ATLAS Minimum Bias Trigger Scintillator Upgrade for LHC RunII

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on behalf of the ATLAS Collaboration

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BINP, Novosibirsk, Russia

Outline

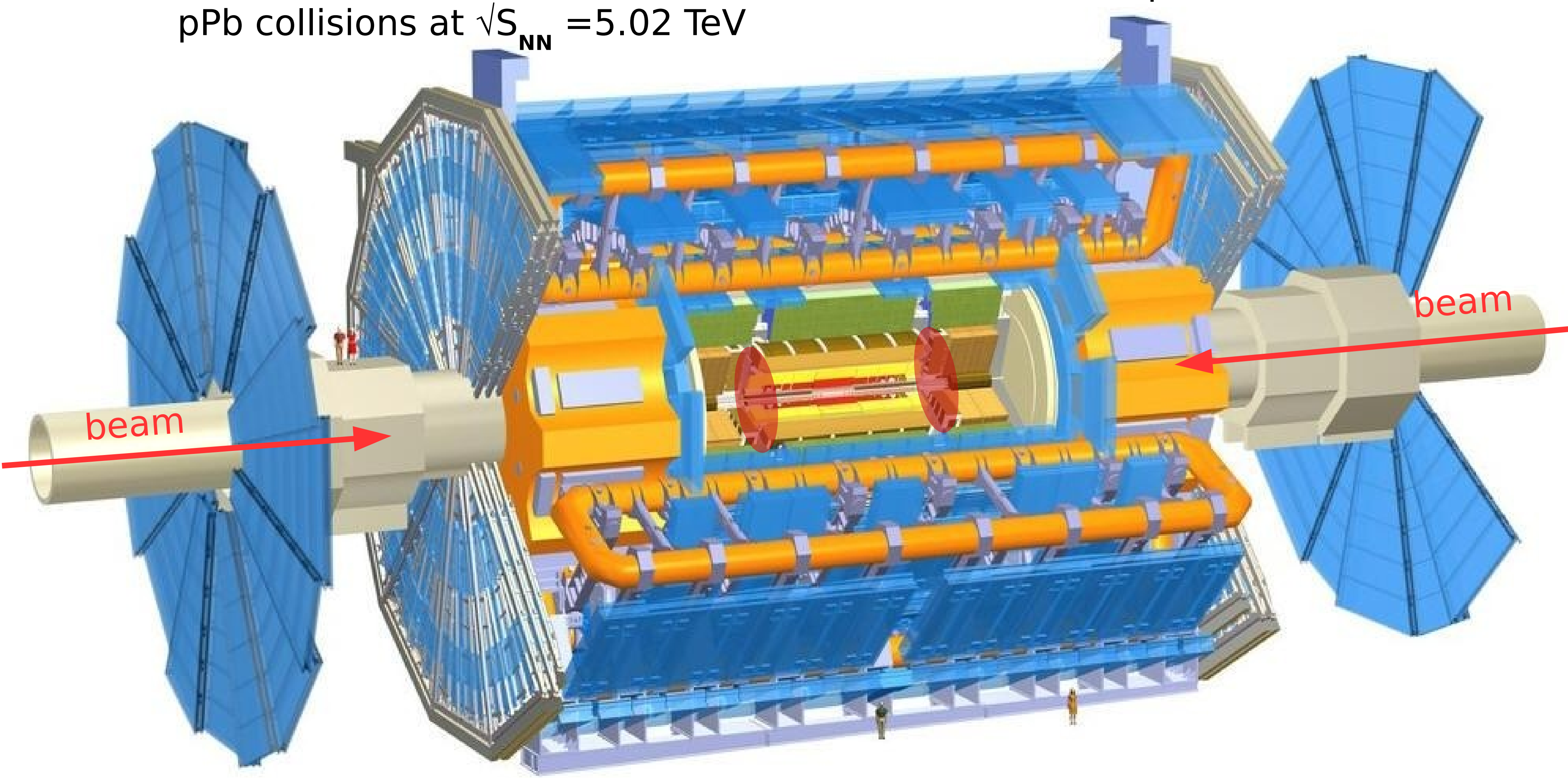
- Minimum Bias Trigger Scintillators (MBTS) in Run I (2009-2013):
  - Physics motivations
  - Physics potential
  - Performance

- Upgrade for Run II (2015-):
  - Design
  - Construction
  - Tests

The ATLAS Detector

pp collisions at $\sqrt{s}$=0.9, 2.36, 7 and 8 TeV
Heavy Ion collisions (HI):
PbPb collisions at $\sqrt{S_{NN}}$ =2.76 TeV
pPb collisions at $\sqrt{S_{NN}}$ =5.02 TeV

LHC in operations from 2009-2013
→ Now in shutdown (LS1)
→ Back to operations in 2015



A long time ago in a galaxy far, far away....

Few years before LHC start up, ATLAS realized that a subdetector able to trigger on genuine low luminosity collision events would be crucial

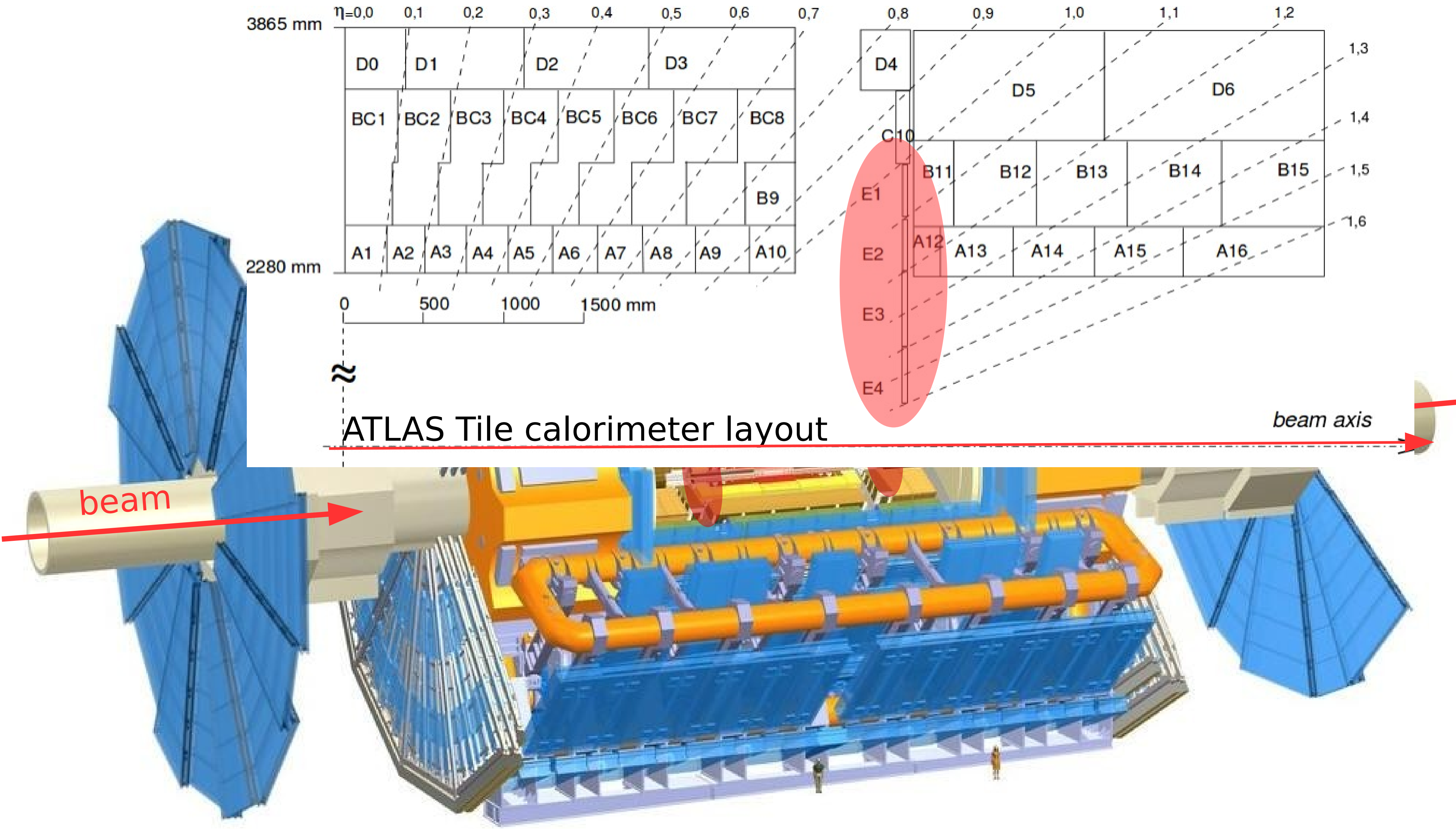
Requirements:

- Sensibility to single low momentum particles → ~~Calorimeter~~
- Trigger at Level 1 with high efficiency→ ~~Inner Detector~~
- Tight time and installation constraints could only allow for a simple detector which could be read out by existing electronics

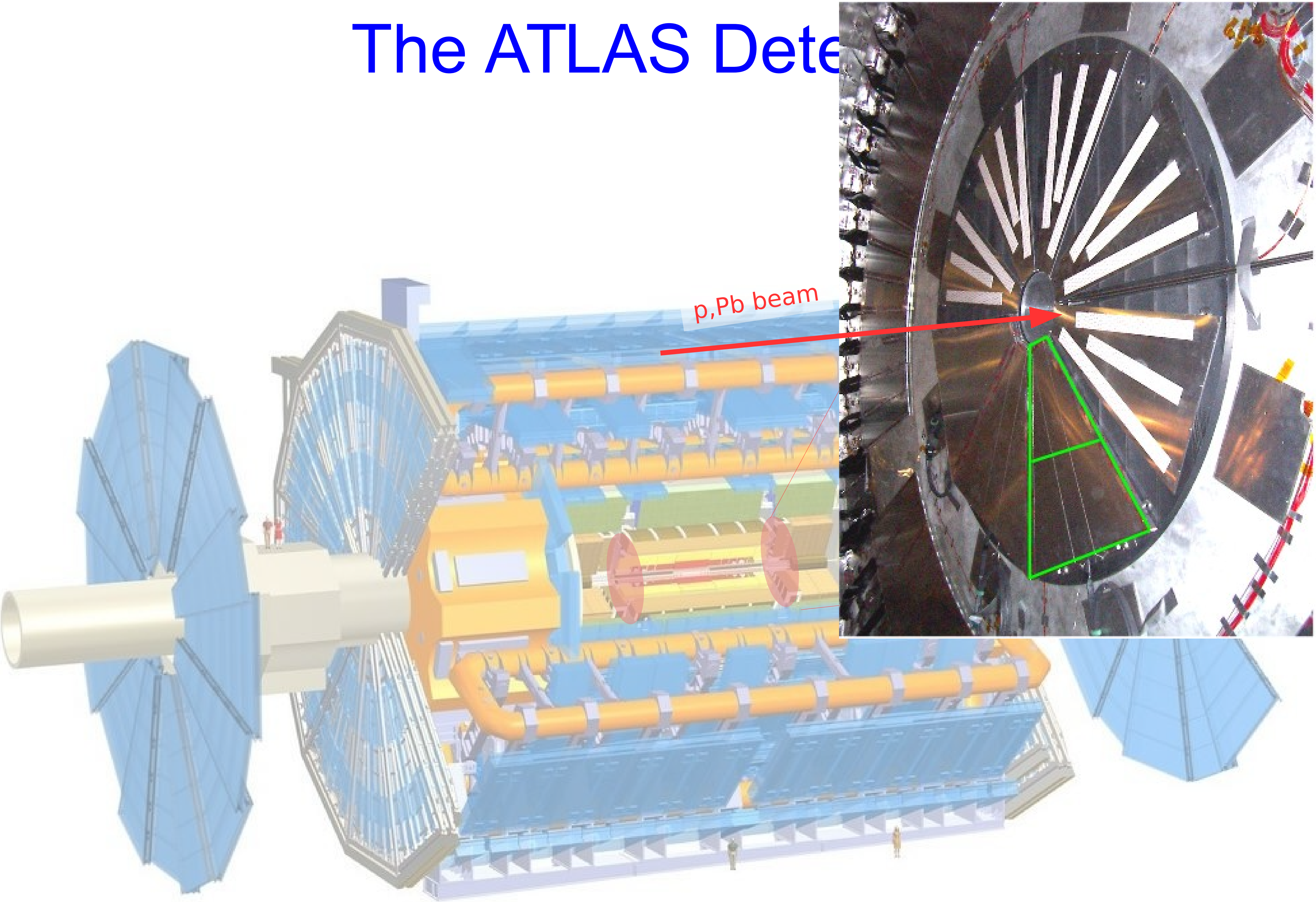
→ The solution: scintillators from JINR (polystyrene, same slabs as preshower and Muon Extension for CDF)

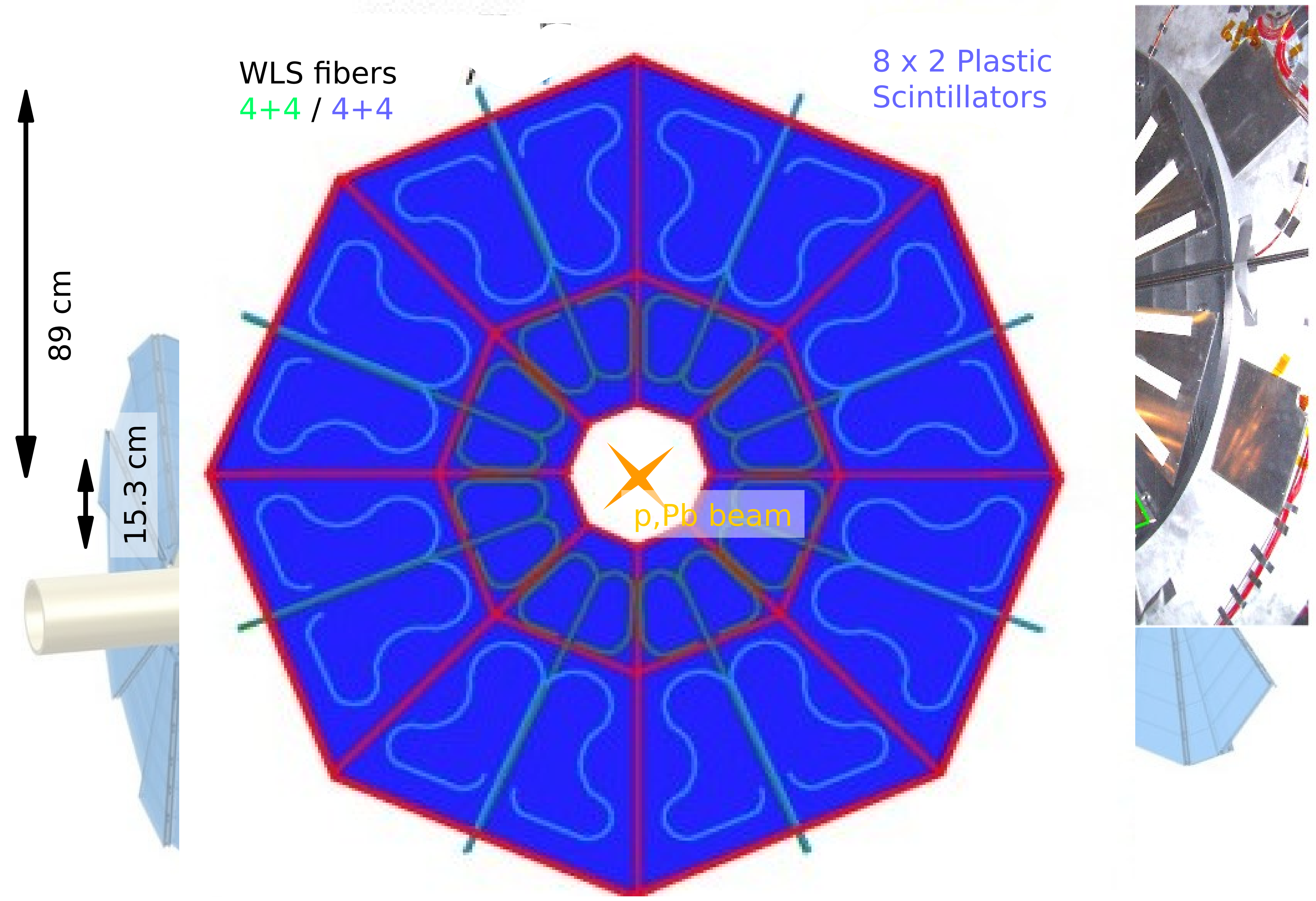
- Instrumentation and readout electronics from Tile Calorimeter

