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QUARK MATTER KRAKÓW 2022

29TH INTERNATIONAL CONFERENCE ON ULTRARELATIVISTIC NUCLEUS - NUCLEUS COLLISIONS

APRIL 4-10, 2022

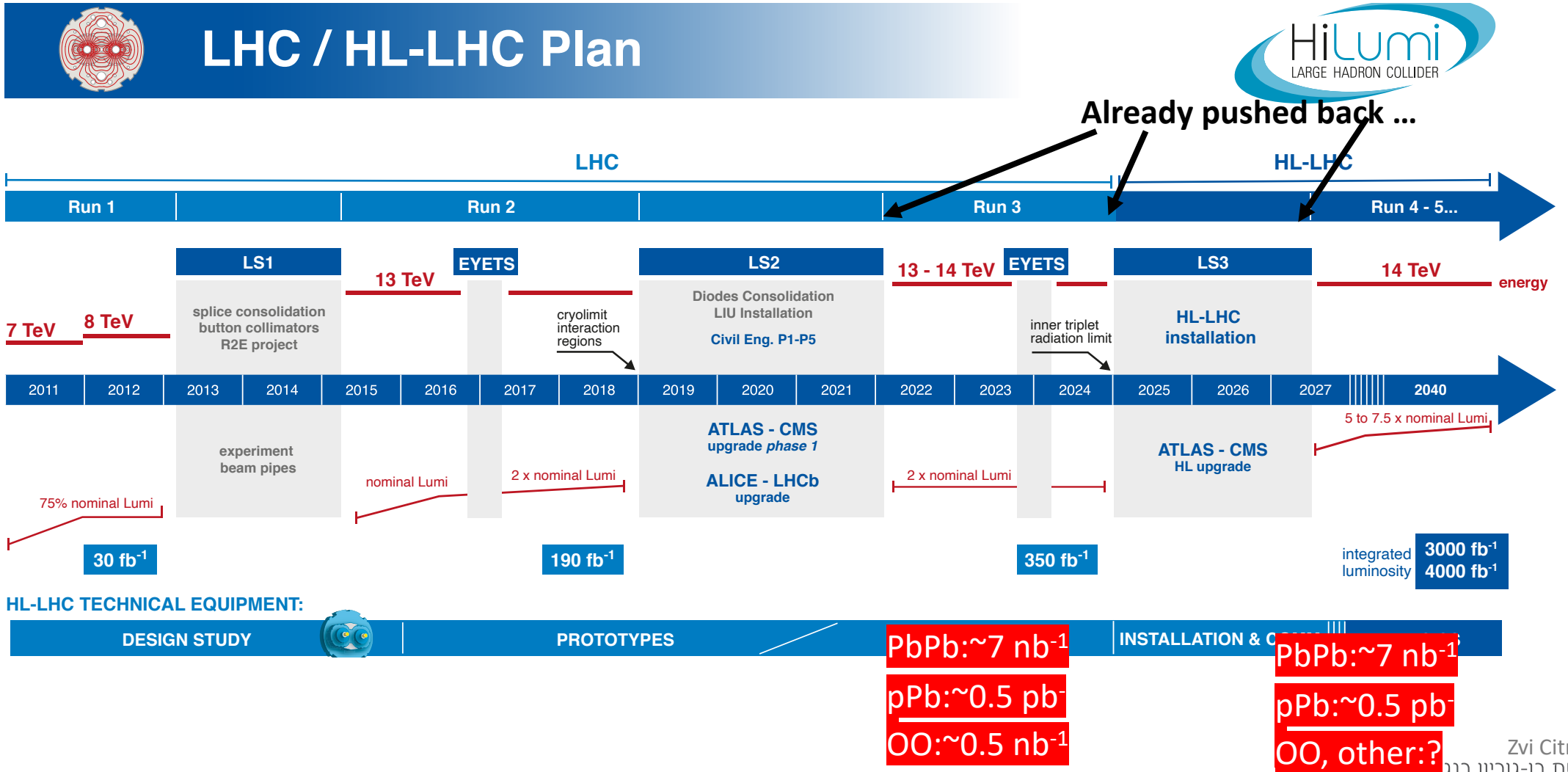
KRAKÓW, POLAND

The ATLAS Upgrade Program

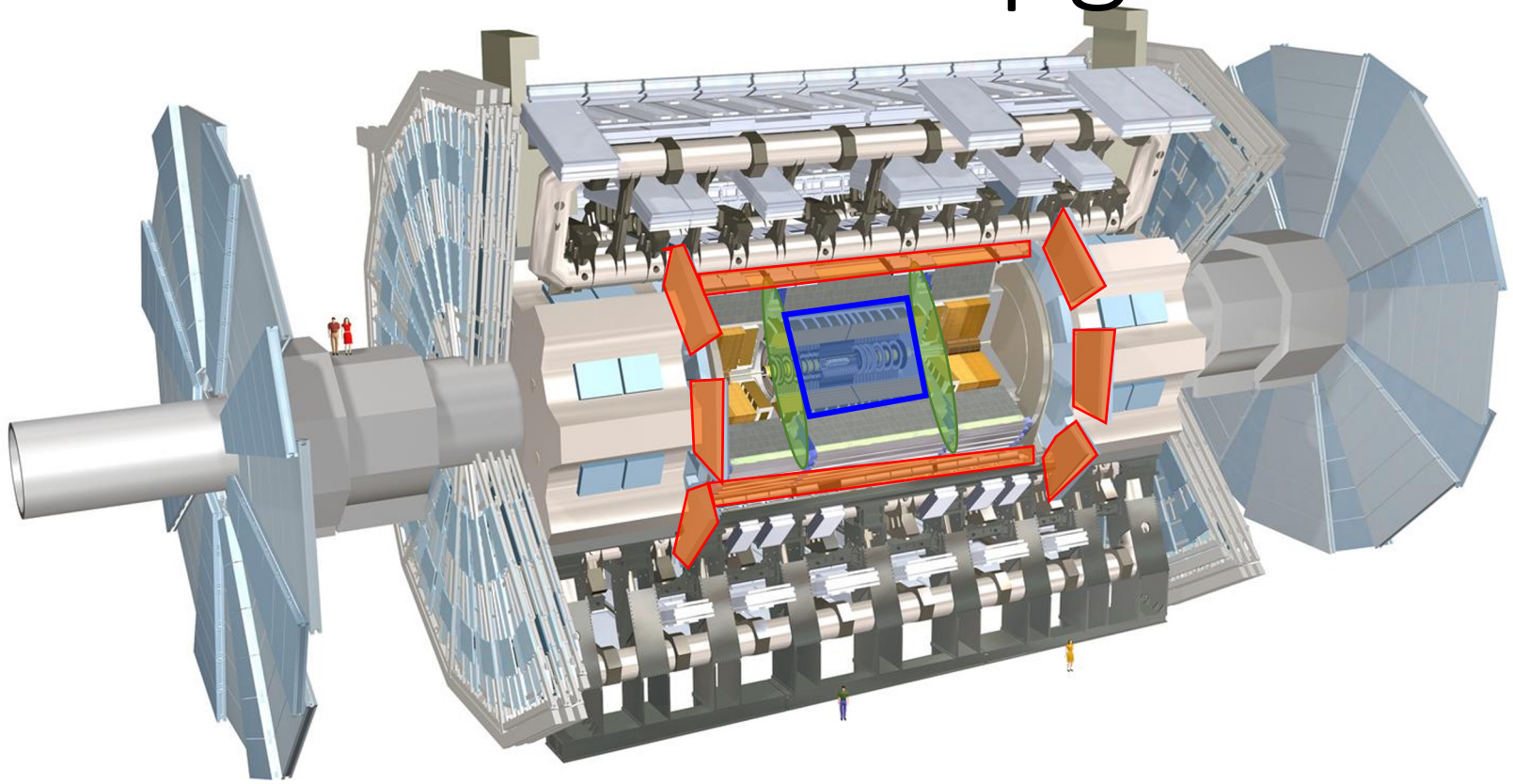
Zvi Citron for ATLAS

אוניברסיטת בן-גוריון בנגב
جامعة بن غوريون في النقب
Ben-Gurion University of the Negev

HL-LHC Schedule



ATLAS HL-LHC Upgrades



Upgraded Trigger and Data Acquisition System

- Single Level Trigger with 1 MHz output
- Improved 10 kHZ Event Farm

Electronics Upgrades

- On-detector/off-detector electronics upgrades of LAr Calorimeter, Tile Calorimeter & Muon Detectors
- 40 MHz continuous readout with finer segmentation to trigger

High Granularity Timing Detector (HGTD)

