{-2}s^{-1}$

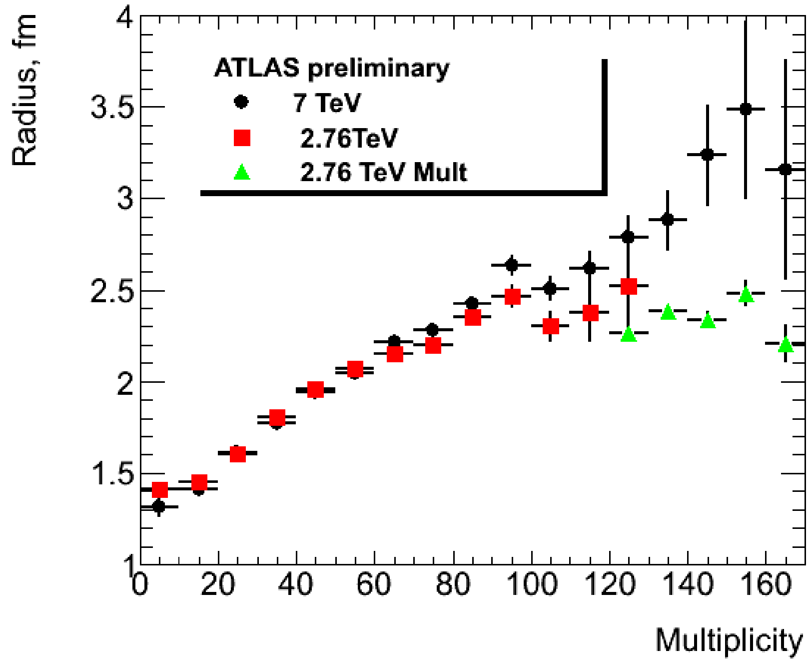
	p_T>20 GeV (kHz)	p_T>40 GeV (kHz)
w/o NSW	60	29
w NSW	22	10

Possible participation of PNPI in assembly of sTGC and front-end electronic development.

Back-up slides

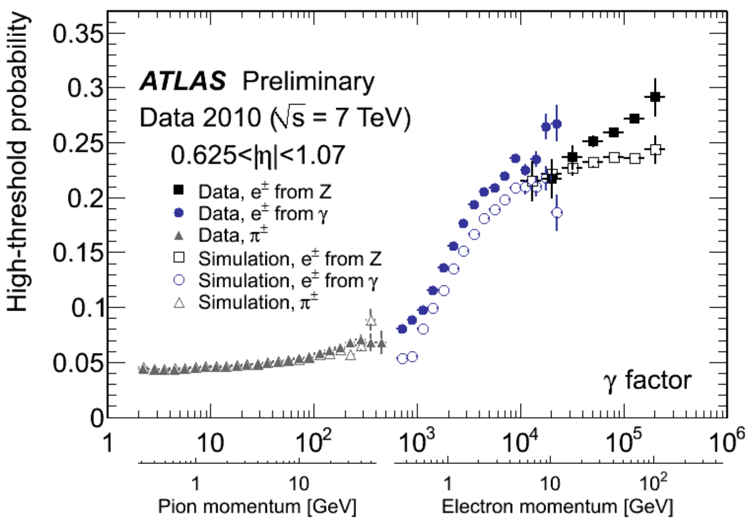
The MC toy model for BEC

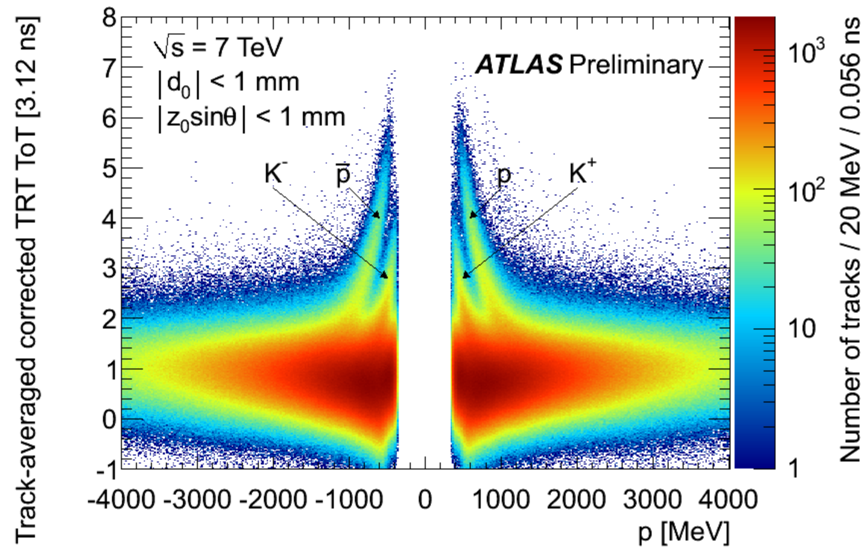
- The MC toy model for Bose-Einstein correlations (BEC) has been proposed to make a best choice from different reference distributions. It occurs that the deviation from the model values of the BEC parameters is provided by the reference sample which is being emulated from "observed" sample by the turn of all momenta vectors in the transverse plane by a random angle.
- In the case of the experimental data analysis the appropriate choice of the reference sample even more important.