The ATLAS Detector



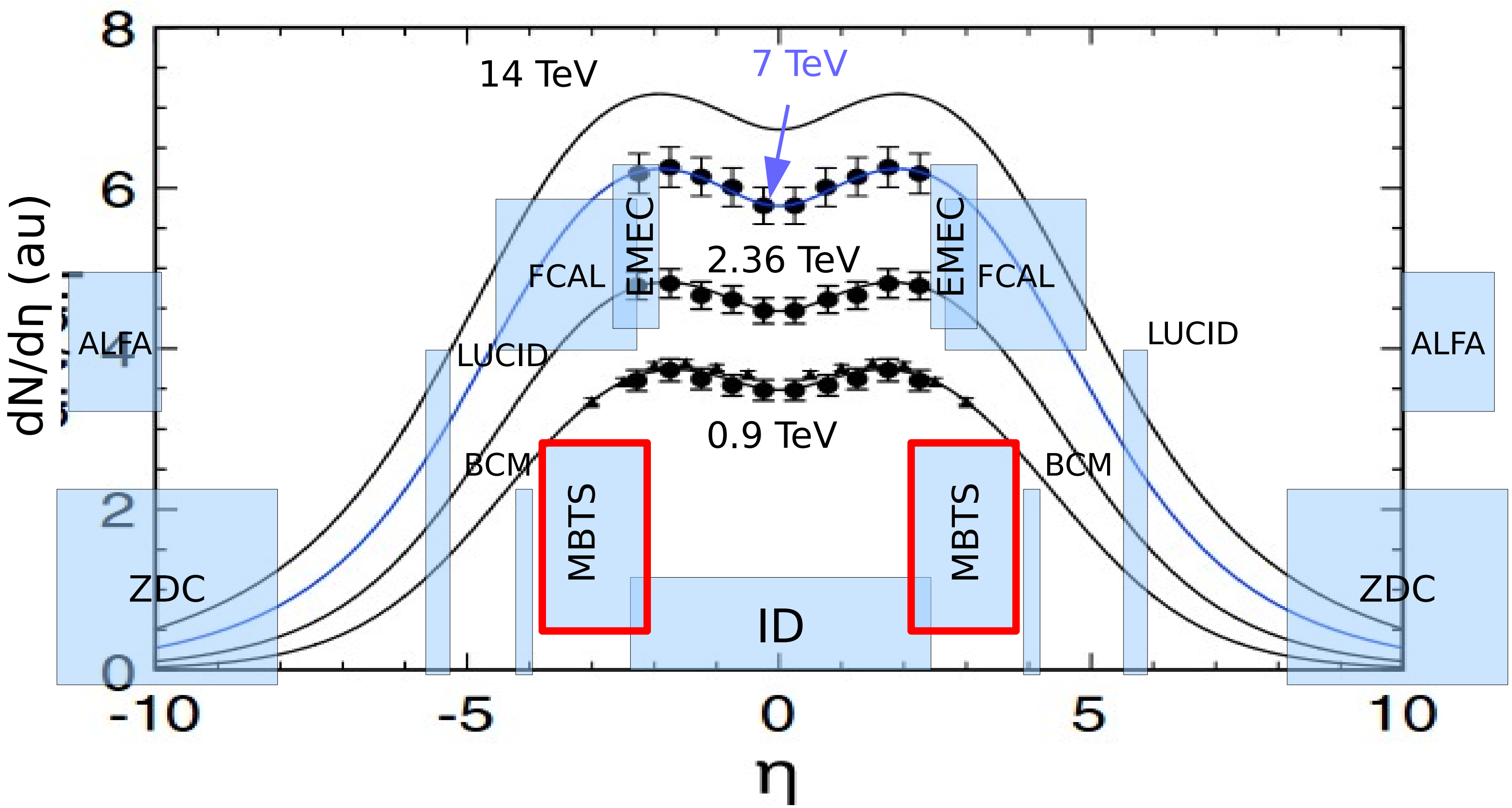
The ATLAS Dete




WLS fibers
4+4 / 4+4
8 x 2 Plastic
Scintillators
89 cm
15.3 cm
p,Pb beam

The ATLAS Subdetectors

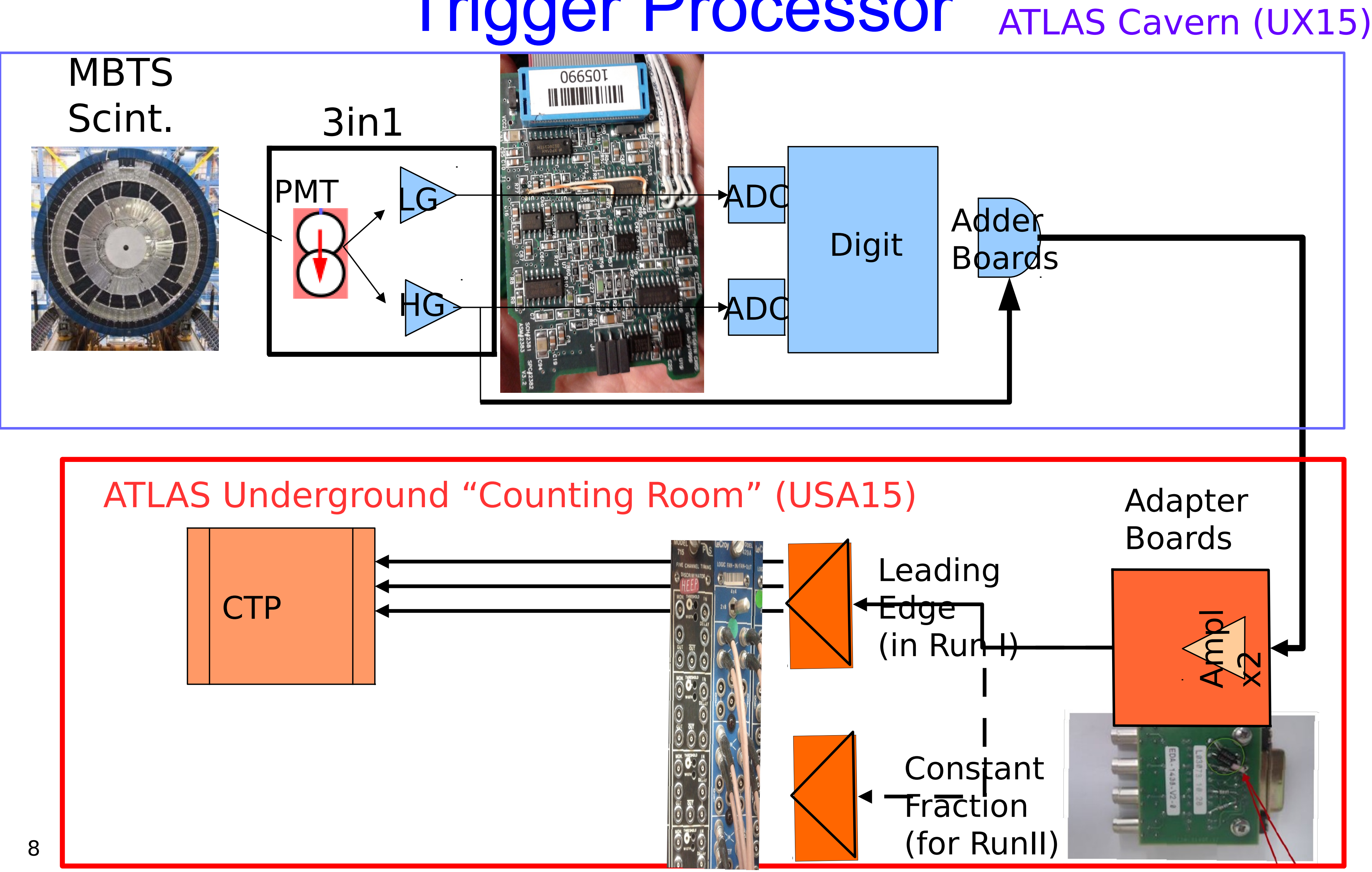
From G. Wolshin EPL **95** 61001 (2011)

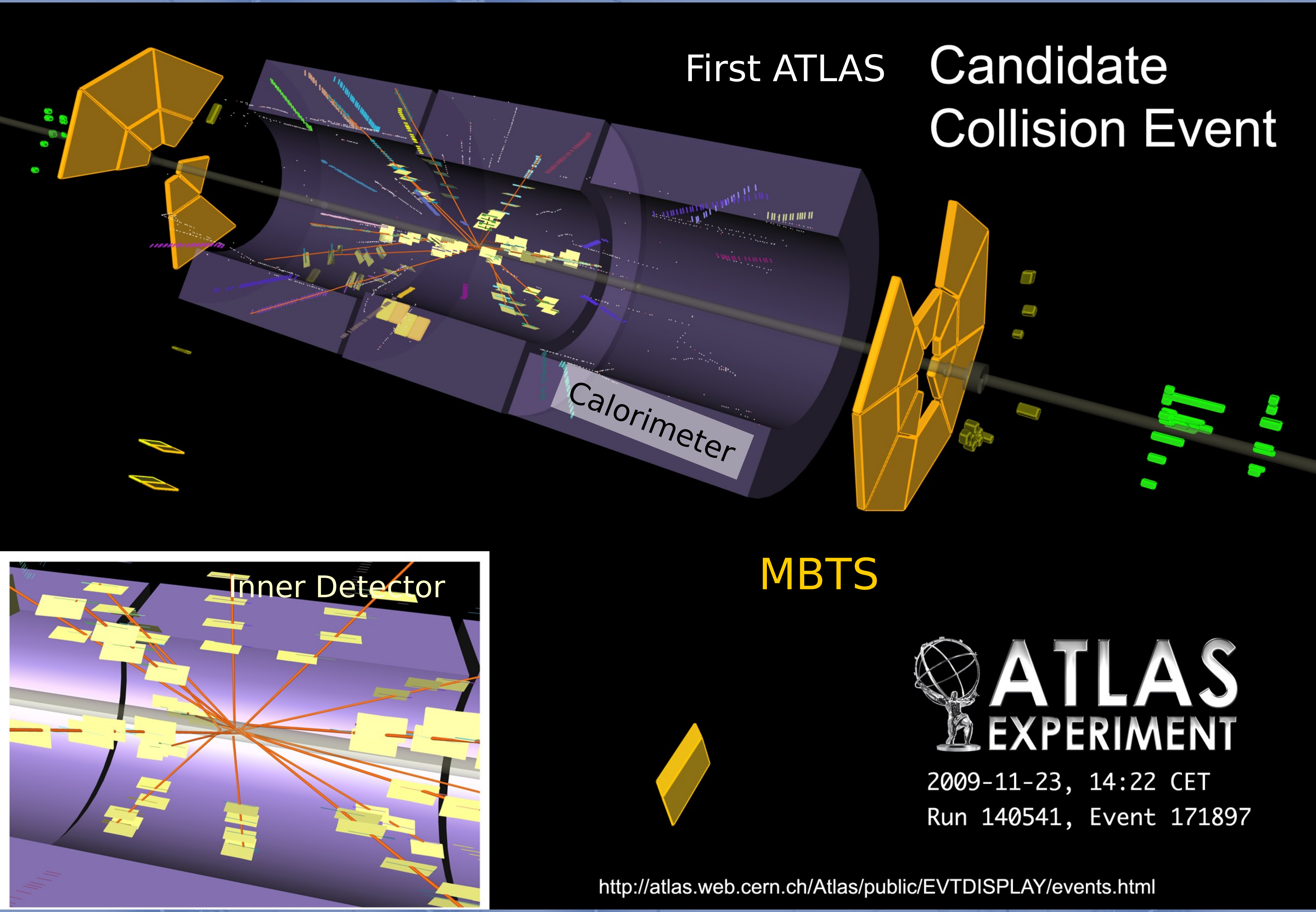


Detector	η coverage
ID (Pix + SCT)	$\lvert\eta\rvert<2.5$
ID (TRT)	$\lvert\eta\rvert<2.0$
MBTS	$2.08<\lvert\eta\rvert<3.75$
Calo: EMEC	$2.5<\lvert\eta\rvert<3.2$
Calo: FCal	$3.1<\lvert\eta\rvert<4.9$

Detector	η coverage
BCM	$\lvert\eta\rvert=4.2$
LUCID	$5.6<\lvert\eta\rvert<6.0$
ZDC	$\lvert\eta\rvert>8.3$
ALFA(RP)	$10.6<\lvert\eta\rvert<13.5$

Signal path: from scintillators to Central Trigger Processor




First ATLAS
Candidate
Collision Event
Calorimeter
MBTS
Inner Detector
ATLAS
EXPERIMENT
2009-11-23, 14:22 CET
Run 140541, Event 171897
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Run I Physics Results Based on MBTS

Excerpt of RunI ATLAS Papers based on MBTS: Soft QCD Physics and Heavy Ion

- Measurement of underlying event characteristics using charged particles in pp collisions at sqrt(s) = 900 GeV and 7 TeV with the ATLAS Detector,
- Measurements of underlying-event properties using neutral and charged particles in pp collisions at 900 GeV and 7 TeV with the ATLAS detector at the LHC,
- Charged particle multiplicities in pp interactions
- Measurement of the Inelastic Proton-Proton Cross-Section at sqrt(s) = 7 TeV with the ATLAS Detector
- Rapidity gap cross sections measured with the ATLAS detector in pp collisions at sqrt(s) = 7 TeV
- Measurement of inclusive jet and dijet production in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector
- Measurement of the centrality dependence of the charged particle pseudorapidity distribution in lead-lead collisions at sqrt(s_NN) = 2.76 TeV with the ATLAS detector
- Observation of a Centrality-Dependent Dijet Asymmetry in Lead-Lead Collisions at sqrt(S(NN))= 2.76 TeV with the ATLAS Detector at the LHC
- and more and more

