Zero Degree Calorimeter at the LHC

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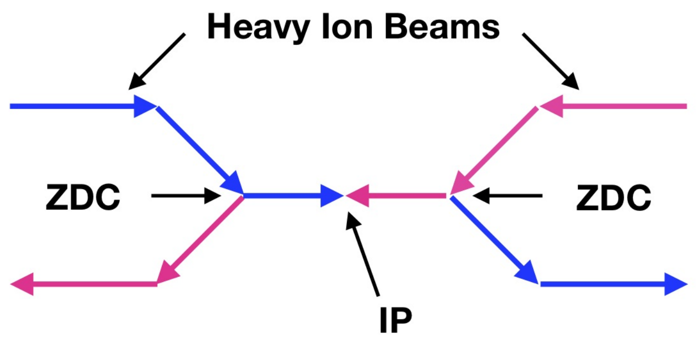
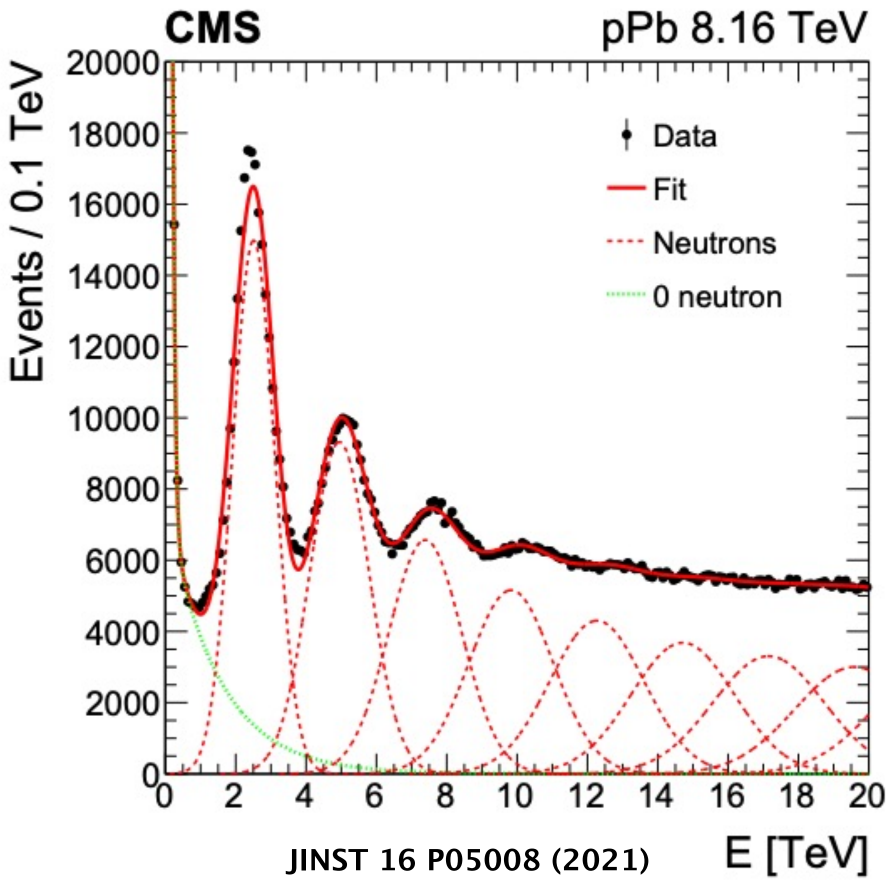
Outline

- ZDC in Heavy Ion Collisions at the LHC
- Current ZDC design and performance at the LHC
- R&D for future ZDC at the LHC (HL-LHC)

ZDC in Heavy Ion Collisions



- ZDC measures neutral particle energy deposit in far forward direction
  - Photons and neutrons
  - $|\eta|>8.3$ (– Run3), $|\eta|>8.5$ (Run 4 –)
- Measuring spectator neutrons
  - Neutron multiplicity