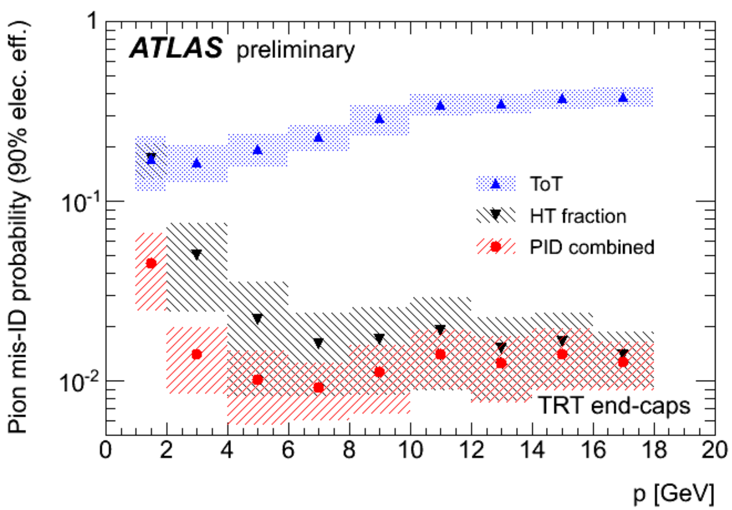


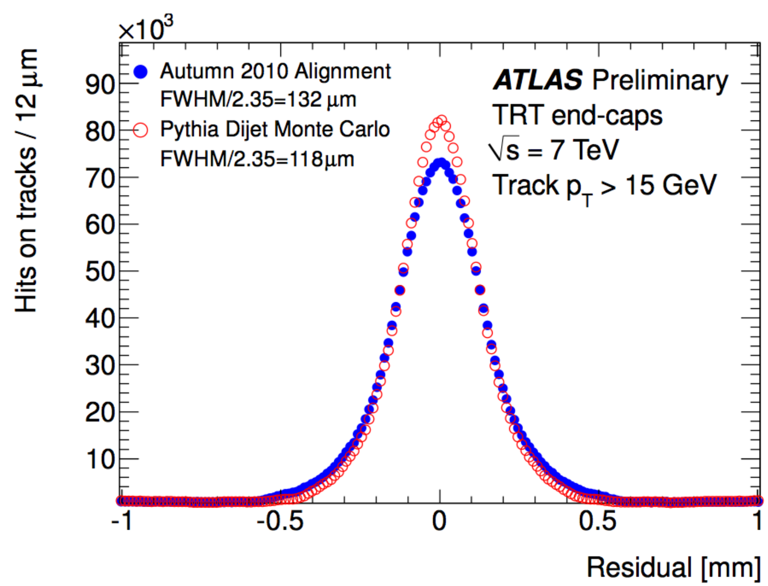
- The ATLAS data on multi-particle production with the beam energy 2.76 TeV and 7.0 TeV analyzed with the selected reference samples.
- For the first time it is established that the radii of the particles radiation area is not dependent on the multiplicity , i.e. the value is saturated. The value of such radii has to be dependent on the beam energy. To make it more convincing, the data with a special trigger on high multiplicity has to be investigated with different beam energy. This is already done for the 2.76 TeV data. Such special sample is also collected with the beam energy 7 TeV. The analysis is under way.