Crucial to get the correct UE tuning for MC at $\sqrt{s}$=13 TeV

Inelastic pp Cross Section Measurement

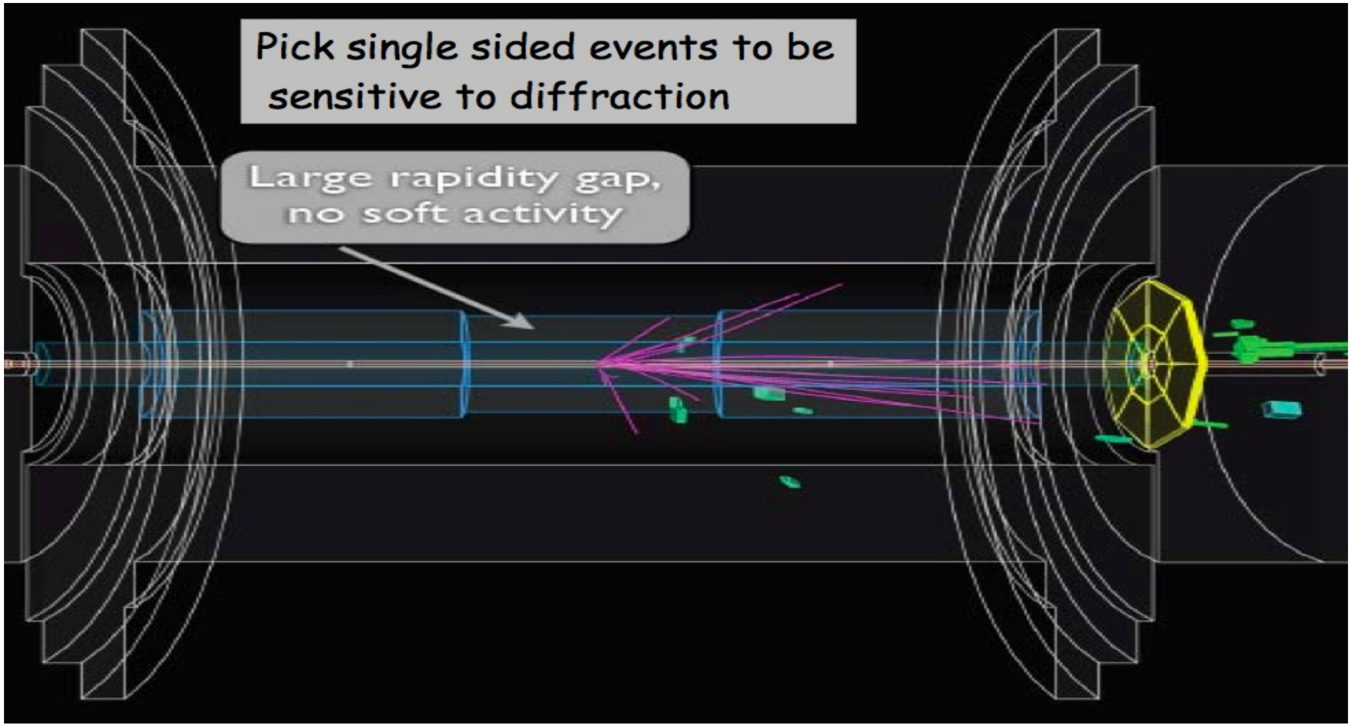
Asymmetric events:

→ Measure R_{ss}: ratio of **single sided** MBTS events wrt total inelastic events

$$\boxed{R_{ss} = \frac{N_{ss}}{N_{incl}}}$$

$$\boxed{R_{SS} = 10.02 \pm 0.03(\mathrm{stat})^{+0.1}_{-0.4}(\mathrm{syst})\%}$$

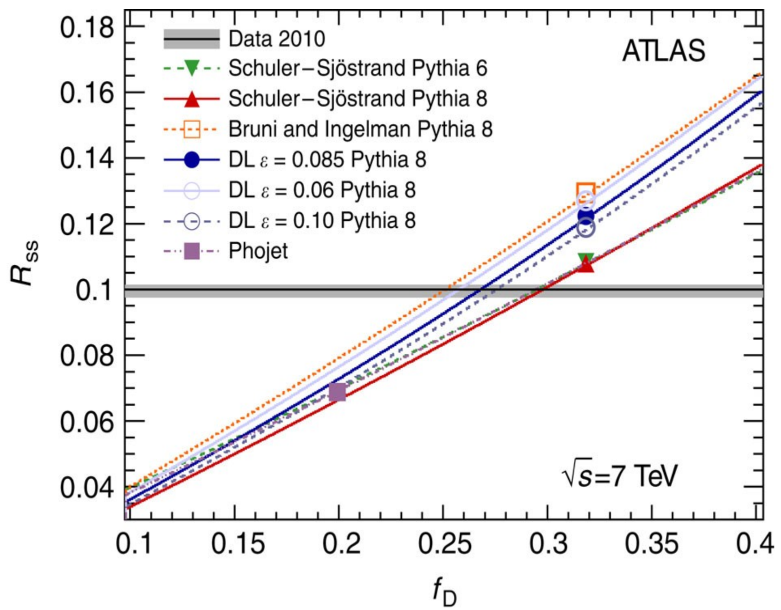
From R_{ss} Measurement → Extract f_D ratio $f_D = \frac{\sigma_{DD} + \sigma_{SD} + \sigma_{CD}}{\sigma_{Inel}}$



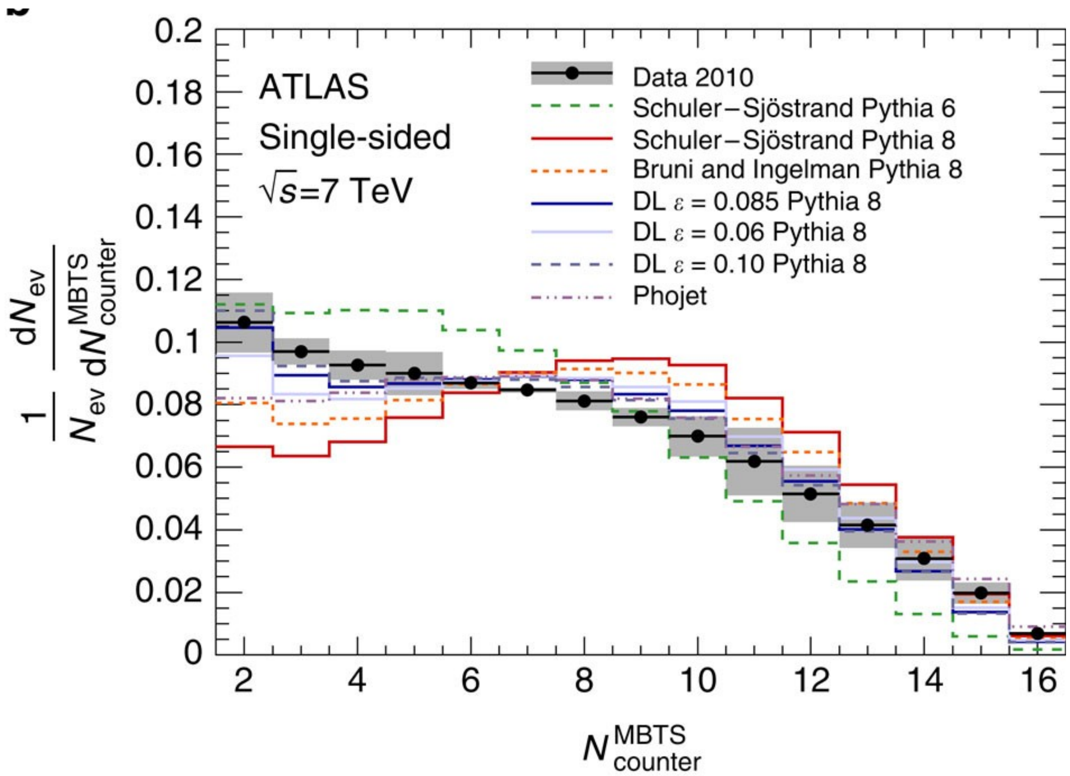
Inelastic pp Cross Section Measurement

$$\sigma_{inel} = \frac{N - N_{bg}}{\epsilon \times A_{inel} \times \int \mathcal{L}dt}$$

$$A_{inel} = A_{inel}^{ND}(1 - f_D) + f_D[A_{inel}^{SD} f_{SD} + A_{inel}^{DD}(1 - f_{SD} - f_{CD}) + A_{inel}^{CD} f_{CD}]$$



f_D predicted from R_{ss} according to several models (main uncertainty)

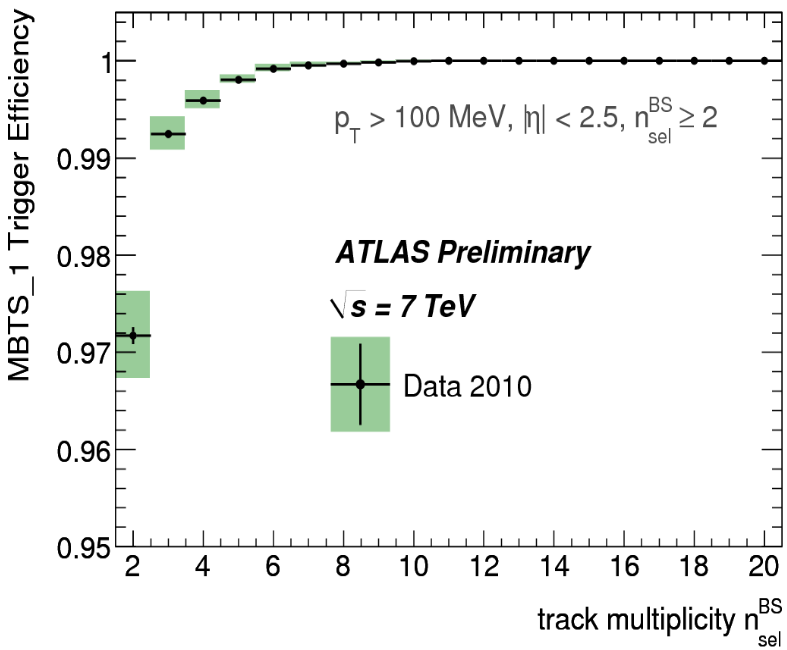


Constraints of the various models based on MBTS multiplicity

σ_{inel}=69.1 ±2.4(stat)± 6.9 (extr) mb

Nature Communications **2**, 463, (2011)

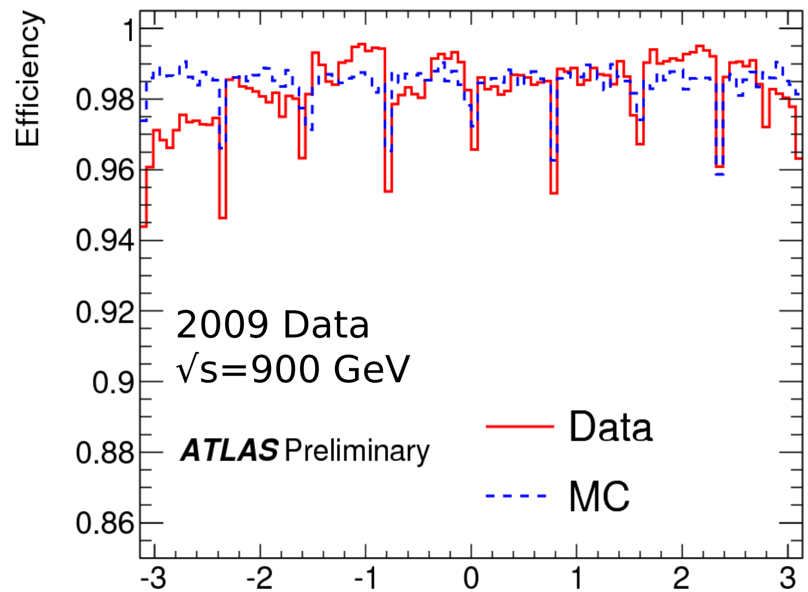
Run I Performance
(900 GeV and 7 TeV Collisions)



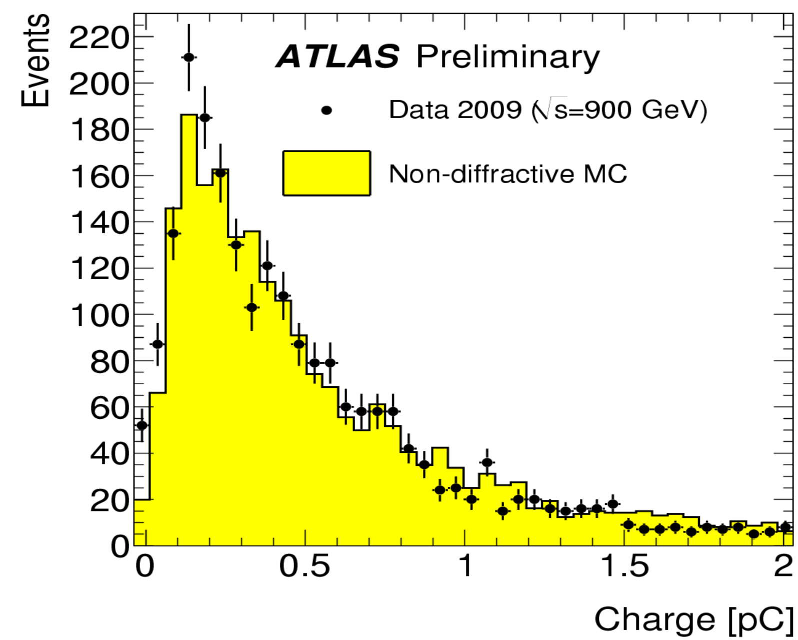
MBTS Trigger efficiency as a function of track multiplicity – Start of LHC Run I (2010)

~1 Efficiency for small track multiplicities

Excellent charge collected Data-MC agreement (after MC Calibration)