- Precision time recon. (30 ps) with Low-Gain Avalanche Detectors (LGAD)
- Improved pile-up separation and bunch-by-bunch luminosity

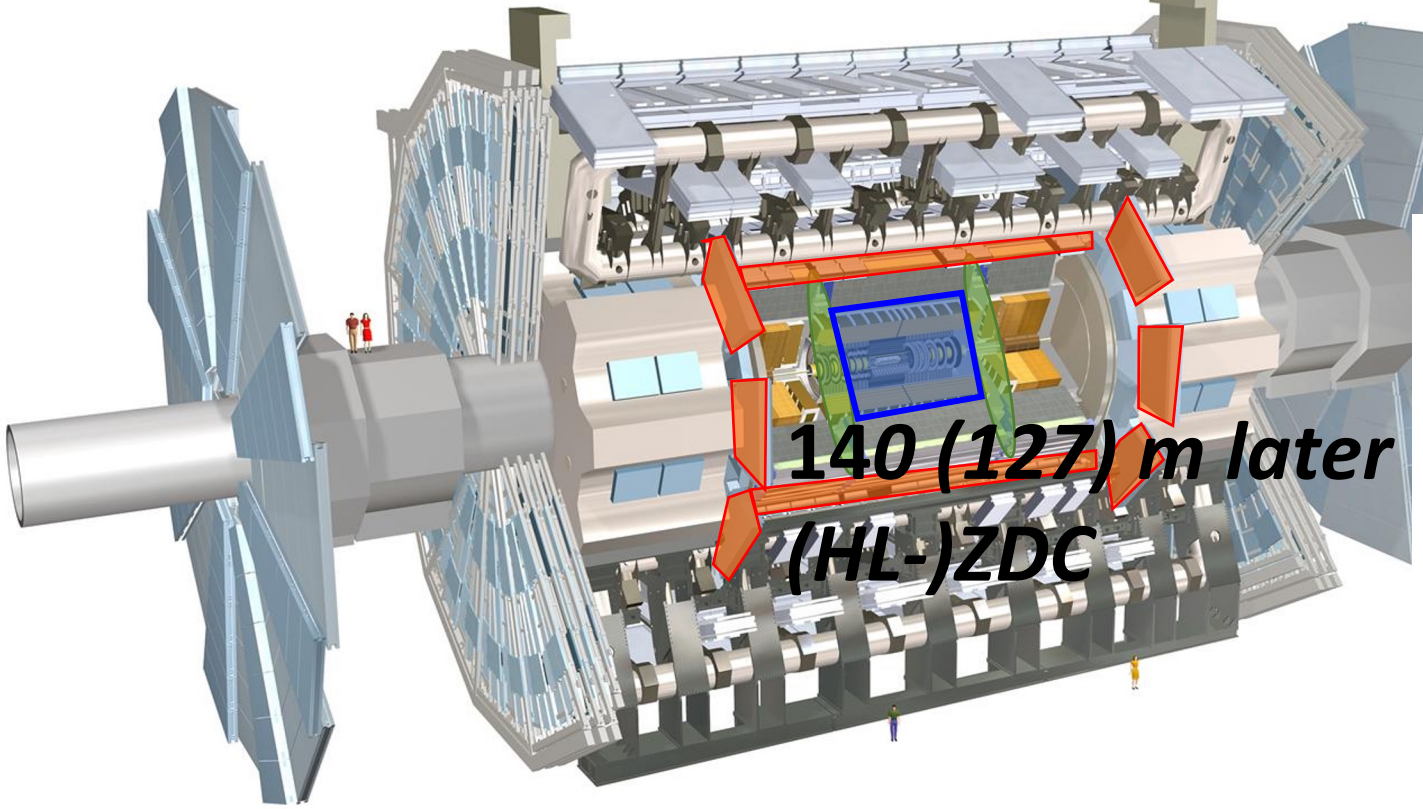
New Muon Chambers

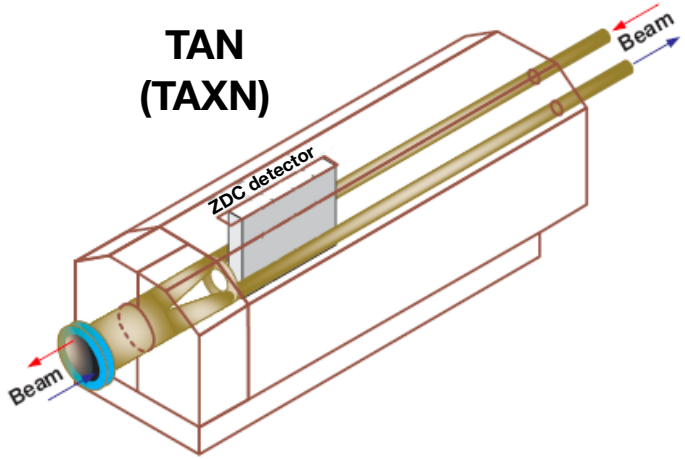
- Inner barrel region with new RPCs, sMDTs, and TGCs
- Improved trigger efficiency/momentum resolution, reduced fake rate

New Inner Tracking Detector (ITk)

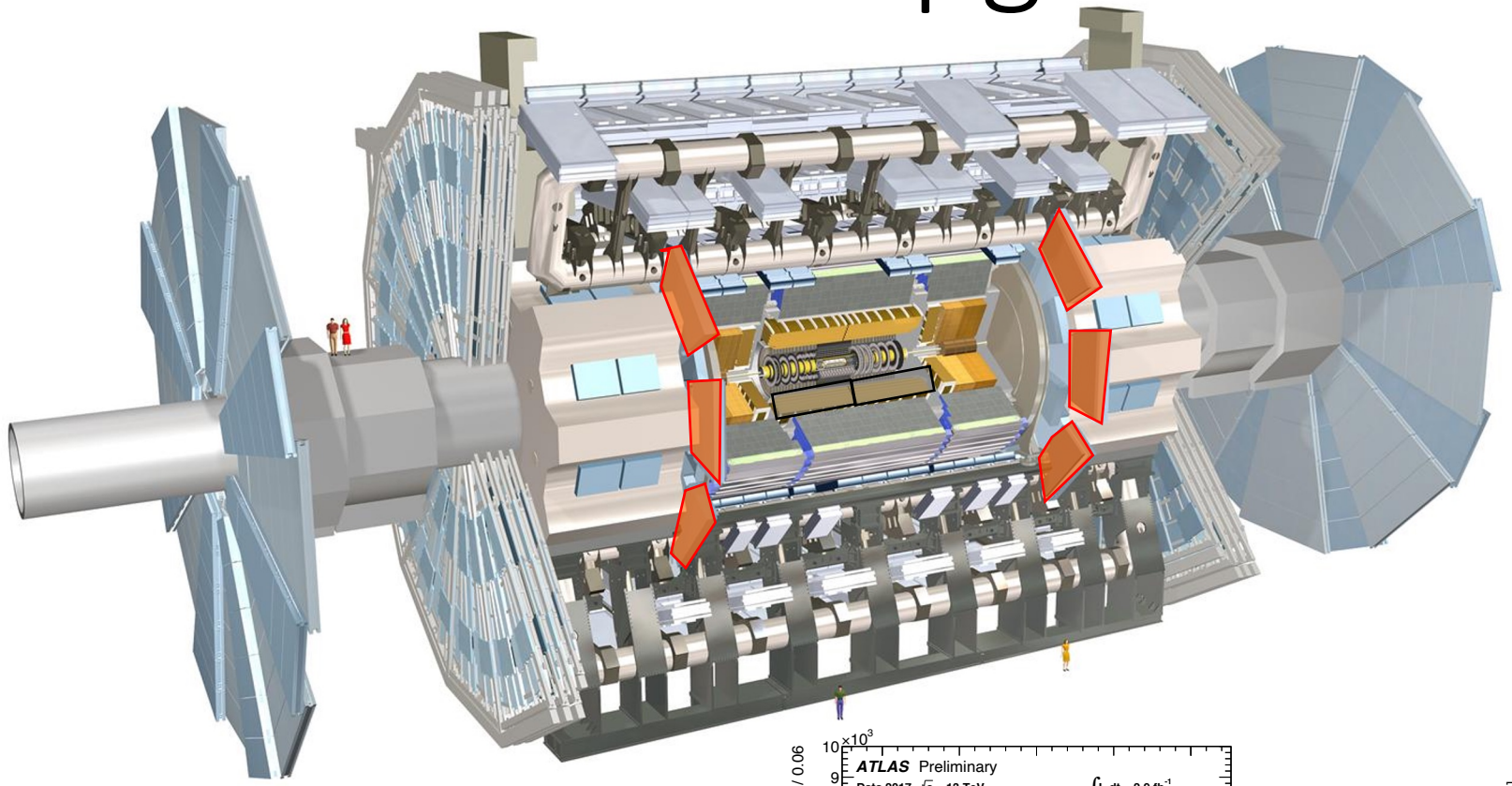
- All silicon with at least 9 layers up to $|\eta| = 4$
- Less material, finer segmentation