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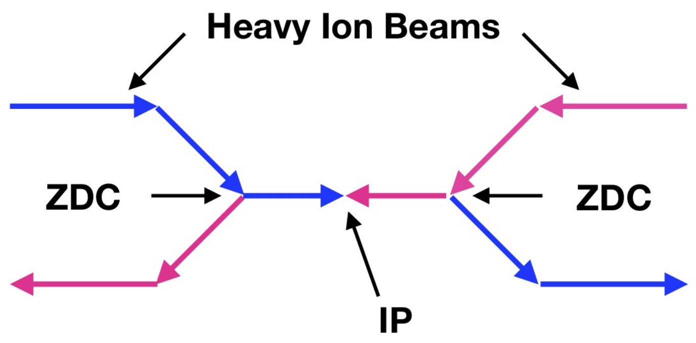
ZDC in Heavy Ion Collisions



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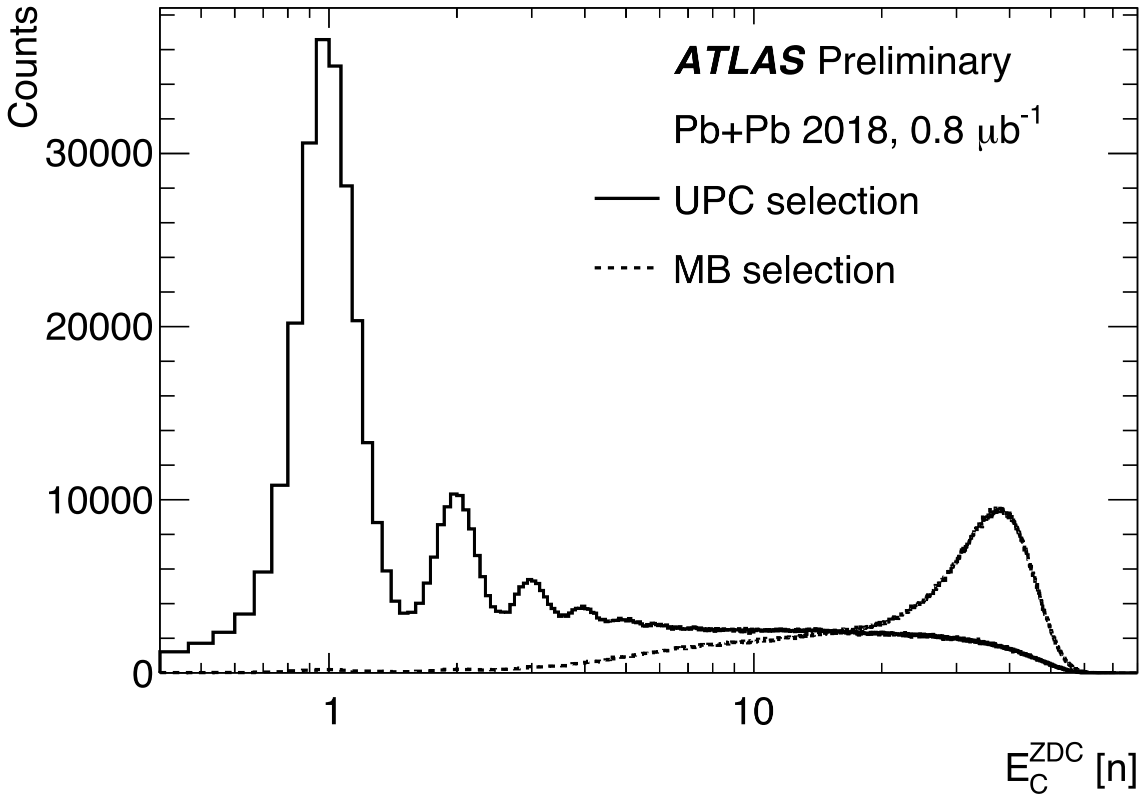
- Event triggering – (non)hadronic
  - Ultra-Peripheral Collisions