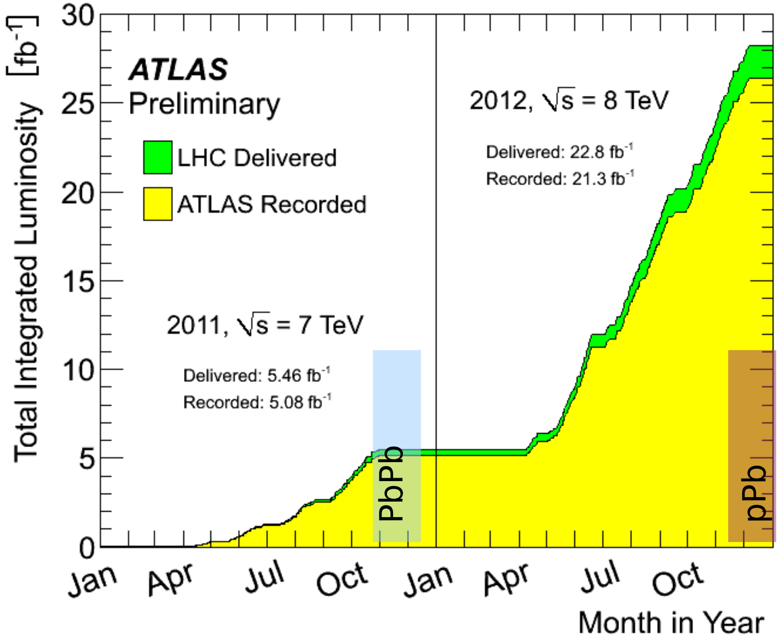


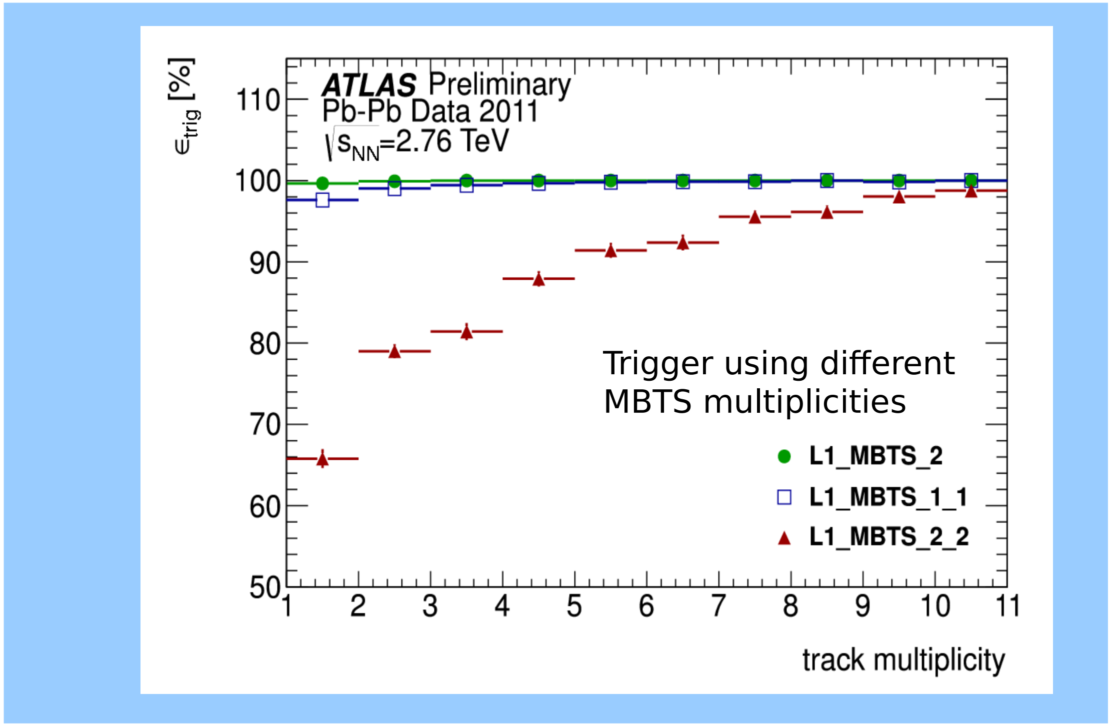
MBTS Trigger efficiency as a function of single track φ

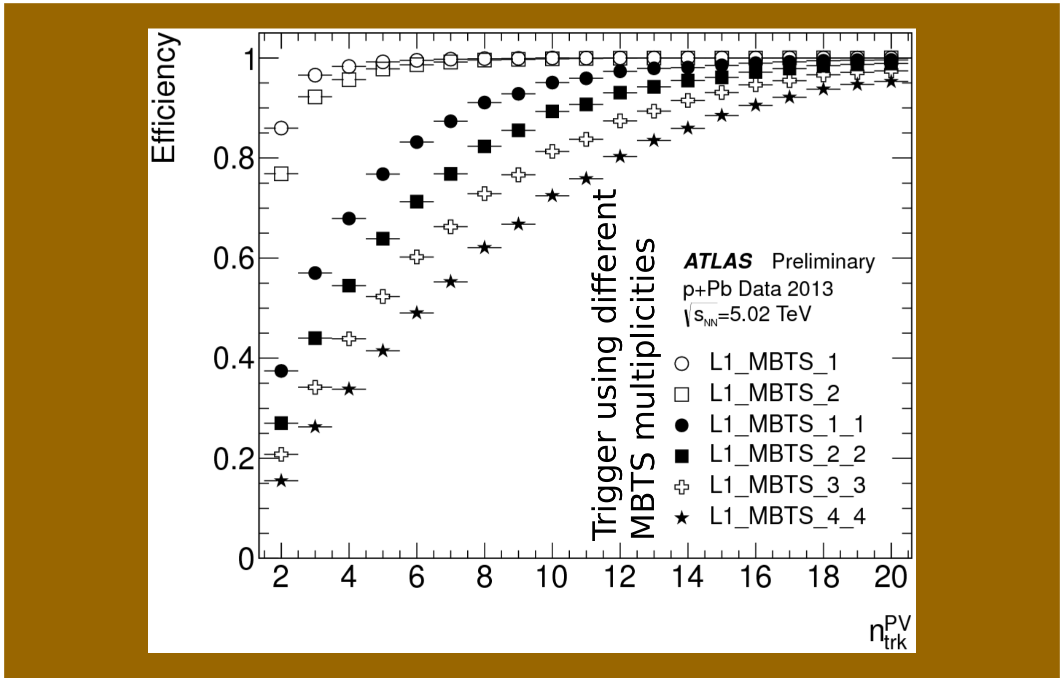


ATLAS-CONF-2010-068 (7 TeV)
ATLAS-CONF-2010-025 (900 GeV)

Extending to Heavy Ions Running



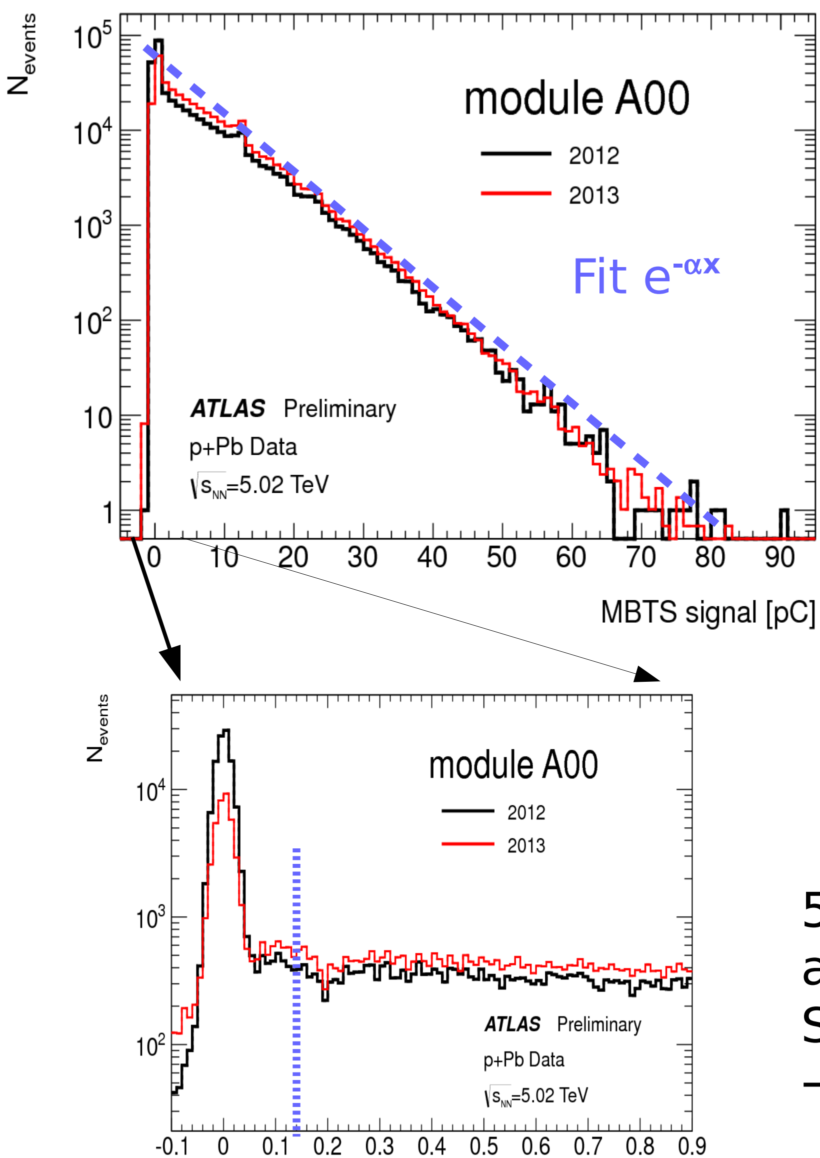




Different physics processes:
PbPb collisions in 2011,
pPb collisions in 2013
Different hardware settings (thresholds, PMT HV)
~30 fb^{-1} of pp collisions until 2013 data taking
→ Still good single track performance

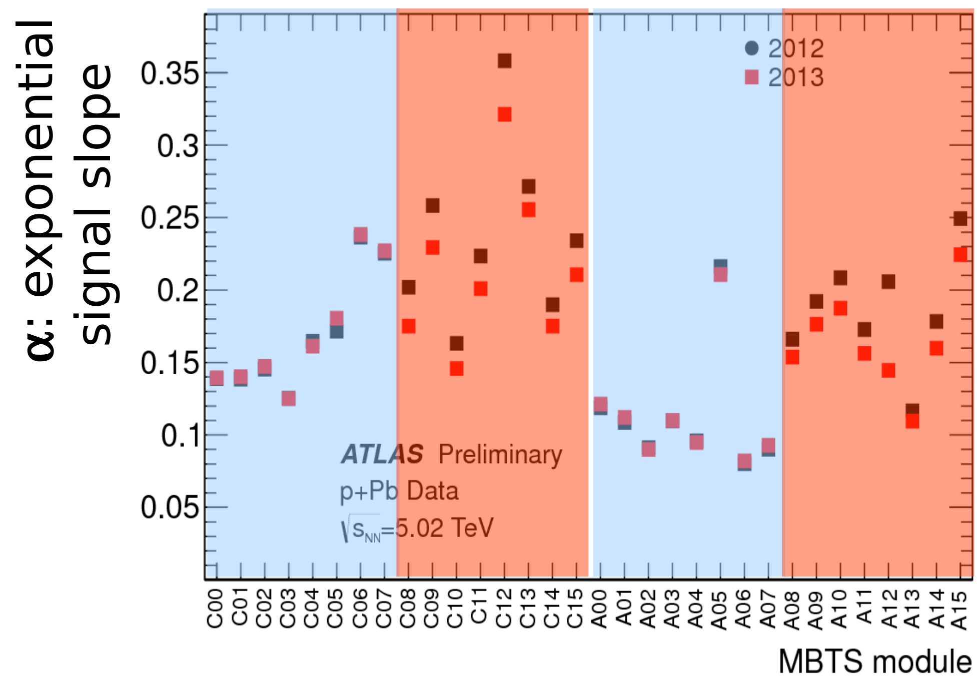
ATLAS-CONF-2012-122
ATLAS-CONF-2013-104

Run I Performance



Threshold LE
Discriminator value

ATLAS-CONF-2013-104



Inner MBTS Modules

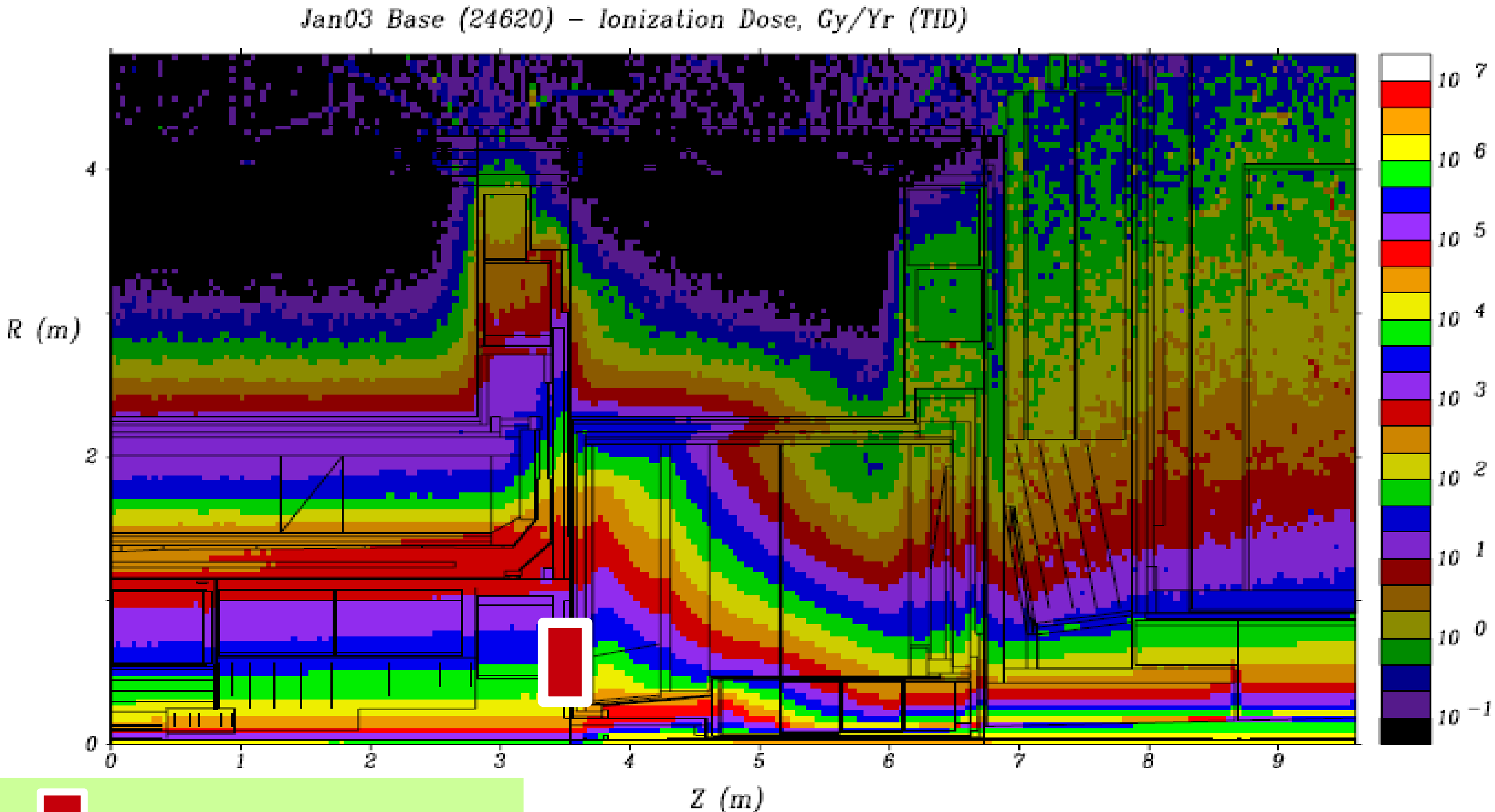
Outer MBTS Modules

5 fb^{-1} of pp collisions between September 2012 and January 2013 measurements

Slightly changed LE threshold values and PMT HV

→ Same physics process (pPb collisions)

Radiation Dose



@10^4 Gy → ~50% Loss Light Transmission

MBTS position

Ionization dose (Gy) prediction after 1 year at 10^{34} $cm^{-2}s^{-1}$ at $\sqrt{s}$=14 TeV

In Run I MBTS accumulated ~0.21 x (0.5-2.0)x 10^4 Gy = [0.1~0.4] x 10^4 Gy

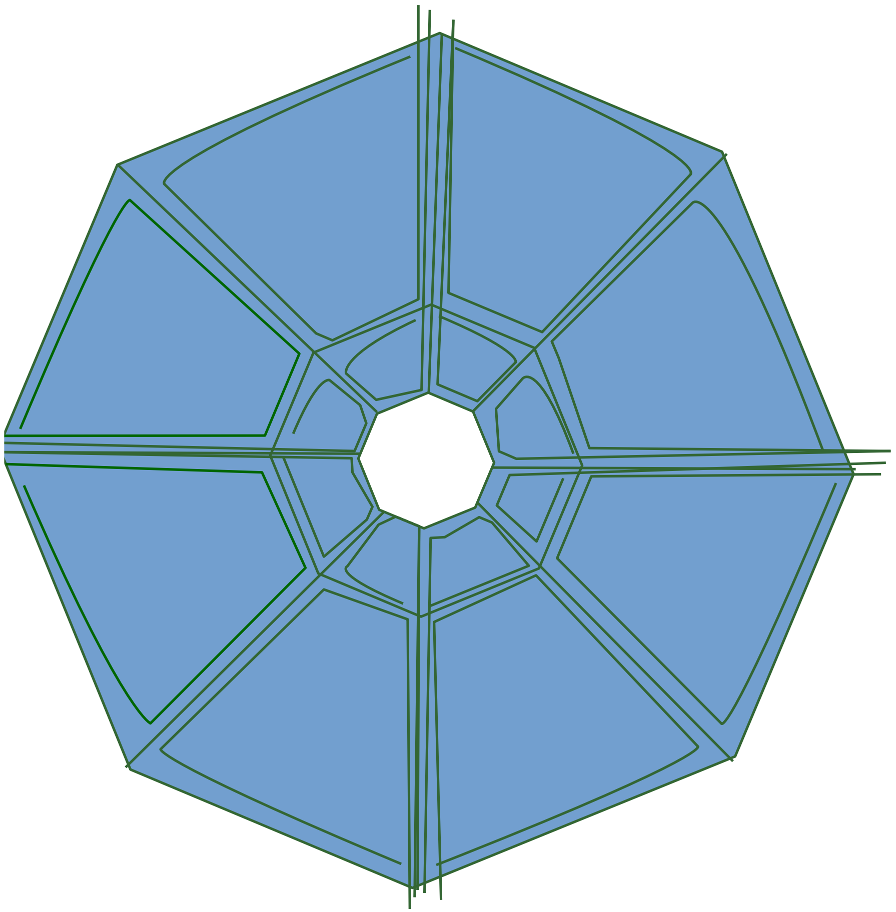
MBTS in Run II

Decided to keep the same Run I readout scheme
→ Instrument Tile crack scintillators
→ need to reduce number of channels used by MBTS

Instead of 16 x 2 channels use 12 x 2 channels.