ATLAS HL-LHC Upgrades





ATLAS Run 3 Upgrades

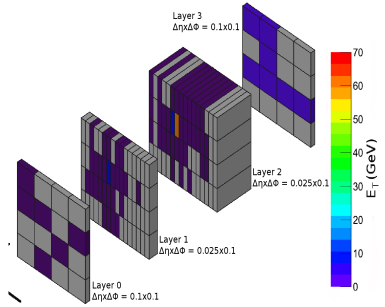


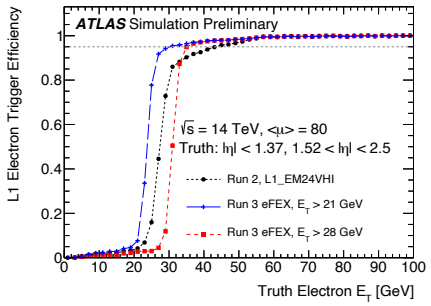
TDAQ Upgrades

- Many upgrades for Run 3 on the way to HL-LHC
- L1 and HLT improvements

LAr Calorimeter Upgrades

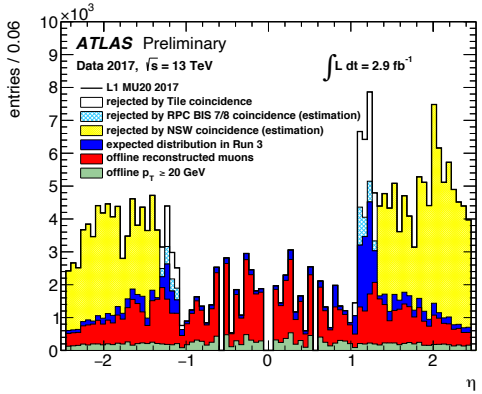
- Segmented Super Cells replace coarse trigger towers
- Shower shape discrimination at trigger level

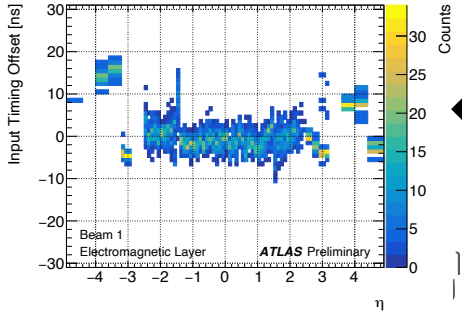




New Muon Chambers

- New Small wheels Installed!

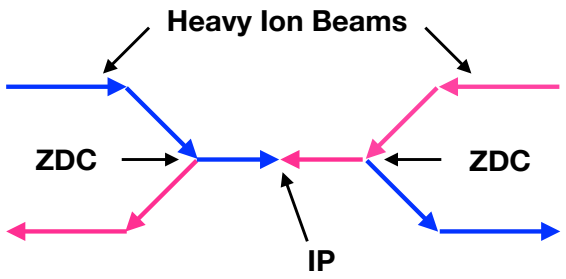


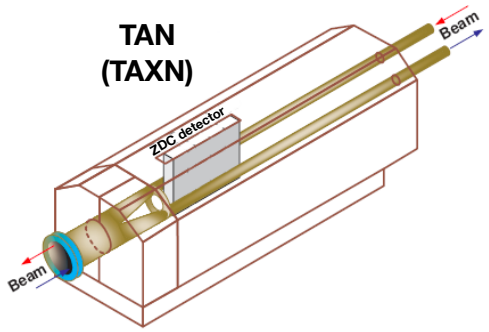


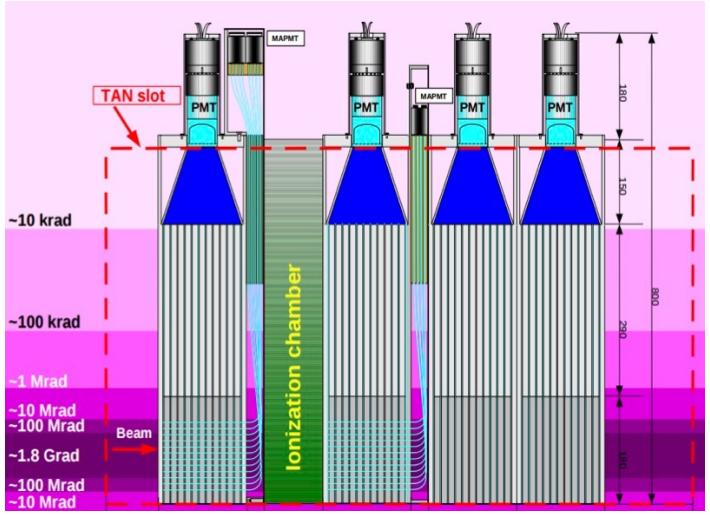
Beam splash from **2021**!

Zero Degree Calorimeters in ATLAS

- Located at ± 140 m from IP in **T**arget **A**bsorber for **N**eutrals, ZDC measure spectator neutrons from AA collisions
- Crucial for triggering in HI collisions
- Crucial for event selection, especially UPC
- High radiation environment
- Limited space and far away …



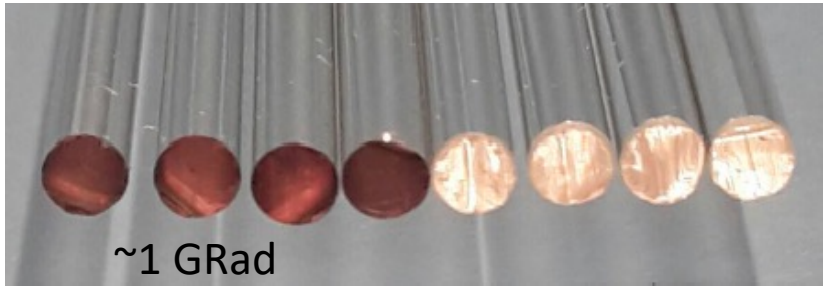


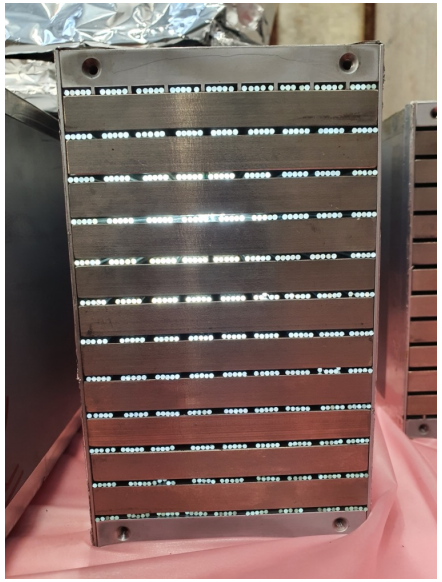


(Run 1/2 pp)