TRT performance



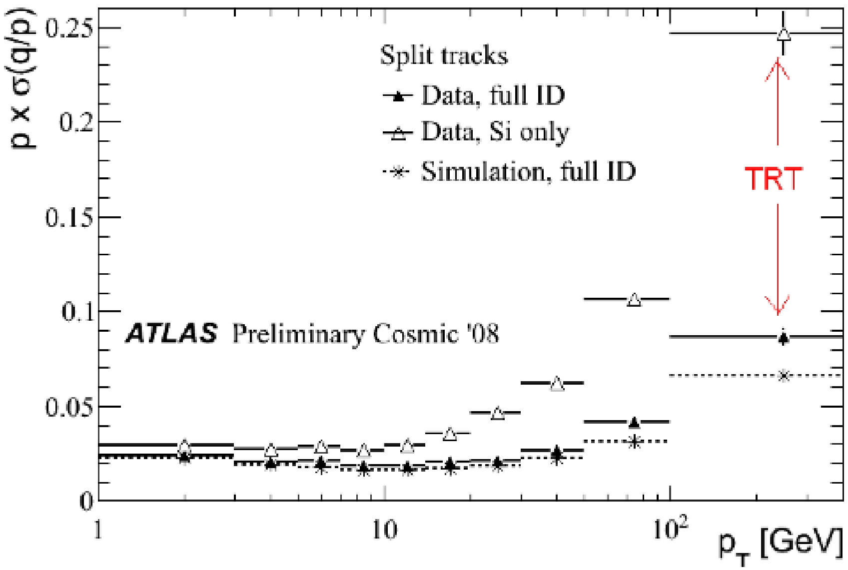


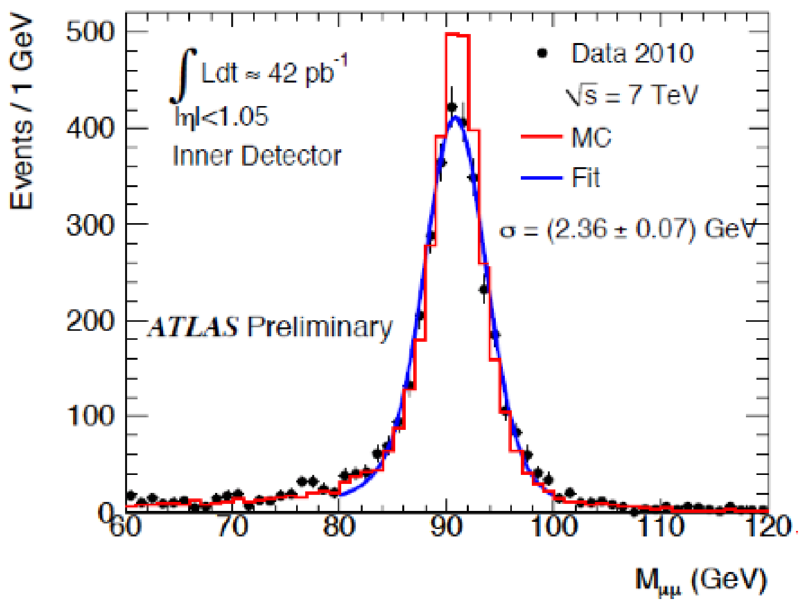




TRT performance

The TRT significantly improves the momentum resolution compared to tracks reconstructed with silicon hits only





- Z mass resolution in the Inner Detector shows good performance σ ~ 2.36 GeV.
- Good agreement data/MC

Preliminary HE-LHC - parameters

	nominal LHC	HE-LHC
beam energy [TeV]	7	16.5
dipole field [T]	8.33	20
dipole coil aperture [mm]	56	40-45
#bunches / beam	2808	1404
bunch population [10^{11}]	1.15	1.29
initial transverse normalized emittance [μm]	3.75	3.75 (x), 1.84 (y)
number of IPs contributing to tune shift	3	2
maximum total beam-beam tune shift	0.01	0.01
IP beta function [m]	0.55	1.0 (x), 0.43 (y)
full crossing angle [μrad]	285 (9.5 $\sigma_{x,y}$)	175 (12 σ_{x0})
stored beam energy [MJ]	362	479
SR power per ring [kW]	3.6	62.3
longitudinal SR emittance damping time [h]	12.9	0.98
events per crossing	19	76
peak luminosity [10^{34} cm^{-2}s^{-1}]	1.0	2.0
beam lifetime [h]	46	13
integrated luminosity over 10 h [fb^{-1}]	0.3	0.5

Target parameters for HL-LHC run

Parameter	Nom. 25 ns	Target 25 ns	Target 50 ns	LIU 25 ns	LIU 50 ns
N_b [10^{11}]	1.15	2.0	**3.3**	1.7	2.5
n_b	2808	2808	1404	2808	1404
I [A]	0.56	**1.02**	0.84	0.86	0.64
θc [μrad]	300	475	445	480	430
β* [m]	0.55	**0.15**	**0.15**	**0.15**	**0.15**
ε_n [μm]	3.75	**2.5**	**2.0**	**2.5**	**2.0**
ε_s [eV s]	2.5	2.5	2.5	2.5	2.5
IBS h [h]	111	25	**17**	25	**10**
IBS l[h]	65	21	**16**	21	**13**
Piwinski	0.68	2.5	2.5	2.56	2.56
F red.fact.	0.81	0.37	0.37	0.37	0.36
b-b/IP[10^{-3}]	3.1	3.9	**5**	3	**5.6**
L_{peak}	1	7.4	8.4	5.3	**7.2**
Crabbing	no	**yes**	**yes**	**yes**	**yes**
$L_{peak\ virtual}$	1	20	22.7	14.3	19.5
Pileup L_{lev}=5L_0	19	95	190	95	190
Eff.† 150 days	=	0.62	0.61	0.66	0.67

baseline

Efficiency is defined as the ratio between the annual luminosity target of 250 fb^{-1} over the potential luminosity that can be reached with an ideal cycle run time with no stop for 150 days: t_{run}= t_{lev}+t_{dec}+t_{turn}. The turnaround time after a beam dump is taken as 5 hours, t_{decay} is 3 h while t_{lev} depends on the total beam current