Reduced granularity for outer disks (4 per side) → Coupling of optical fibers from adjacent scintillators
Kept same granularity for inner disks (8 per side)

→ Maximum care to guarantee the same light yield than in RunI



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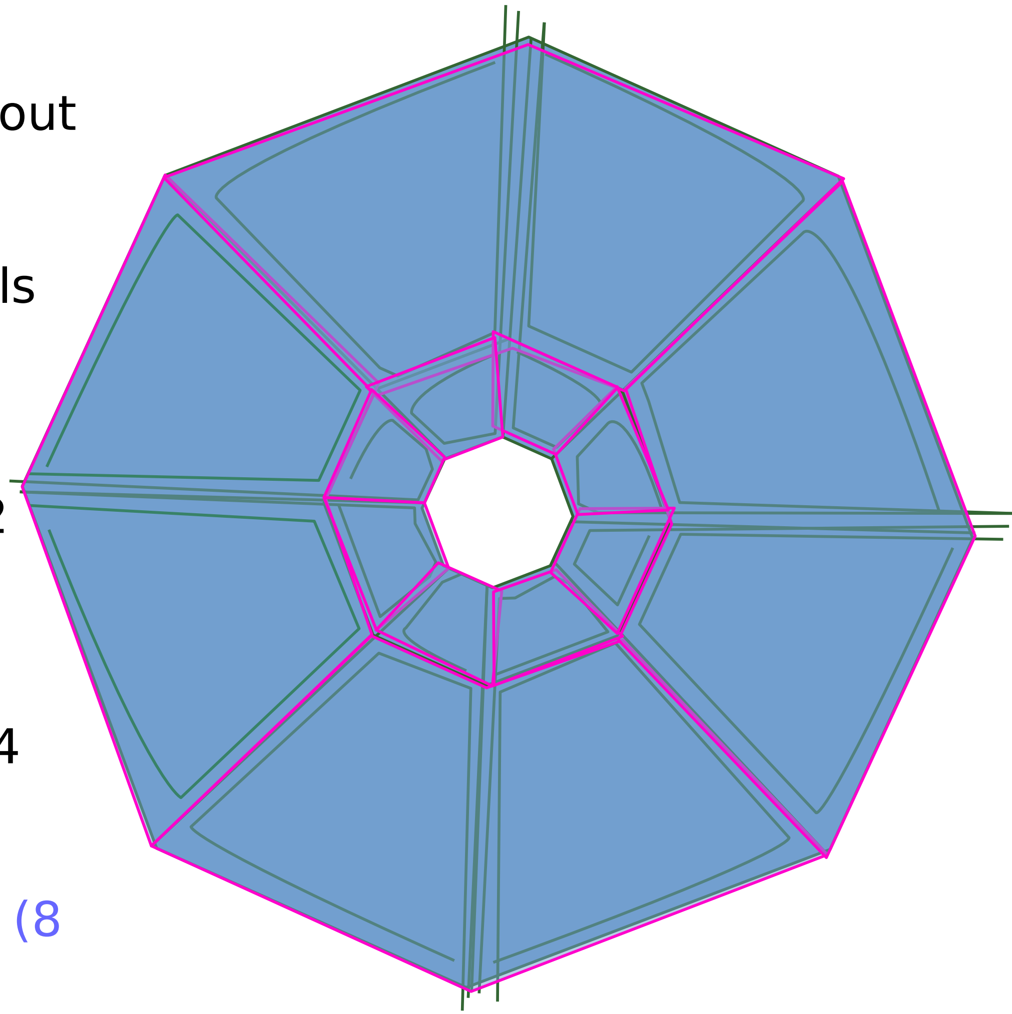
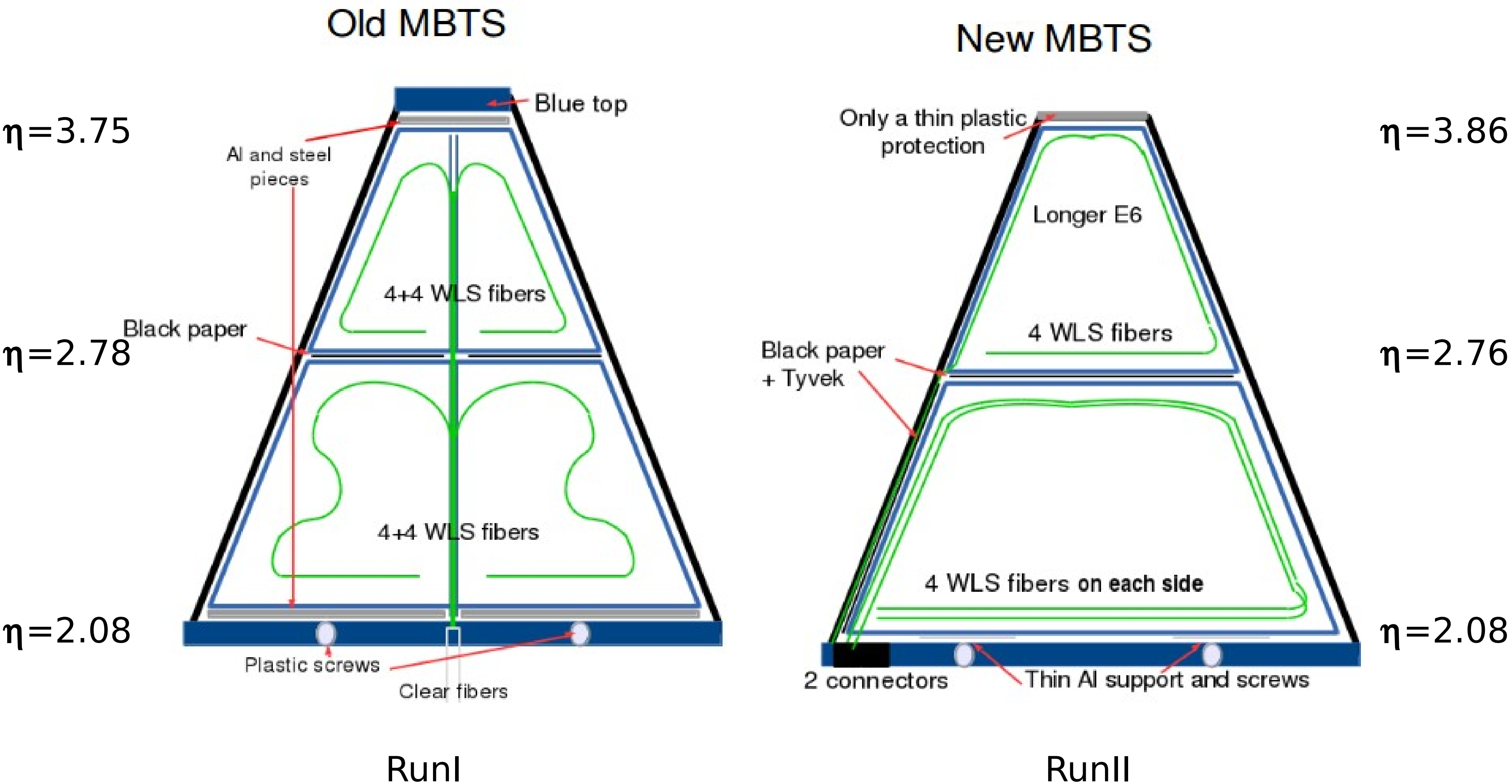
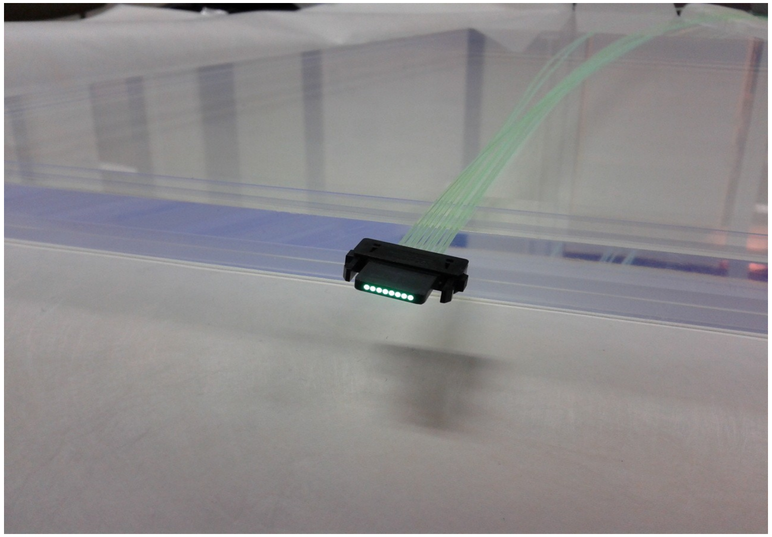


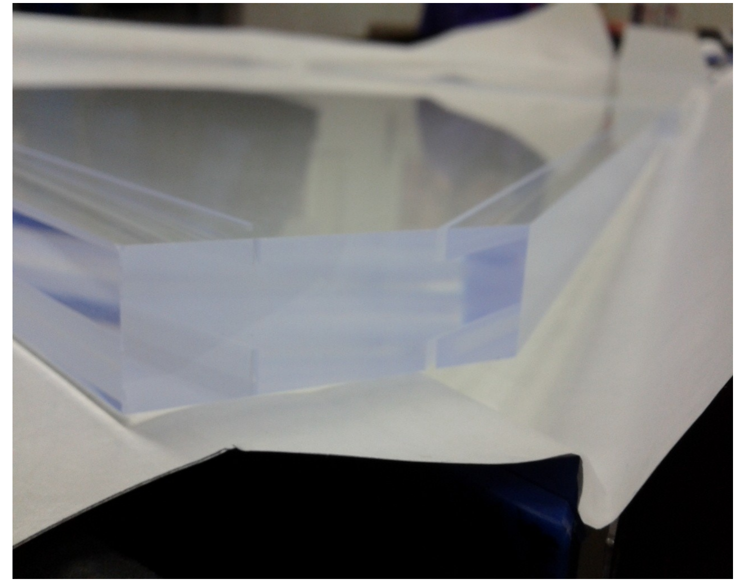
MBTS: Run I vs Run II Design

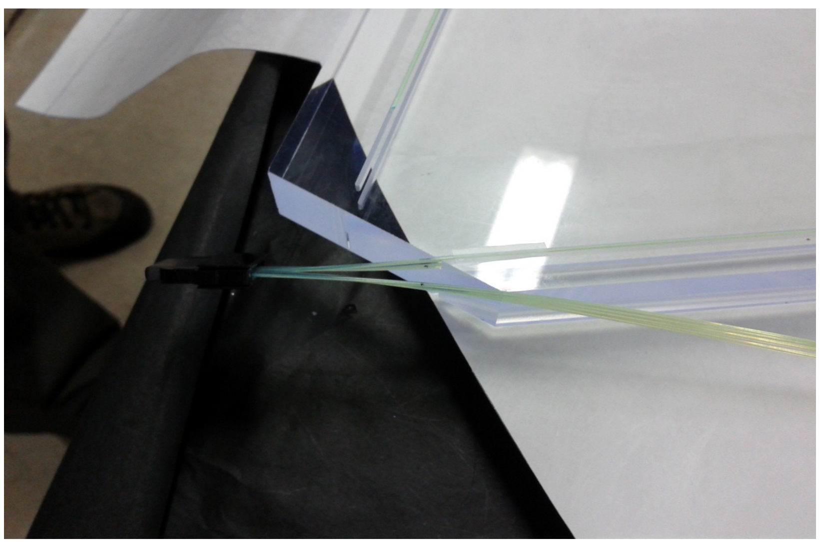


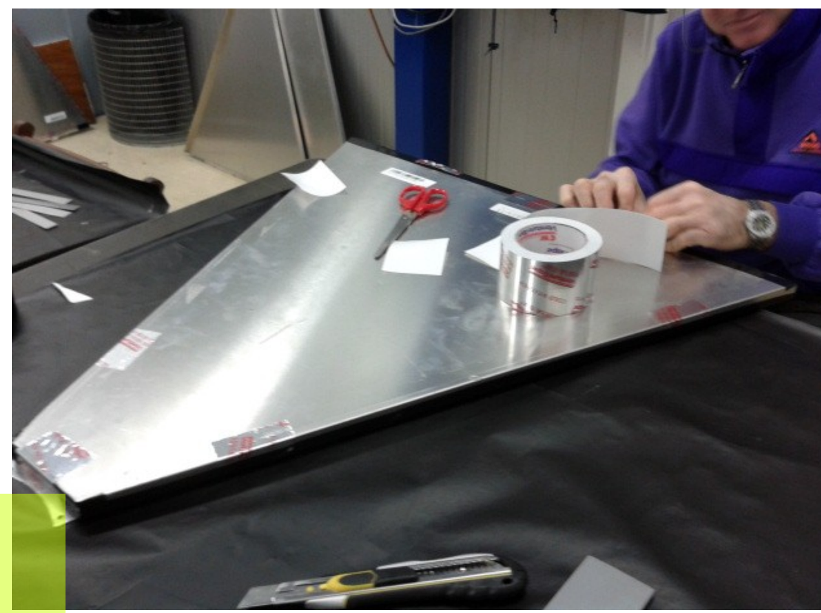
Black paper to avoid cross-talk
Fiber grooves (depth = 4.5 mm) (Kuraray Y11 (200) MSJ)
4 fibers on each side (8) for large scintillator
4 fibers for small scintillator
Connection fibers Bicron BCF -98 (1mm)
Slight geometry change in Run II (increase η coverage)