What's New For ZDC Run 3 - Instrumentation

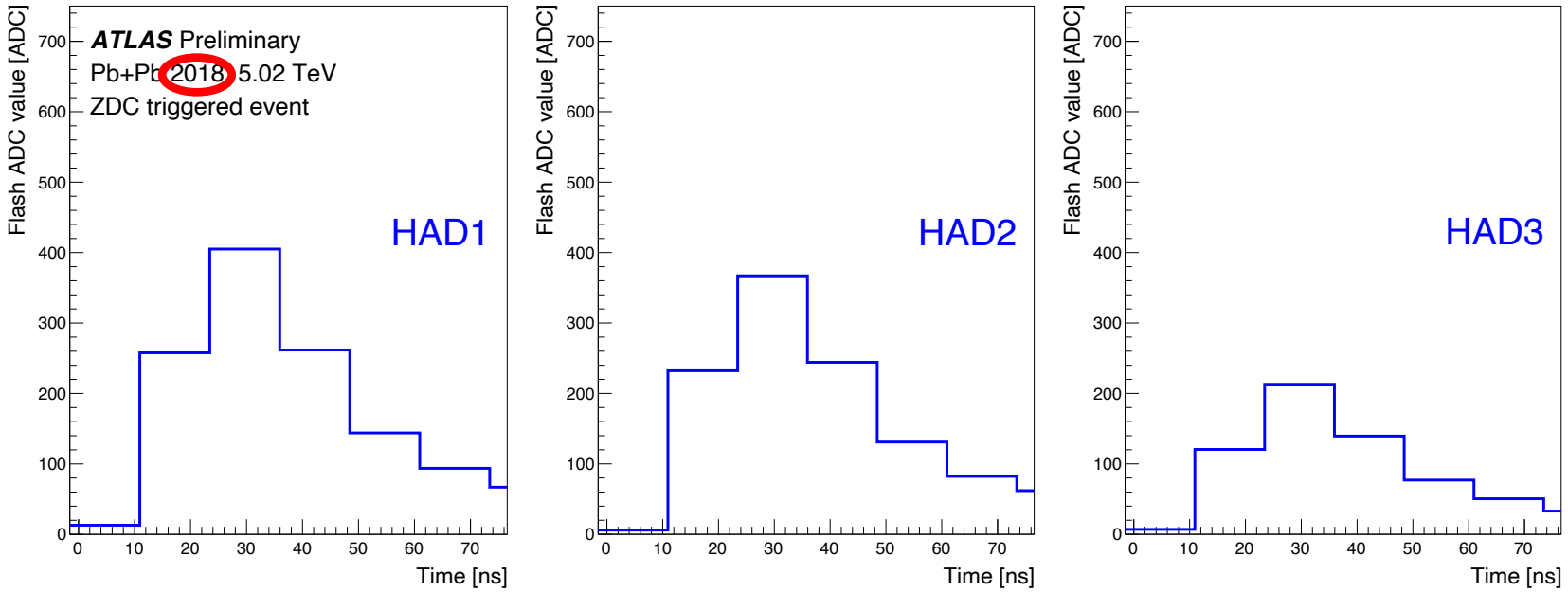
- Run 1/2 ZDC used quartz rods for Cherenkov photons
- Suffered from severe instantaneous and integrated luminosity dependent light output due to **radiation damage** of the quartz rods
  - Run 2 Pb+Pb totalled ~ 10 MRad
  - Even run to run, O(hr), damage required PMT gain adjustments.
- Involved R&D to find better option than quartz
  - Valuable input from BRAN detector experience!
- →Quartz rods replaced with radiation hard(er) fused silica rods
  - **Run 3 anticipate ~130MRad**
  - Expected to be robust to **~hundreds of MRad**





What’s New For ZDC Run 3 - TDAQ

- All digital **readout** & trigger implemented with LUCROD board
  - 16 Channels: Analog inputs → Flash ADC → FPGA
  - On board baseline subtraction, pulse detection, signal summing
  - Trigger decisions – Multiple thresholds across both ZDC sides
- Improvement in cabling improves pile-up handling
-



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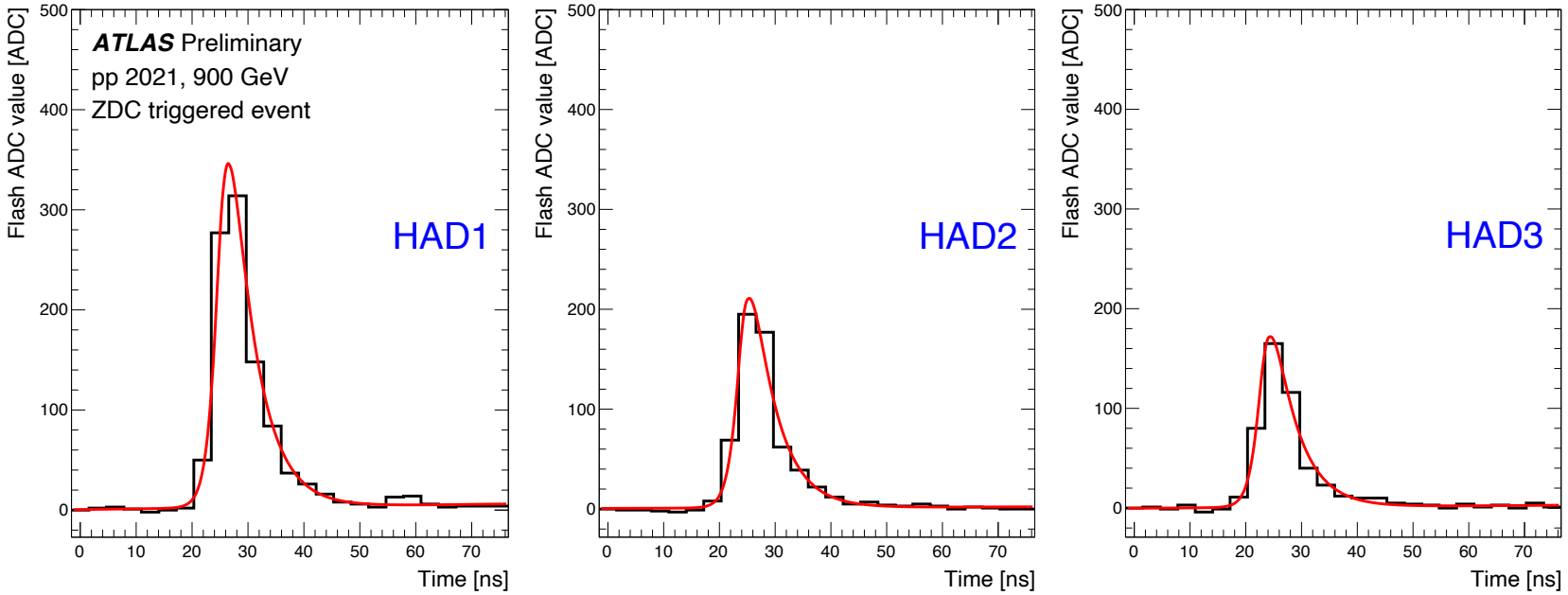
- Tested in 900 GeV pilot beam!



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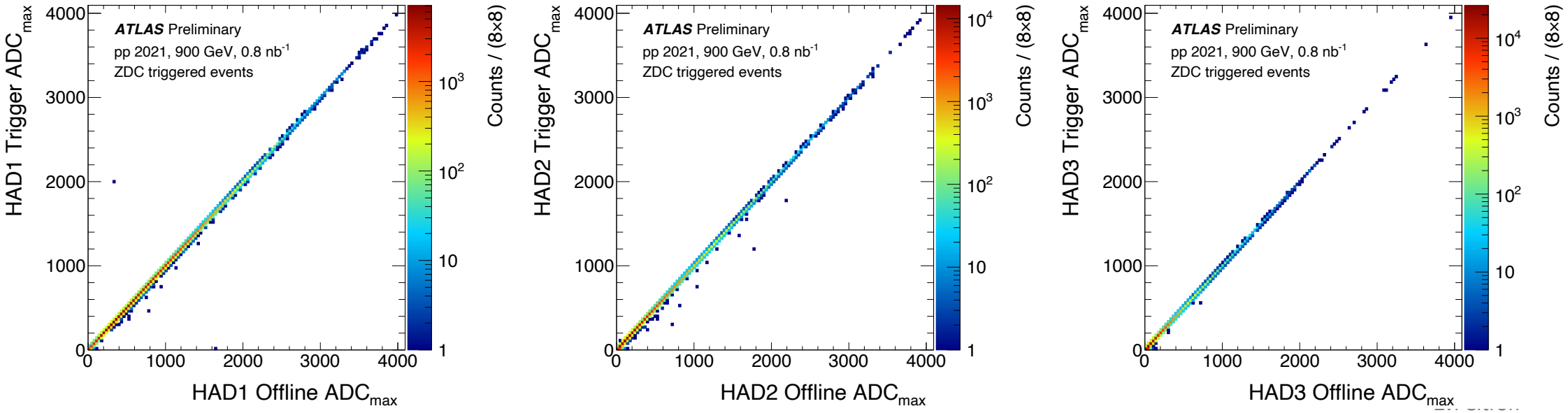
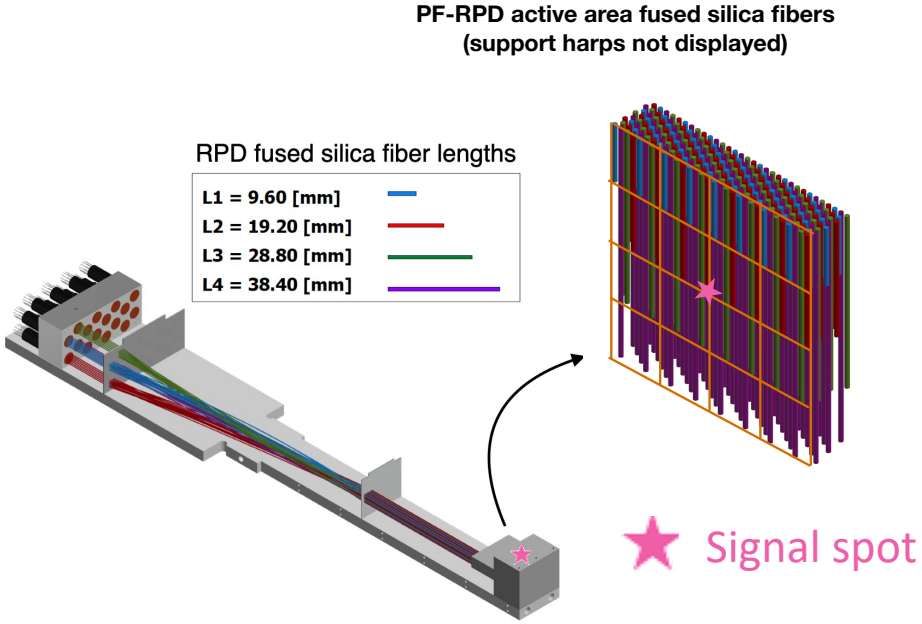
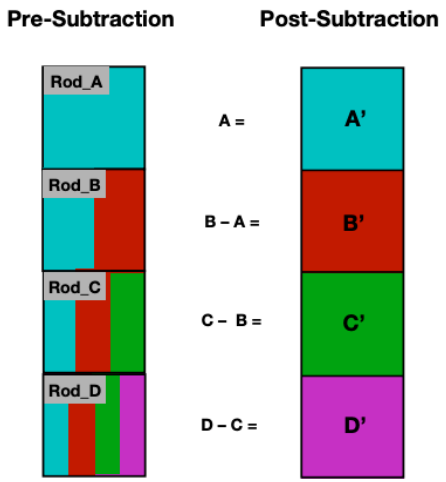