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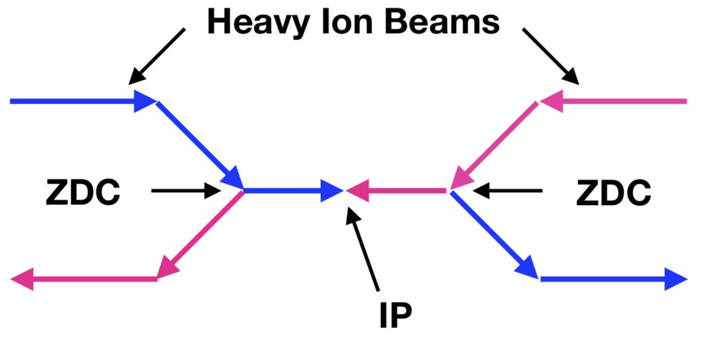

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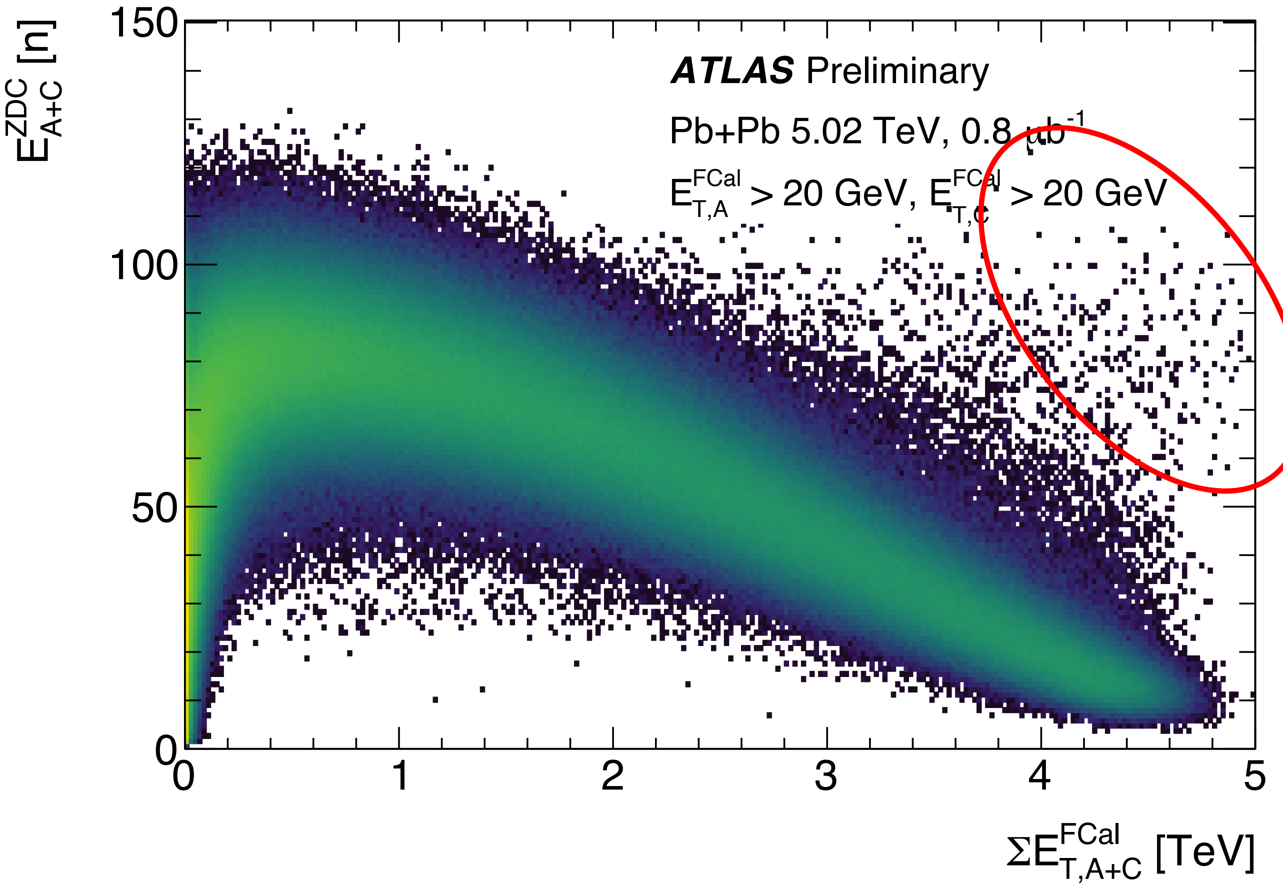
- Pile-up rejection
  - Ultra-Central Collisions
- Impact parameter – Centrality