MBTS Run II Construction







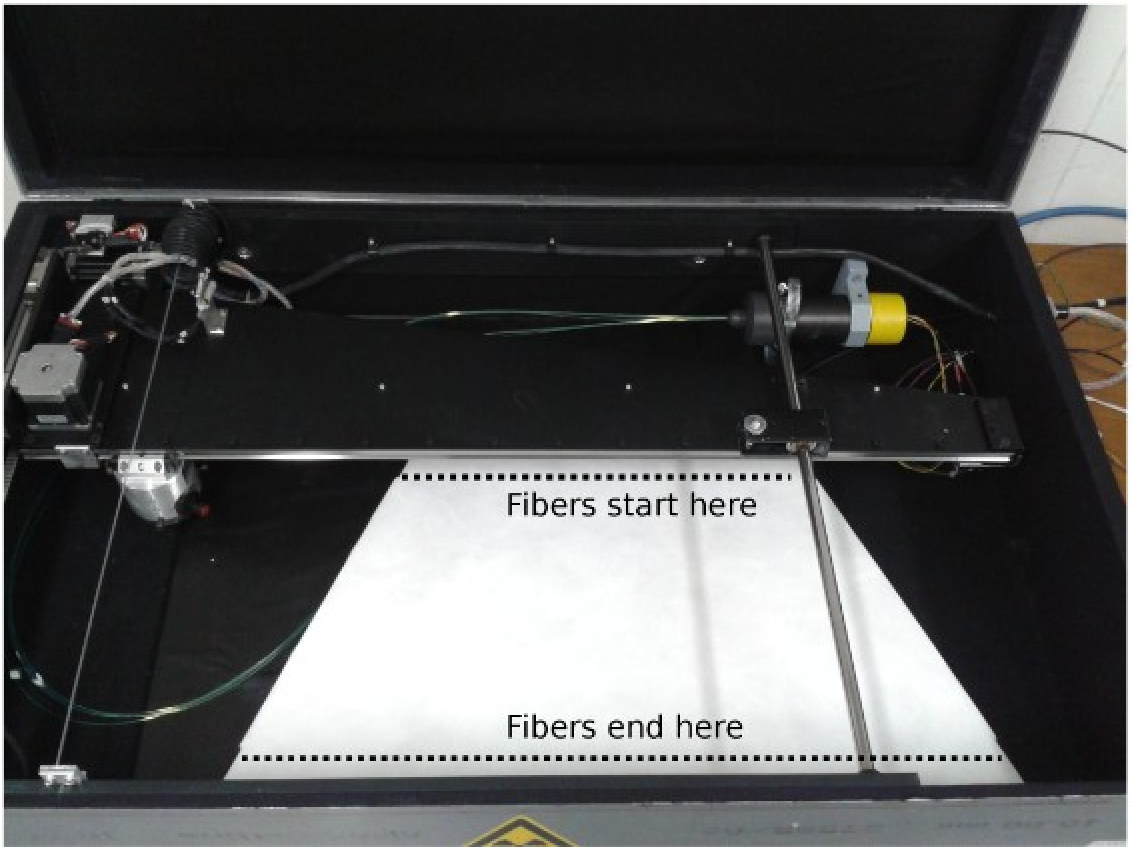


MBTS side A already installed
MBTS side C to be installed before May 2014
Upgraded system will join ATLAS common cosmics data taking in July 2014

MBTS Side A Installed!

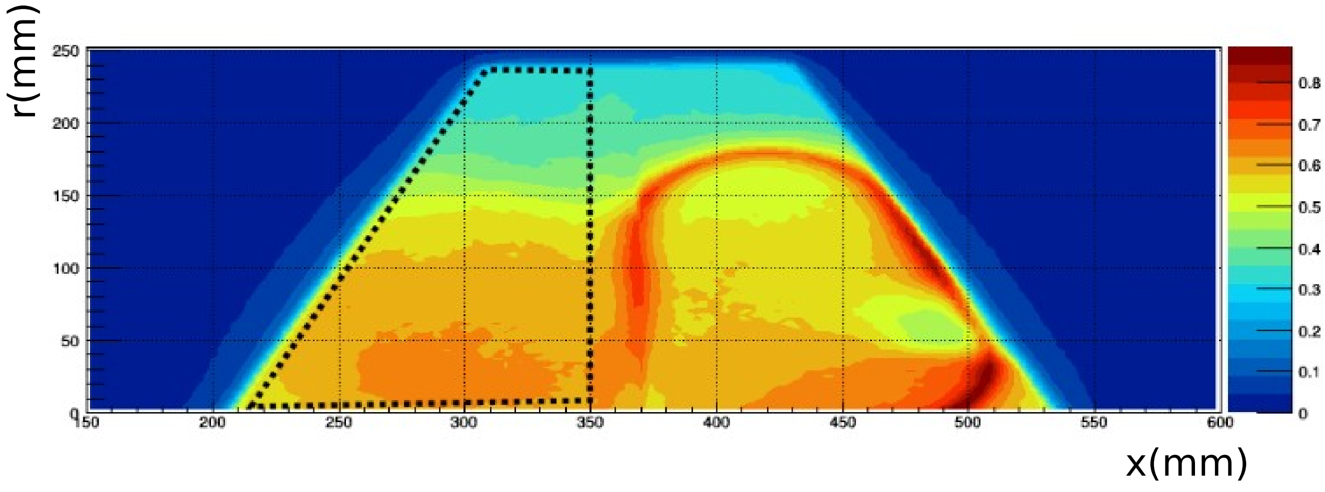
MBTS Run I *vs* Run II

Light transmission checked with Sr90 source



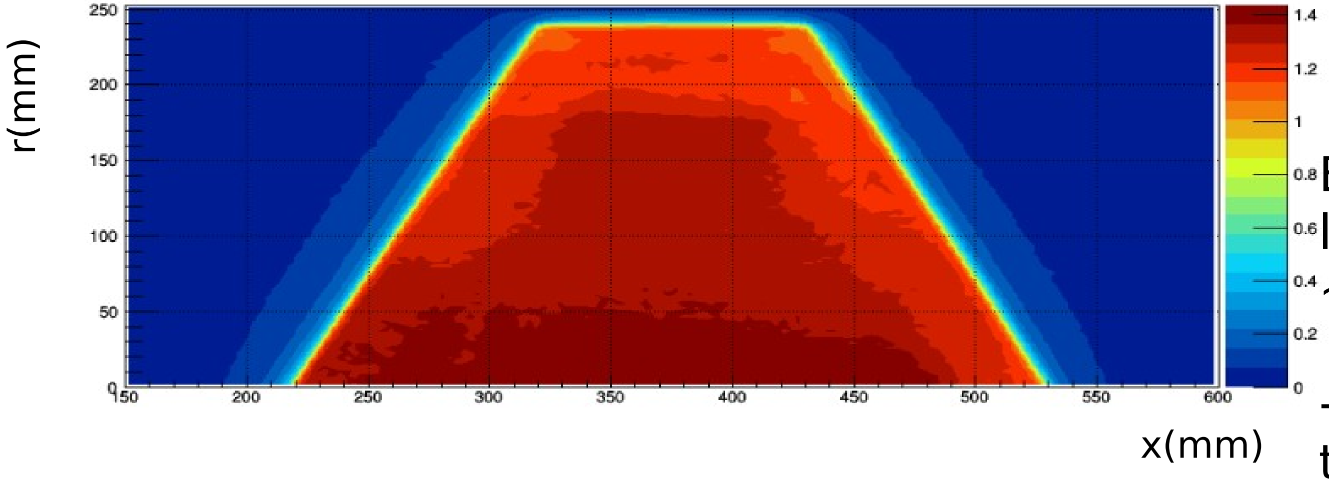
Test scintillator and fibers moving the Sr source on the scintillator surface
→ precise relative map of light transmittance

MBTS Run I vs Run II



Inner MBTS scintillators

Run I:
Moderate R dependence on irradiated sample
→ Damage from radiation under control (or recover)



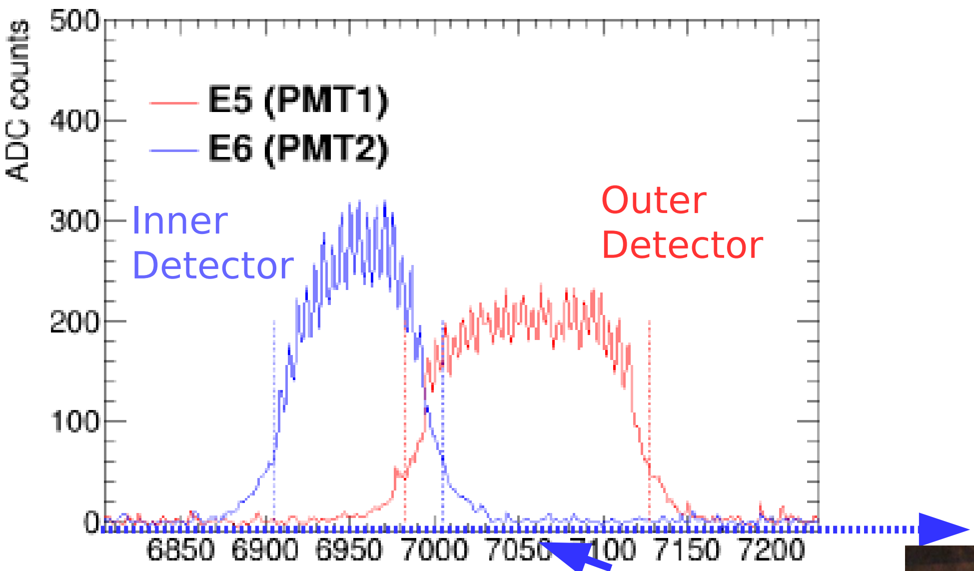
Run II:
→ more uniformity

Expected light yield wrt Run I larger for inner scintillators
~similar for outer ones

→ Full light yield depends on the full optics path

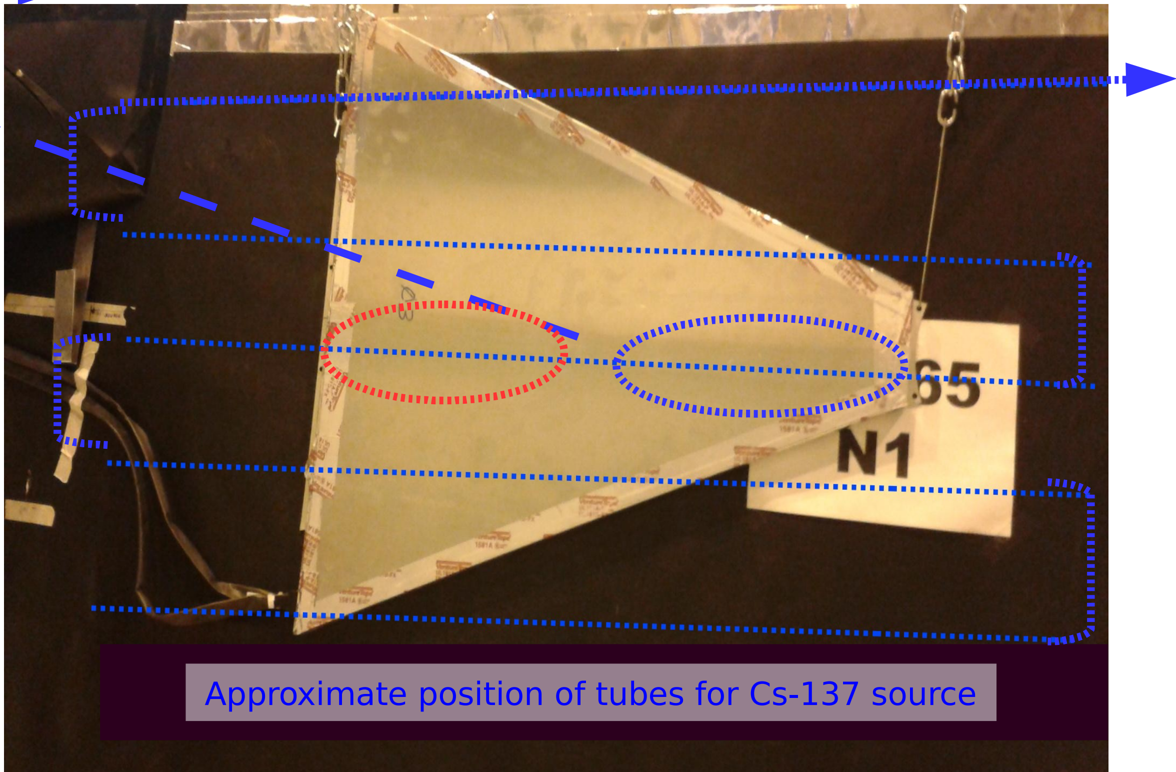
Relative check of light transmission

Cs Scans



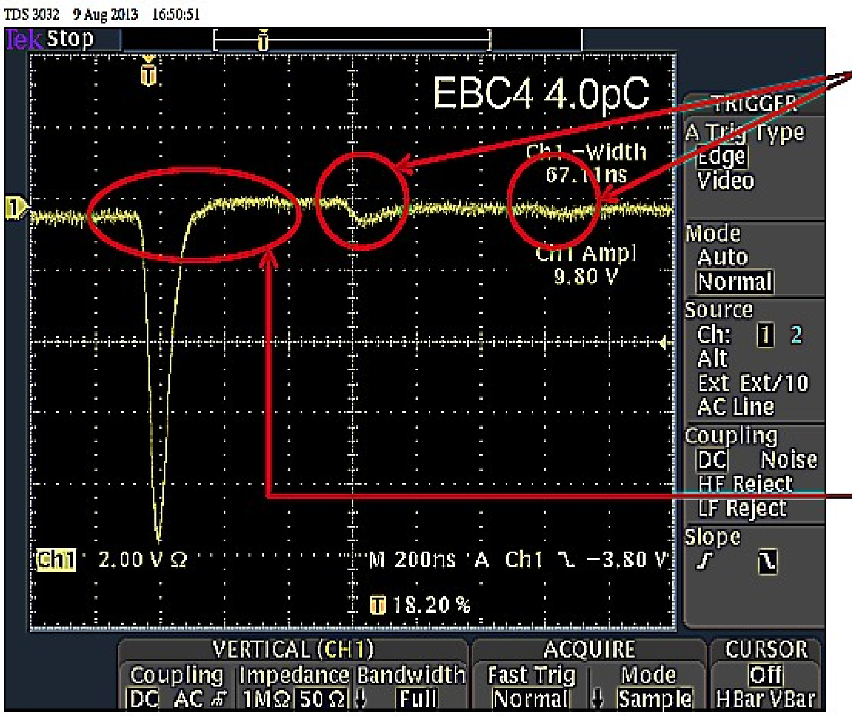
Position of Cs probe

All MBTS counters have been scanned with Cs scan setup
Checks performed on optics quality and response checks of every scintillator assembly before installation.