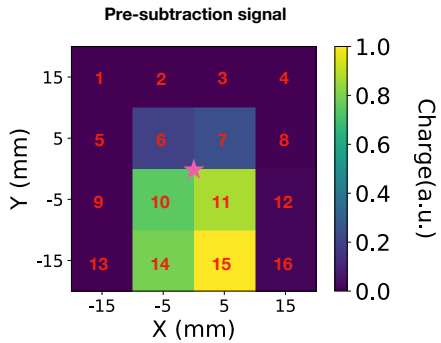
What’s New For ZDC Run 3 – RPD

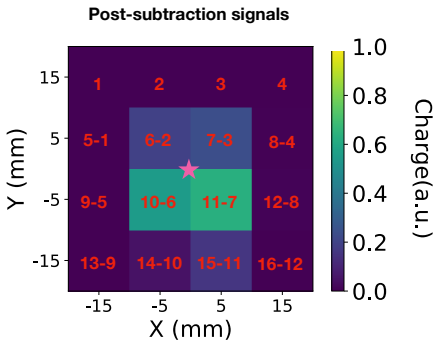
- Reaction Plane Detector measures **transverse** position of spectator neutrons
- Novel design with radiation hard fibers of varying lengths grouped into virtual tiles



Signal spot







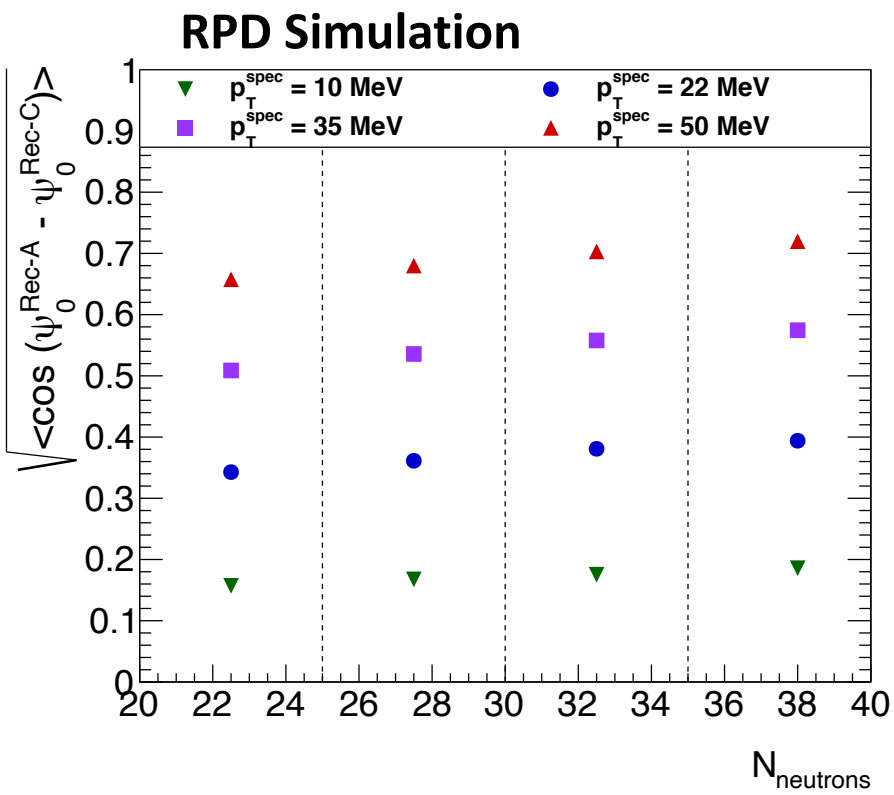
RPD Performance Estimates

- Primary RPD use case is for determining reaction plane
- Quantify correction as

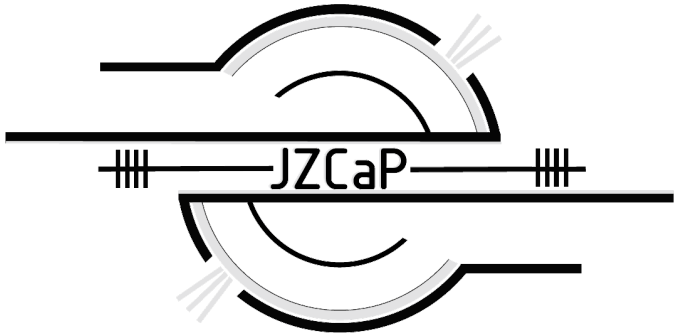
$$\langle \cos[k(\psi_0^{Sub} - \psi_0^{Truth})] \rangle = \sqrt{\langle \cos[k(\psi_0^{A} - \psi_0^{C})] \rangle}$$

where *k*=1 (directed flow) and A&C are opposite side RPDs

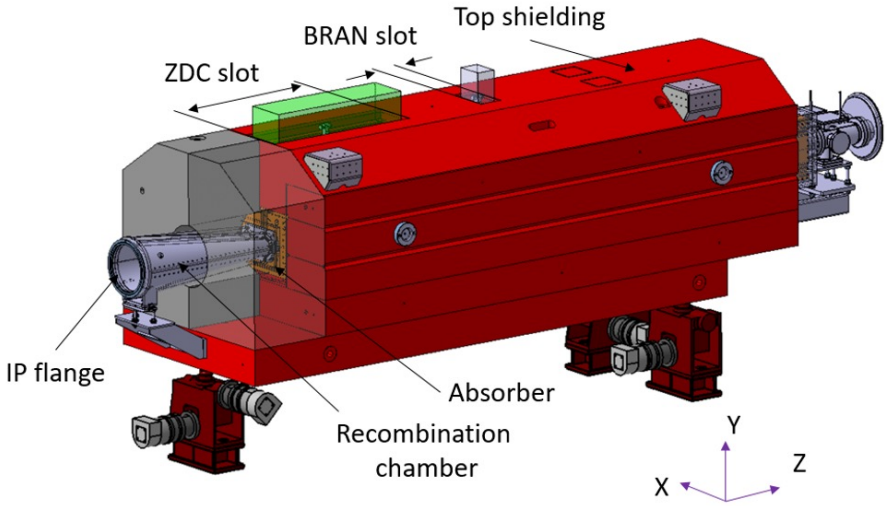
- Prototype has been constructed and tested in beam, final detector being prepared for shipment to CERN

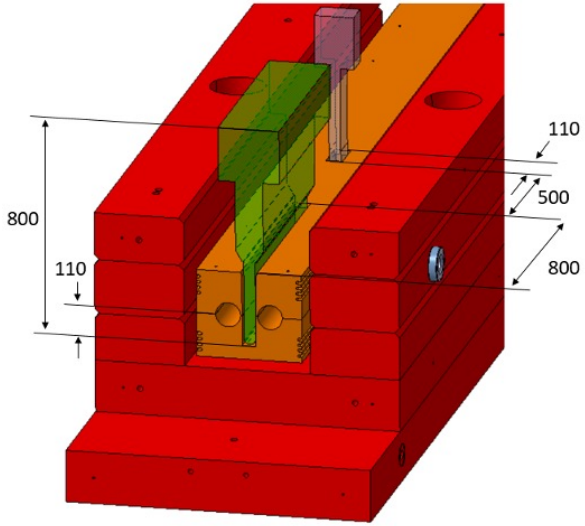


ATLAS ZDC → JZCaP HL-ZDC



- **New detector for HL-LHC**
- The **J**oint **Z**dc **Ca**lorimeter **P**roject (JZCaP) is a combined ATLAS-CMS effort to develop an improved ZDC
  - Currently joint R&D and design
  - "HL-ZDC" proposed for both experiments for HL-LHC
- Accommodates Run 4 beam optics
  - TAN → TAXN at ± 127 m from IP (13 m closer)
  - Monolithic design (previously separate modules)
  - Narrower *x*-profile: 4.6 cm (previously twice as wide)
    - Energy containment remains comparable due to *z* length
- Continues from Run 3 R&D
  - Radiation hardness
  - Light collection
  - TDAQ capabilities
  - Transverse measurement capabilities





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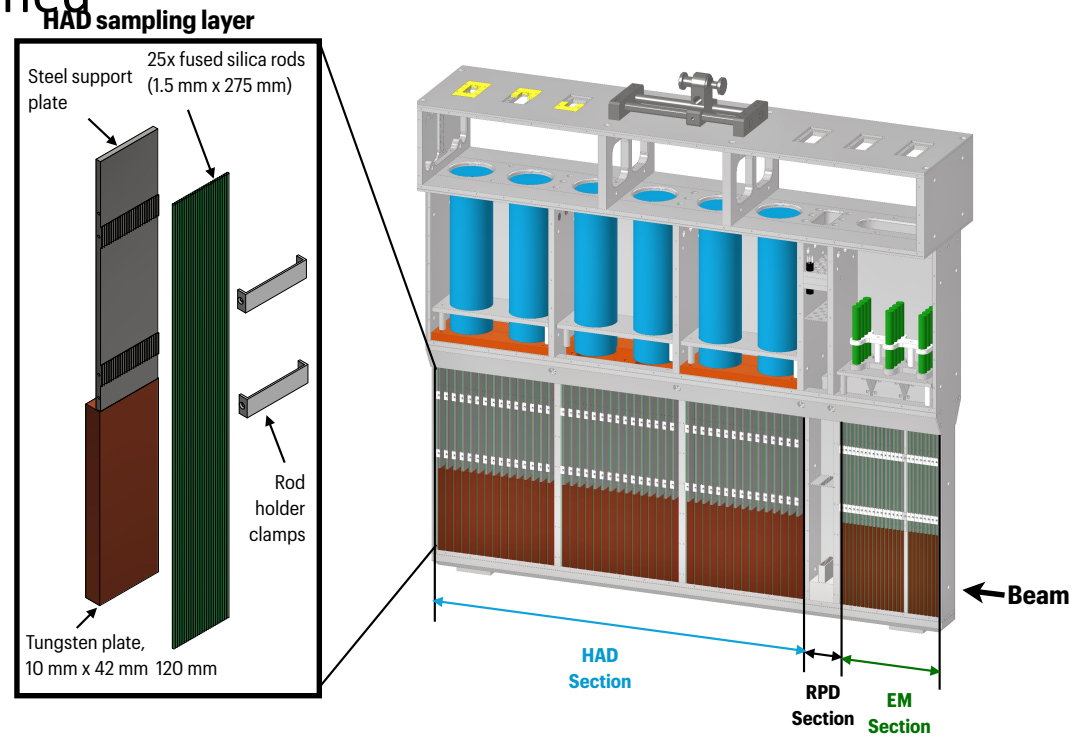

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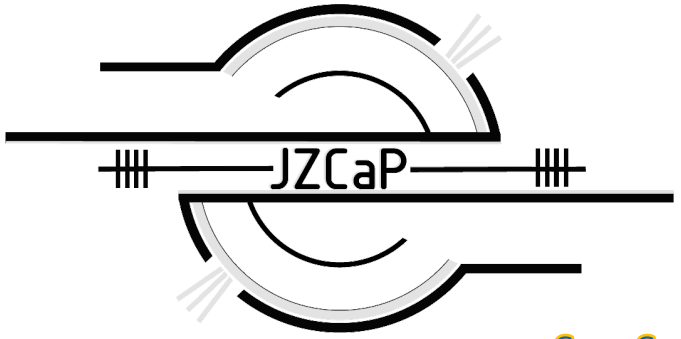

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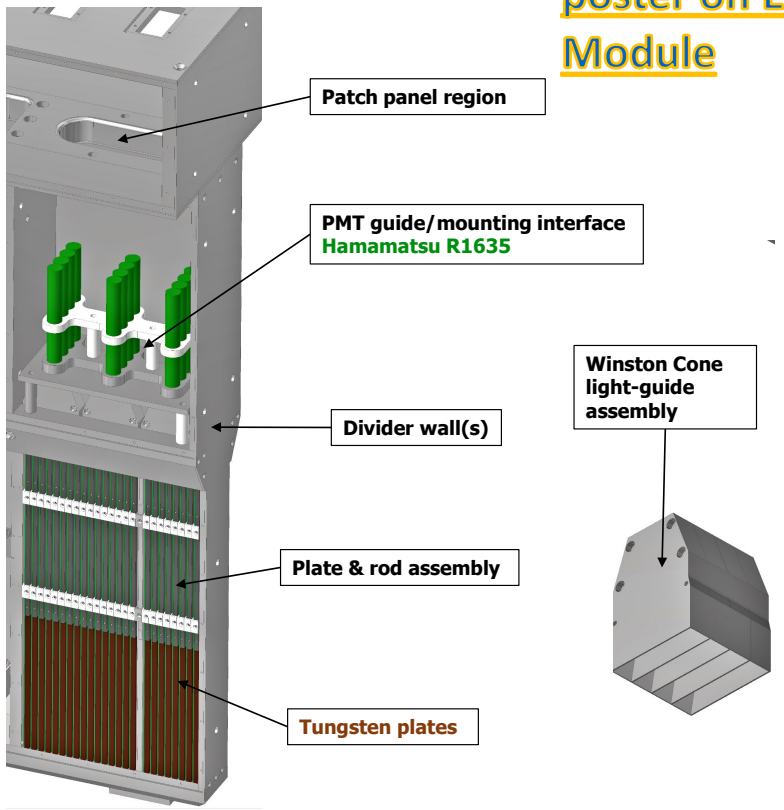
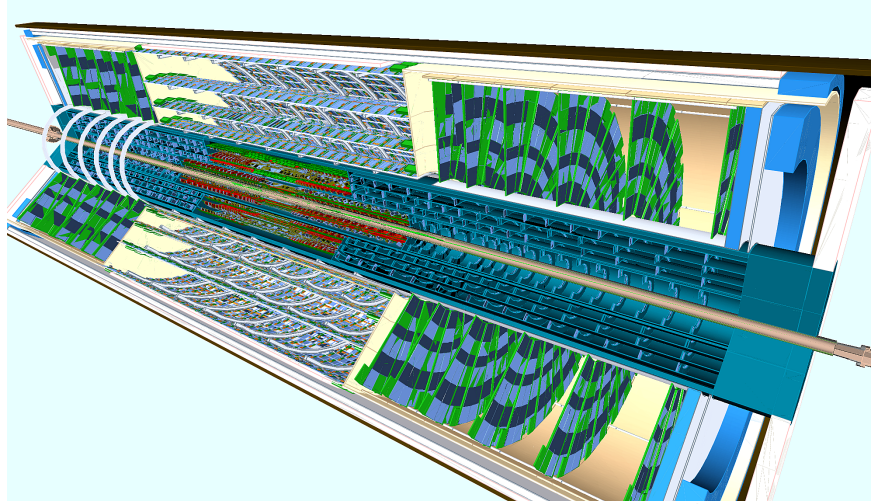
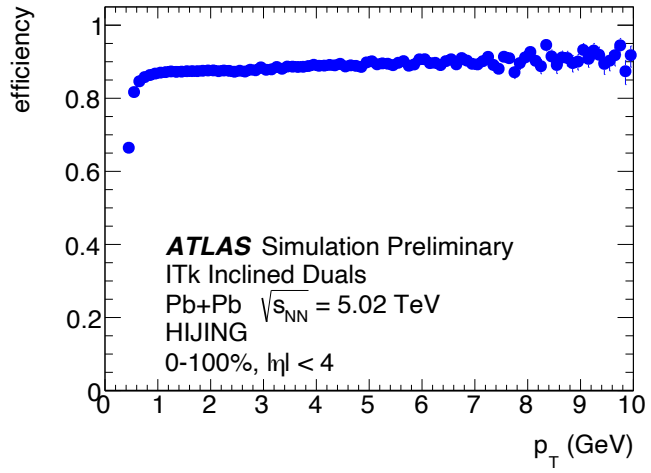
See S. Shenkar's poster on EM Module