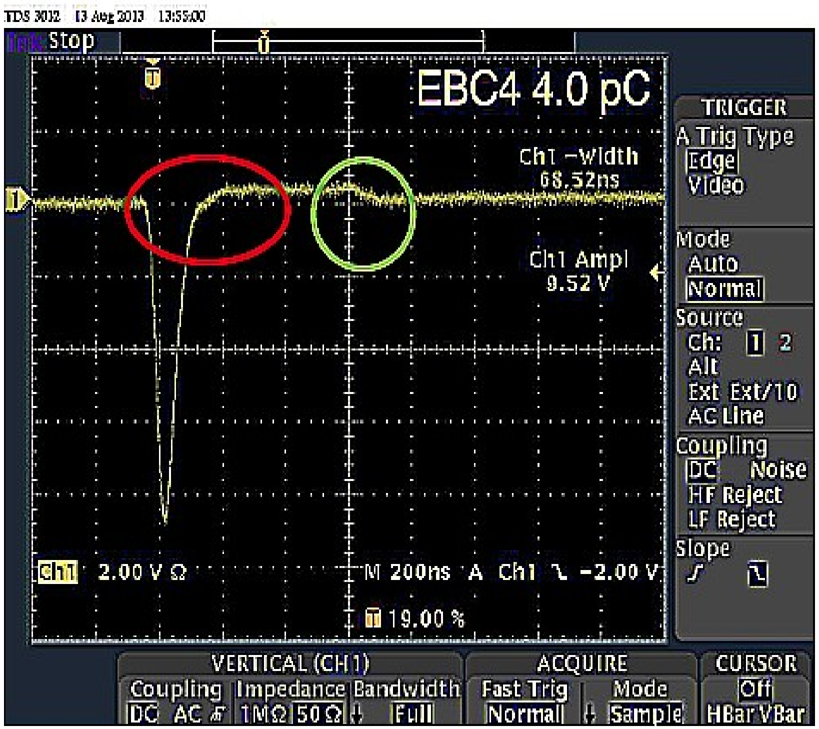


Modifications from Run I

Reflections → causing large accidental rates
From adapter boards for trigger signal impedance mismatch



Before the input impedance fix



After the input impedance fix

Use Constant Fraction Discriminator
Large signal variations
time walk fix

Conclusions

MBTS upgrade for Run II is progressing well

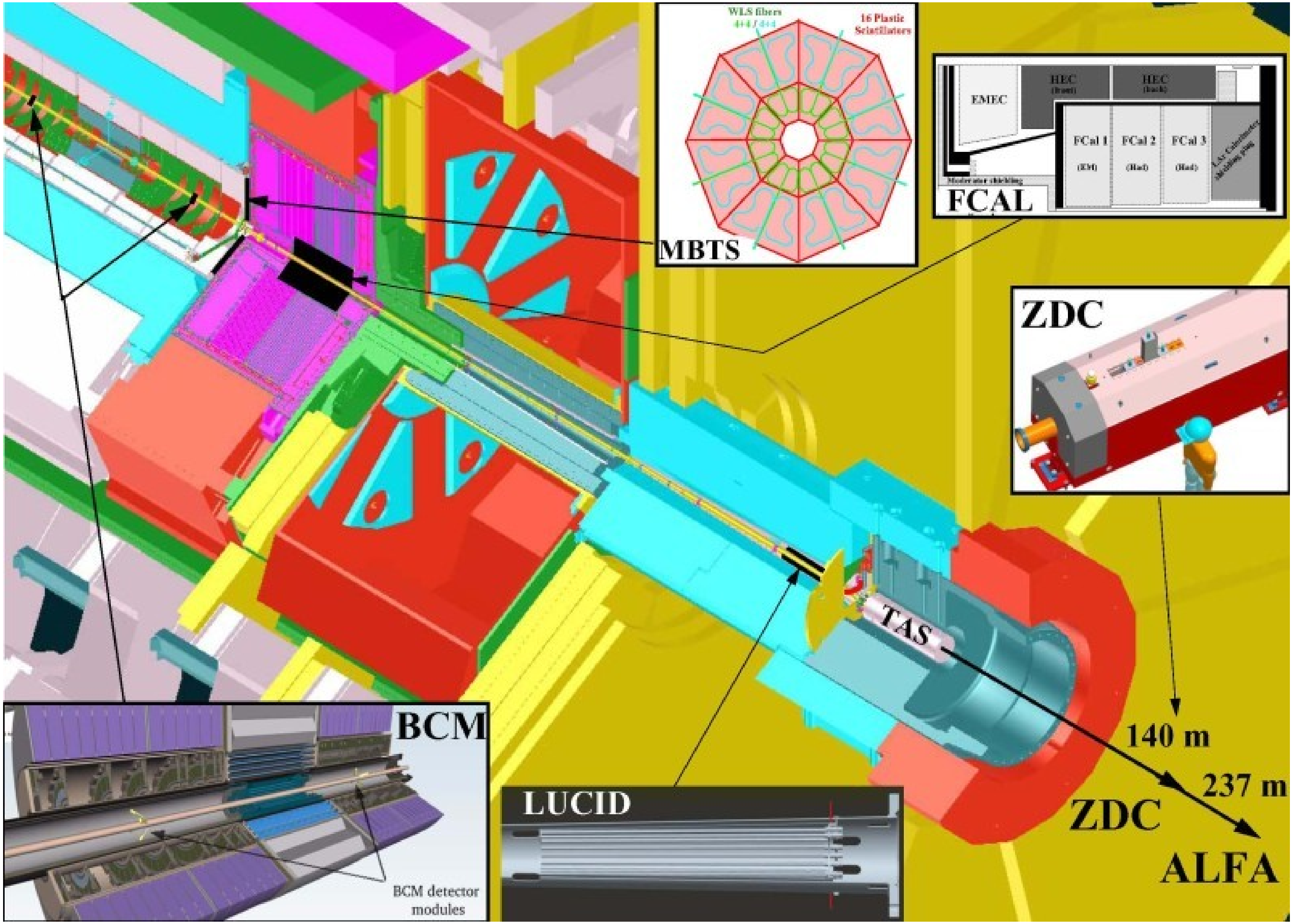
→ Crucial to trigger on *"Soft QCD"* physics events during first Run II LHC fills
→ MBTS still useful for all low luminosity LHC fills
Damage from radiation seems under control

Adjustment of electronics to fix issues suffered during Run I operations

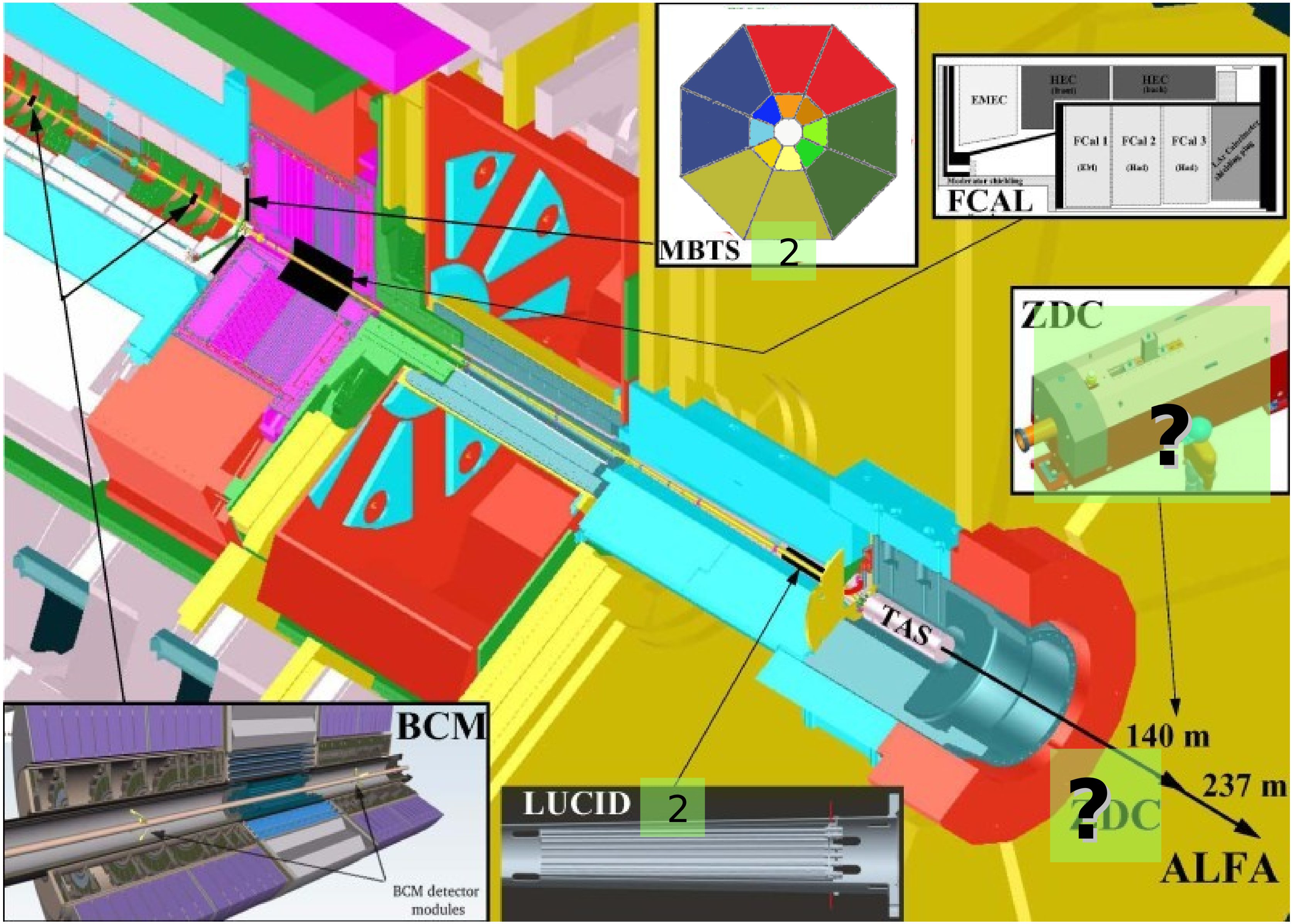
In the remaining part of 2014 (before LHC start up)
→ optimization of PMT HV and thresholds
→ Cosmic test stand
→ Join ATLAS common cosmic data taking (from July 2014)

BackUp

The ATLAS Forward Detectors (LHC Run I)



The ATLAS Forward Detectors (LHC Run II)



AFP

Experimental Tools II: Rapidity Gaps

For ND events $dN/d\eta(@P_T>100\ \mathrm{MeV}, \sqrt{s}=7\mathrm{TeV})\sim 6 \rightarrow \langle\eta_j-\eta_k\rangle\sim 0.15$ (cf G. Brandt talk)

Larger η gaps are exponentially suppressed except for Diffractive events

Measuring $\Delta\eta$ is a measurement of $M_{X(Y)}$

$$\Delta\eta = \ln s/M_X^2 = -\ln\xi$$

Difficult measurement of $M_{X(Y)}$ → Produced particles escape undetected in the beam pipe

η acceptance is defined in the largest η range $-4.9<\eta<4.9$

→ However max η gap determined by MBTS position (→ trigger) (Max $\Delta\eta\sim 8$)

Using ID+EM+HEC+FCAL

Experimentally (detector) η rings (variable width 0.2, 0.4 according to η region):

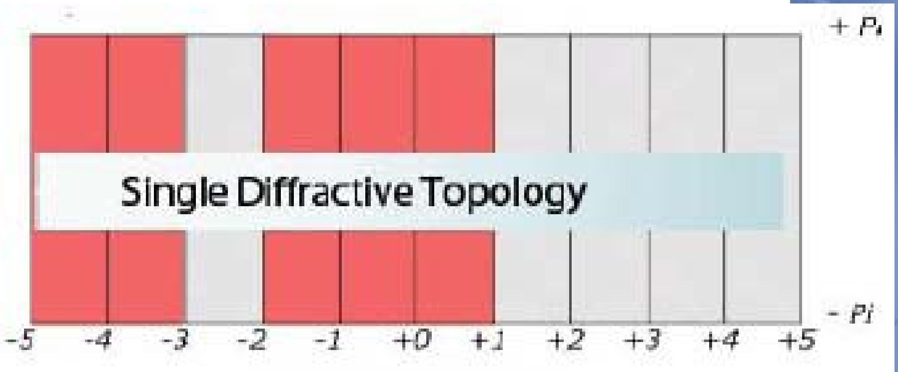
Active ring if:

- At least one track with $P_T>200$ MeV (also P_T threshold=400,600,800 MeV/c)
- At least one calorimeter cell above noise threshold (η-dependent threshold, no noise in Tile) and E_T cut (same as track)

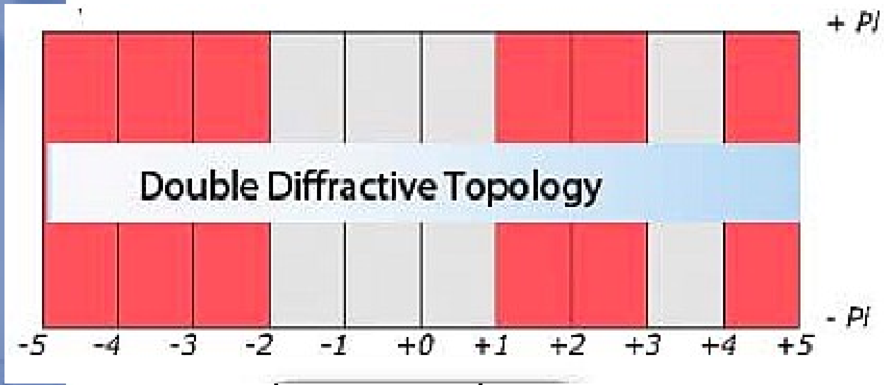
Large Rapidity Gaps

$\Delta\eta_F$ is defined as "largest η gap in the event"

Large $\Delta\eta_F$ sample is composed by SD + DD Events



$\Delta\eta_F$=4

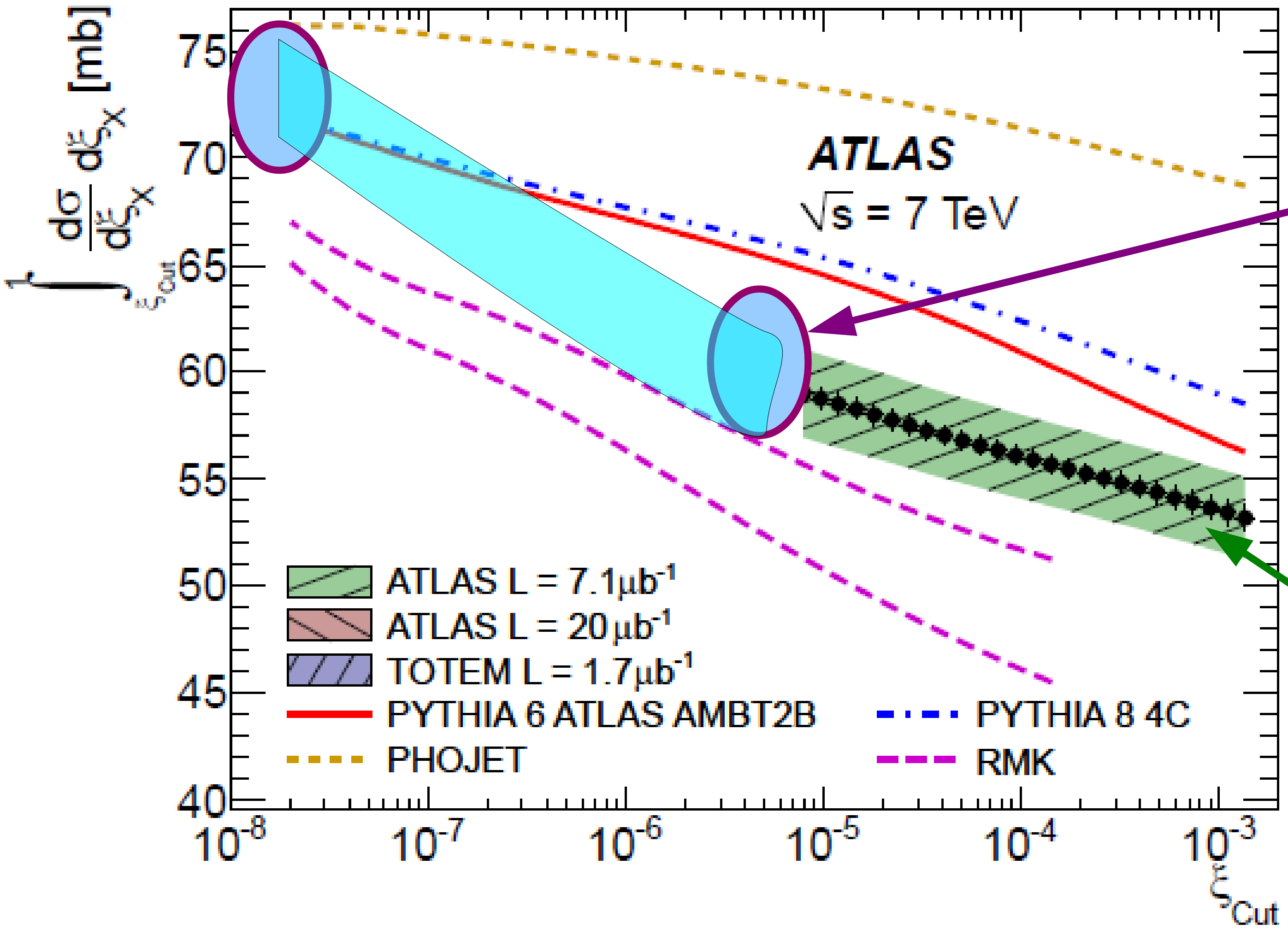


$\Delta\eta_F$=0 since Rapidity gaps start at η edge

Measure differential cross section varying P_T thresholds and comparing different MC (PHOJET and Pythia 8)

$$\frac{d\sigma}{d\Delta\eta_F}$$

Cross Section as a function of Mx



Inelastic xsection with asymmetry

More low mass SD in data than in theory

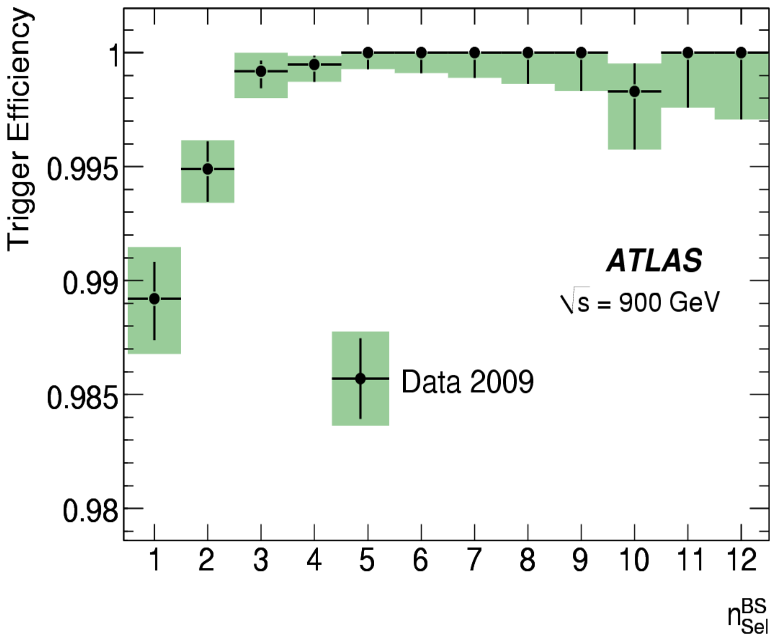
Current Measurement

Vertical bars → all uncertainty except luminosity

Single cross section measurements performed with detectors at different η

Reference: Eur. .Phys. J. C72 (2012) 1926, arXiv1201:2808

Trigger Efficiency 2009



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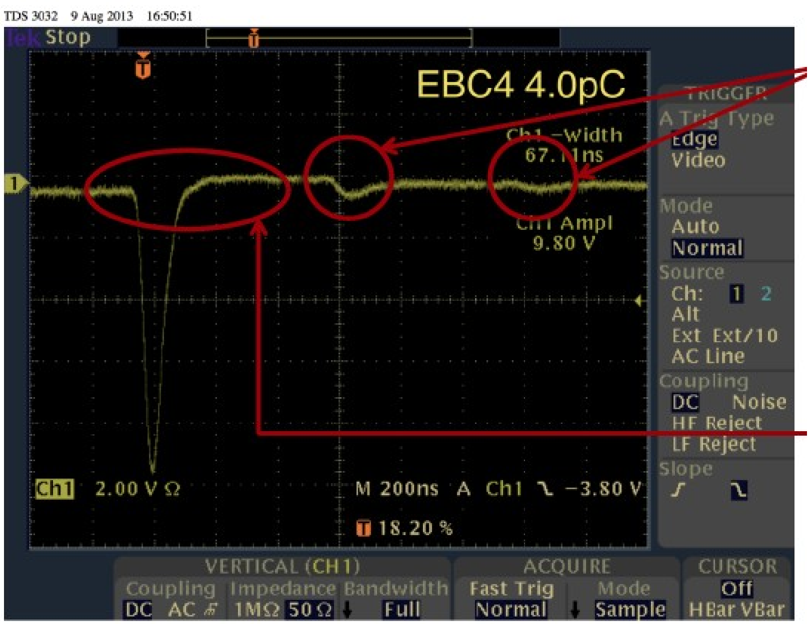

Before the input impedance fix

After the input impedance fix

Use Constant Fraction Discriminator
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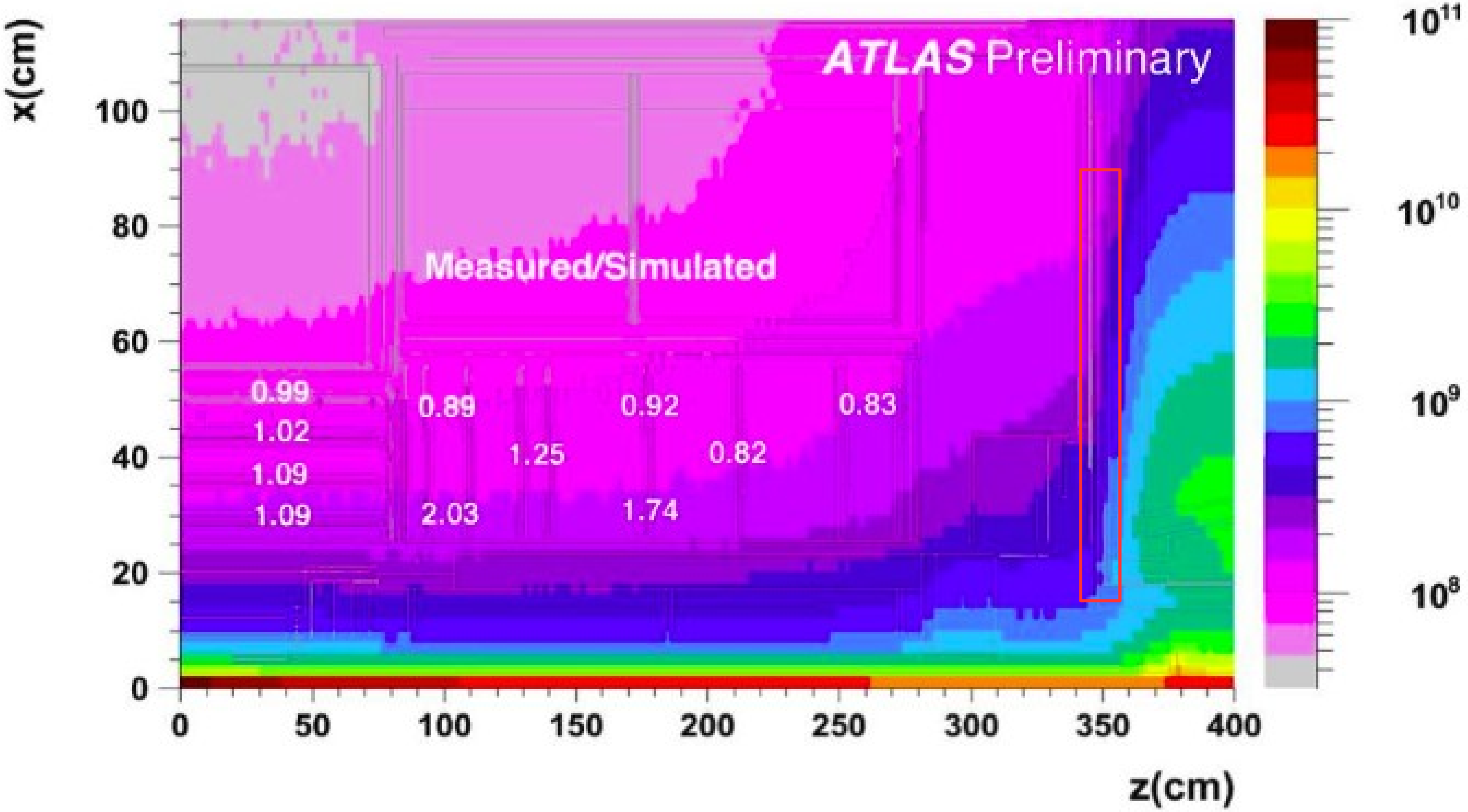
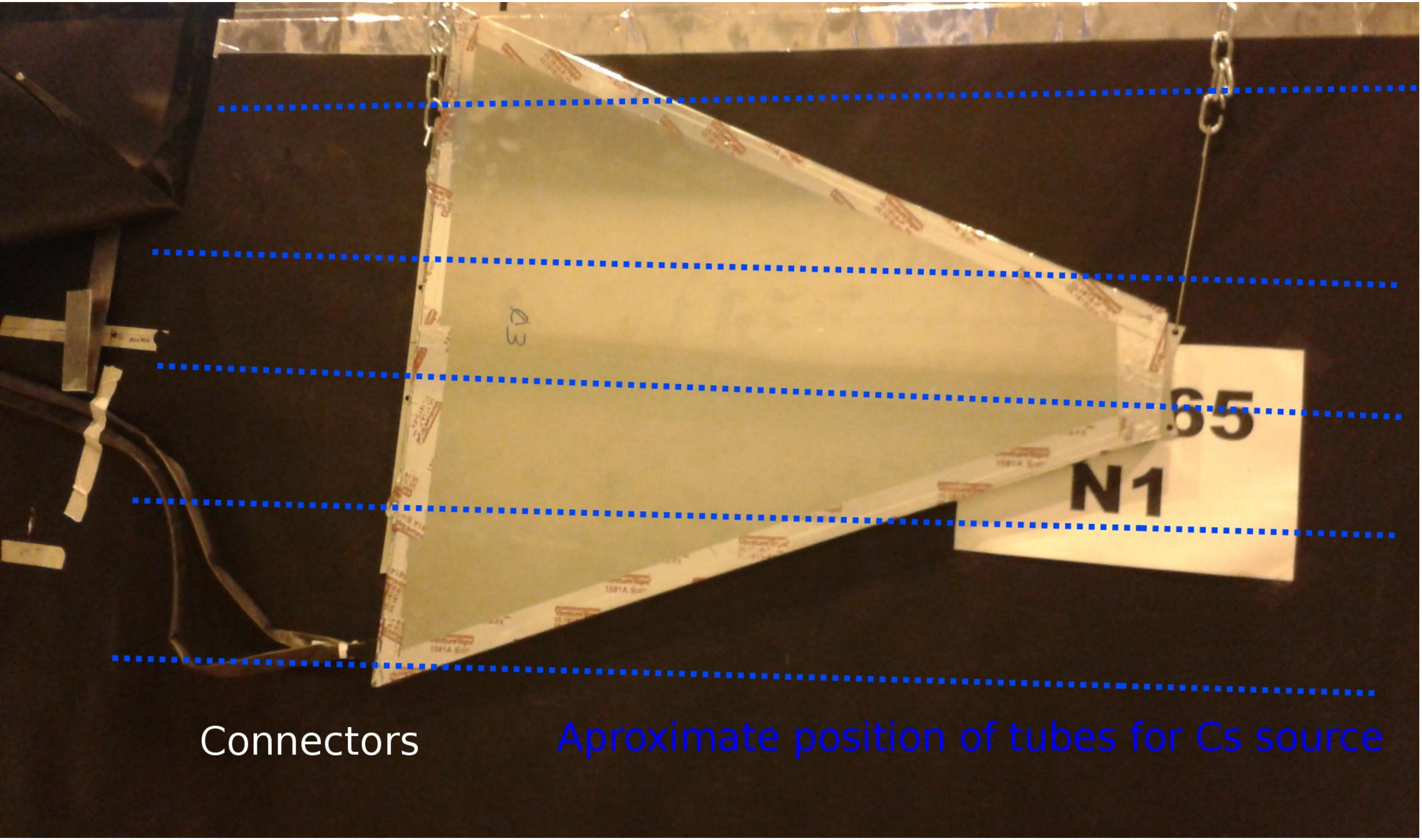
Dose Received



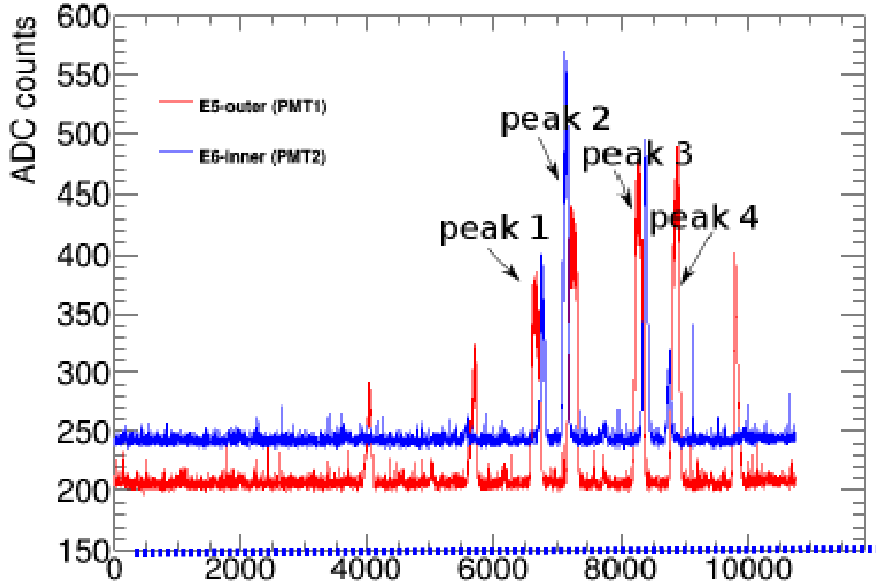
From TDR

Cs Scans for MBTS



Cs Scans for MBTS

Complete Signal



Blue: Inner Counter
Red: Outer Counter

Position of Cs probe