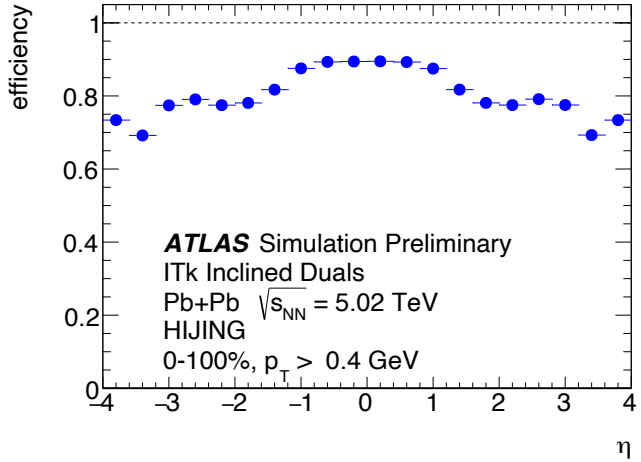


New Inner Tracker (ITk) for HL-LHC

- New all-silicon inner tracker
- Extends η acceptance to ±4 (from 2.5)
  - Improves flow measurements (where increased statistics of HL-LHC is less important)



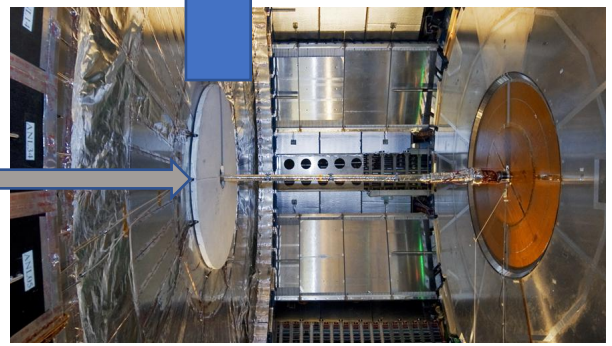


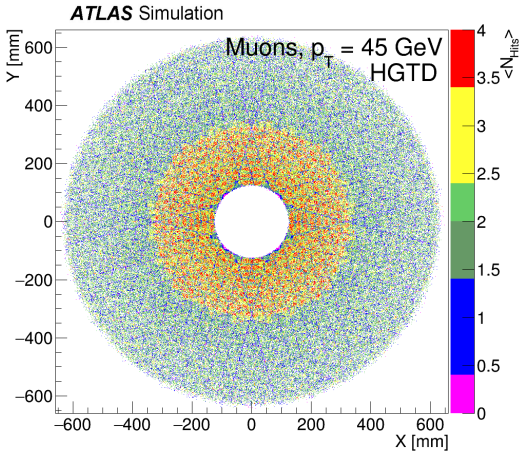


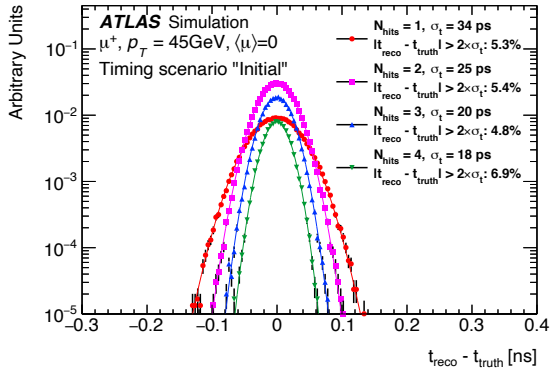
New High Granularity Timing Detector (HGTD)

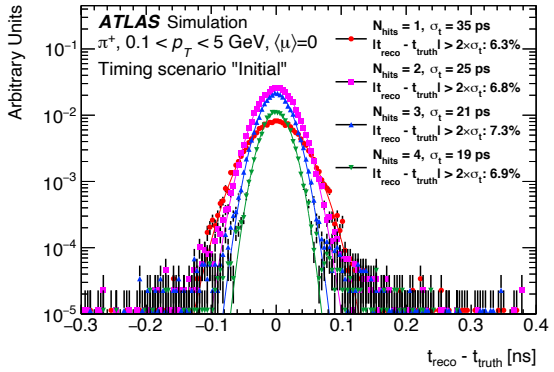
- Complements new ITk with timing information in 2.5<|η|<4
- Timing is key for pileup rejection at high multiplicity
- Replaces MBTS as baseline trigger for HI collisions
- Low Gain Avalanche Detectors
  - Next generation detectors are (almost) here

HGTD to be installed!









Summary

- Major upgrades to ATLAS for HL-LHC coming up, but fun has already started for Run-3
- ZDC are key detectors for the HI program, in ATLAS Run-3:
  - New fused silica is radiation hard(er)
  - All new digital read-out and triggering
  - New detector with transverse segmentation, RPD
- HL-ZDC will be built for ATLAS+CMS for HL-LHC
- New inner tracker (ITk) and timing detector (HGTD) crucial to HI program for HL-LHC
  - (And of course benefit from all upgrades)

Extras

THE JOINT ZERO DEGREE CALORIMETER PROJECT

Ben Gurion University of the Negev
Zvi Citron
Yftach Moyal
Lion Sudit
Shir Shenkar

Brookhaven National Laboratory
Peter Steinberg

Columbia University
Brian Cole

Kansas University
Allen Hase
Bill Burley
Christian Hornhuber
Juan Marquez
Cole Le Mahieu
Michael Murray
Matthew Nickel
Sorina Popescu*
Quan Wang

University of Maryland
Eric Adams
Samuel Lascio
Alice Mignerey
Timothy Koeth

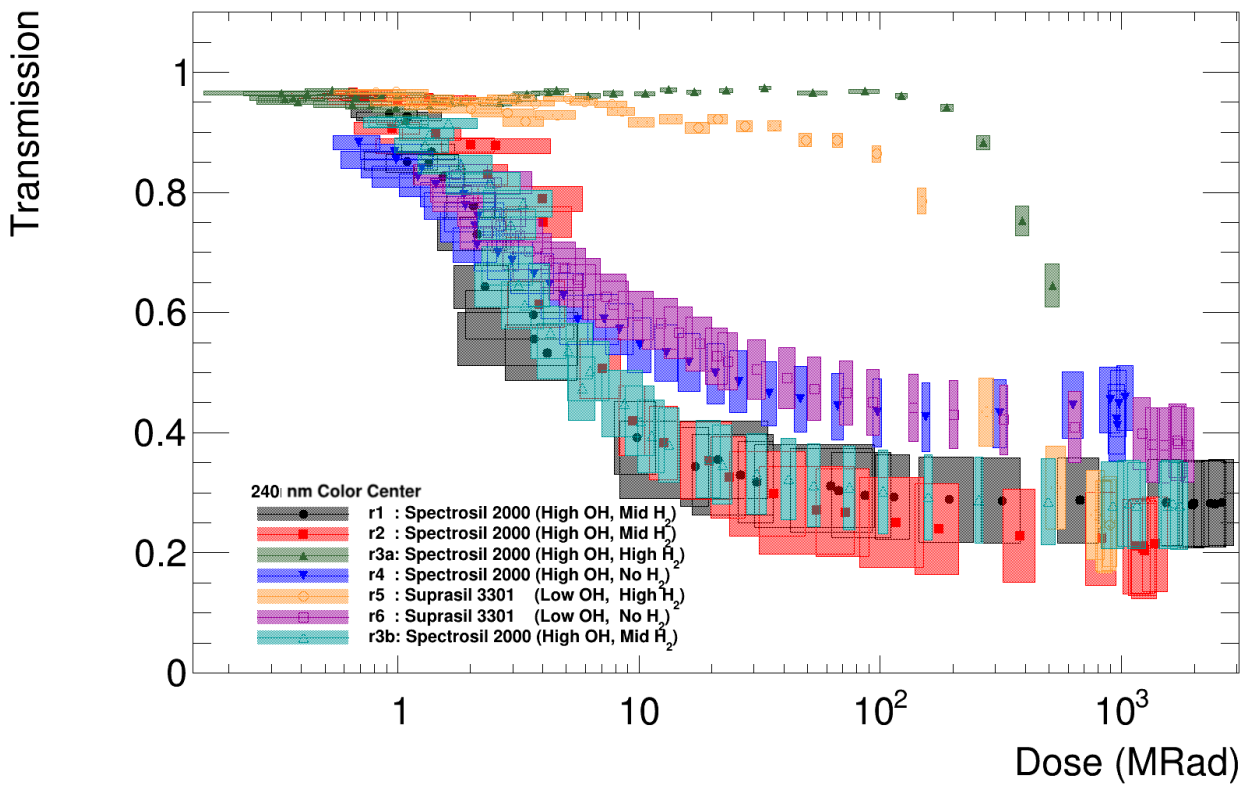
UIUC
Jacob Fritchie
Matthias Grosse Perdekamp
Matthew Hoppesch
Chad Lantz
Riccardo Longo
Xuesi Ma
Daniel MacLean
Paul Malachuk
Jain Pranay
Anna Przybyl
Farah Rafee
Aric Tate
Aryan Vaidya
Sheng Yang

* On leave from IFIN-HH, Magurele, Buchrest Romania

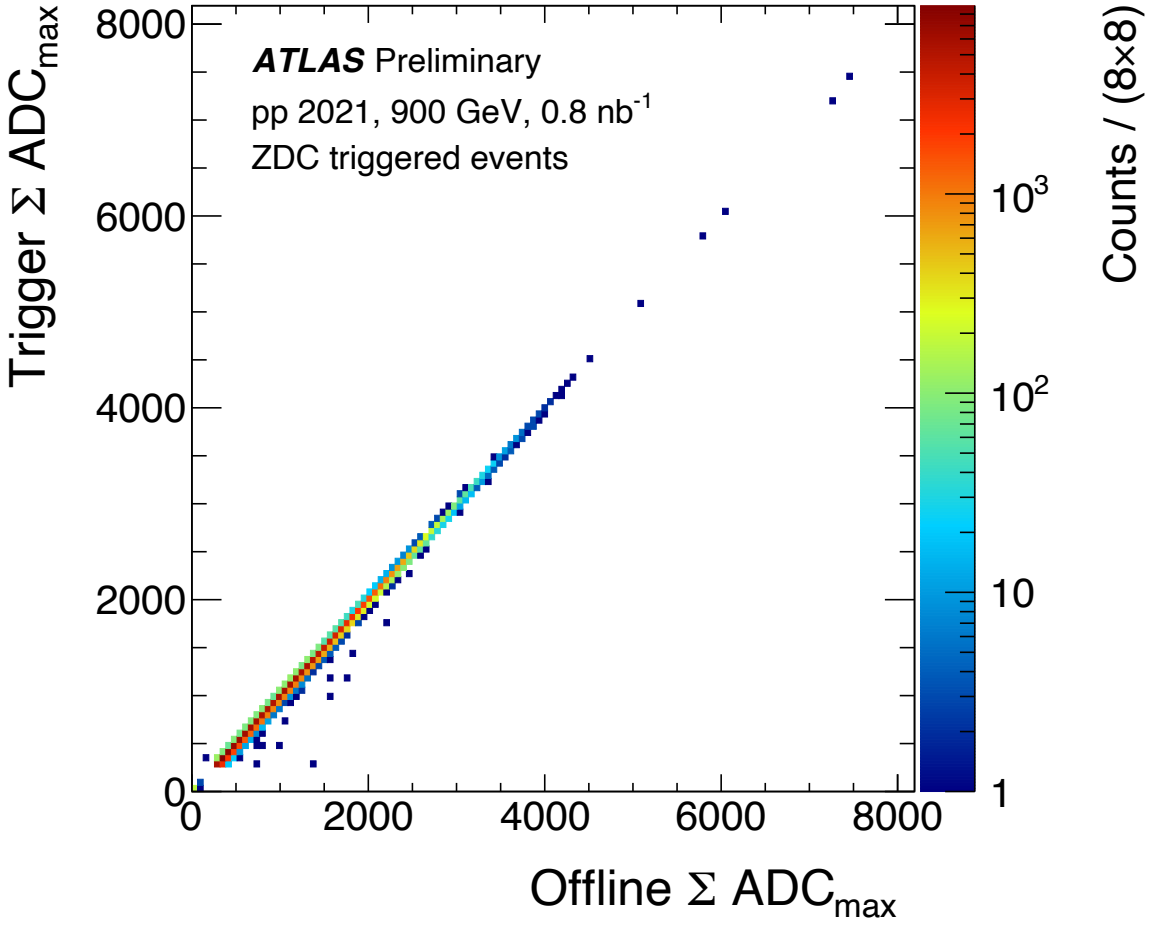
Run 3 Installations Big and small

- Significant upgrades to the muon system
  - New small wheels installed!
- Zero Degree Calorimeter refurbished

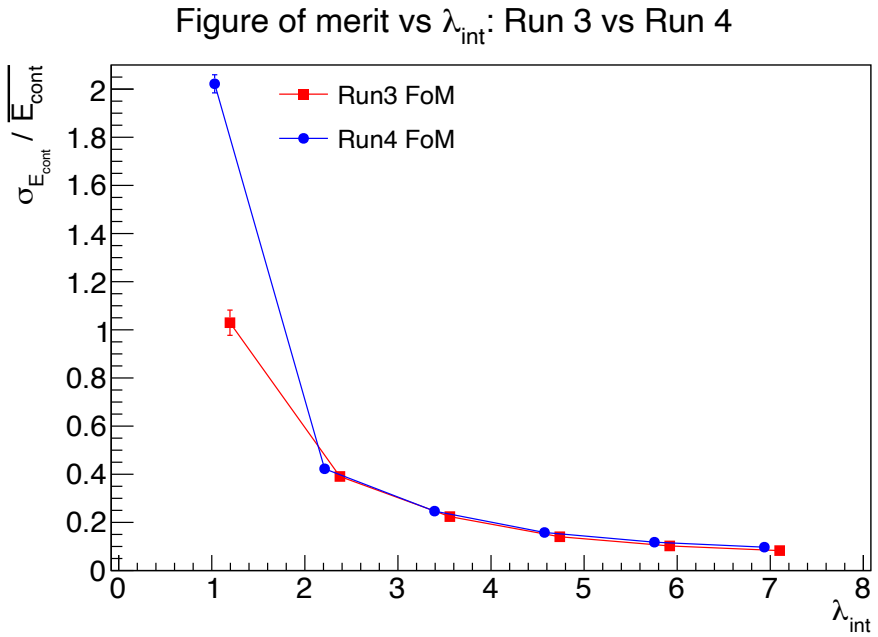
Fused Quartz Radiation Hardness

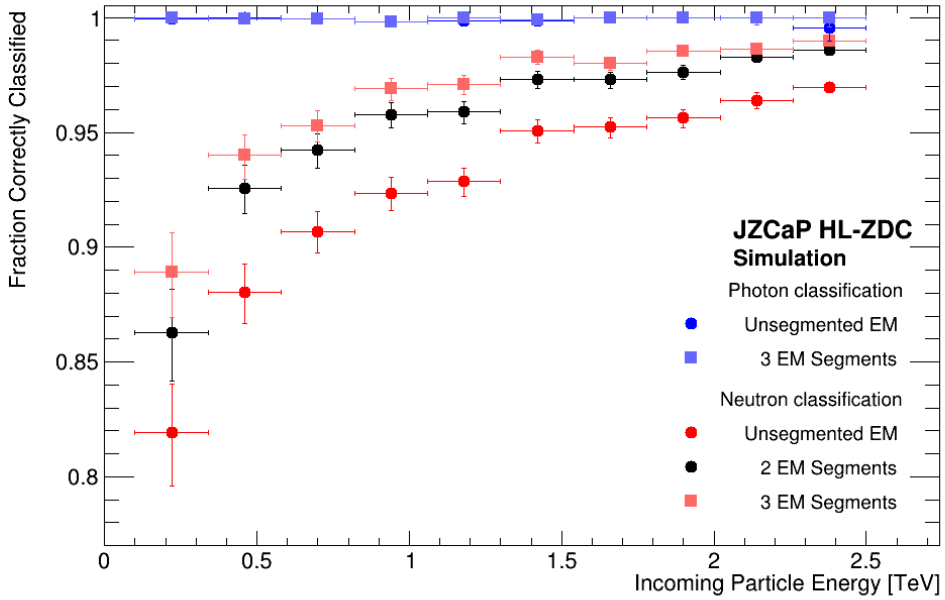


Summed ZDC Trigger in Pilot Beams



HL-ZDC Performance





RPD Beam Test