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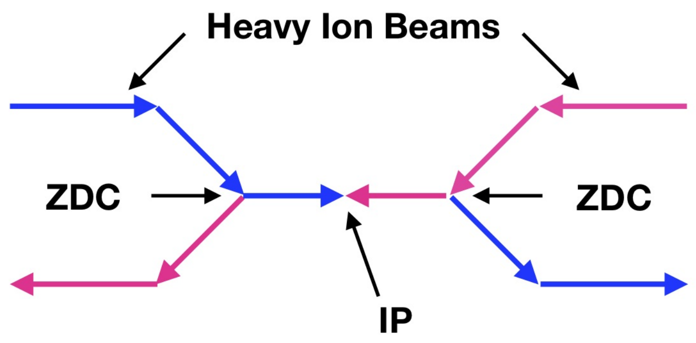

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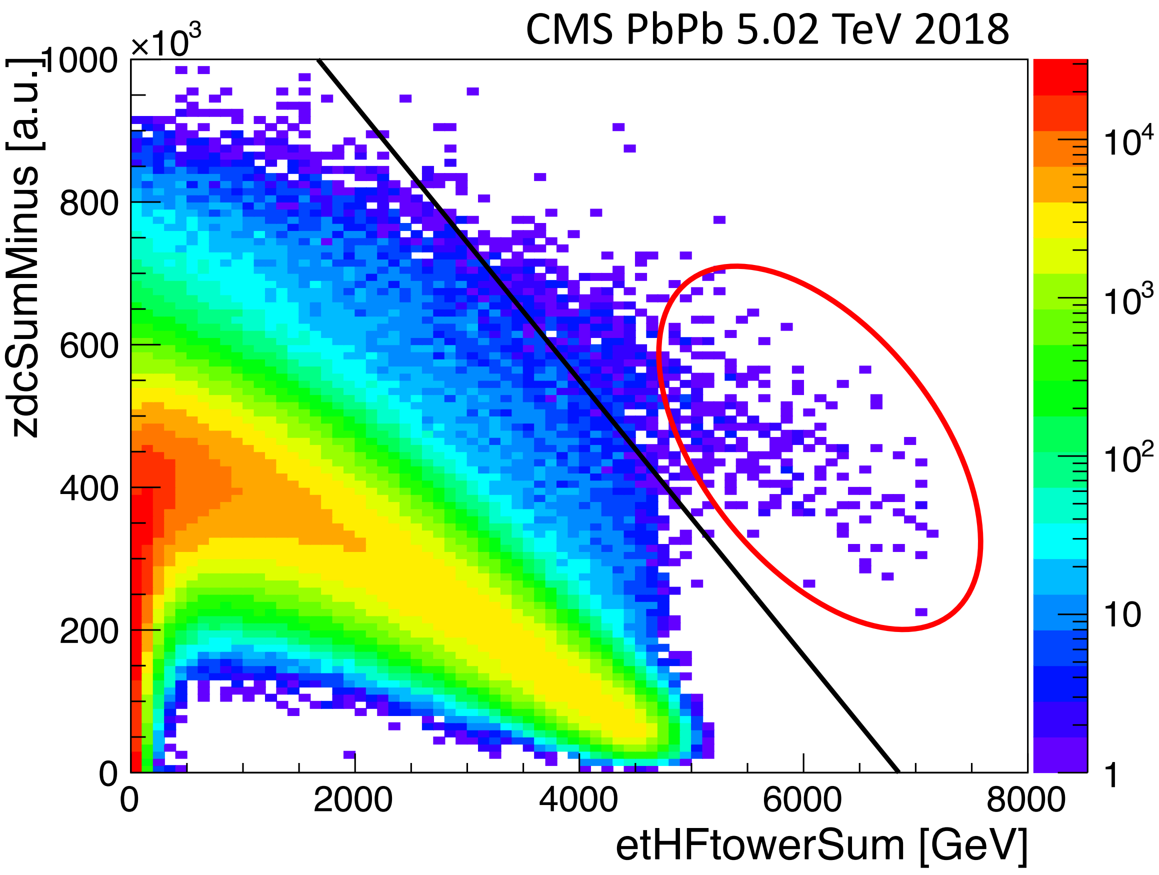
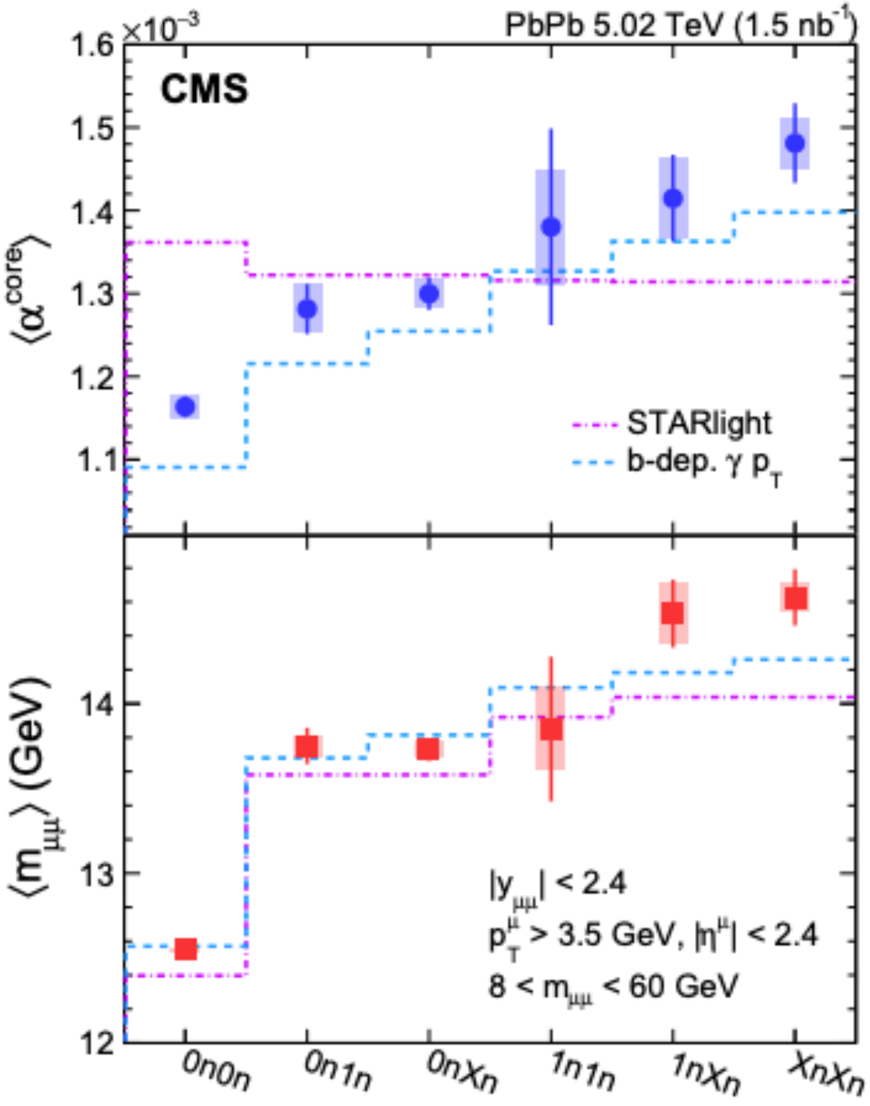


ZDC for LHC Physics

- Dimuon acoplanarity in $\gamma\gamma$ UPC PbPb at CMS
  - $\gamma\gamma \rightarrow \mu^+\mu^-$, as a function of neutron multiplicity
  - Acoplanarity: $\alpha=1-|\phi^+-\phi^-|/\pi$



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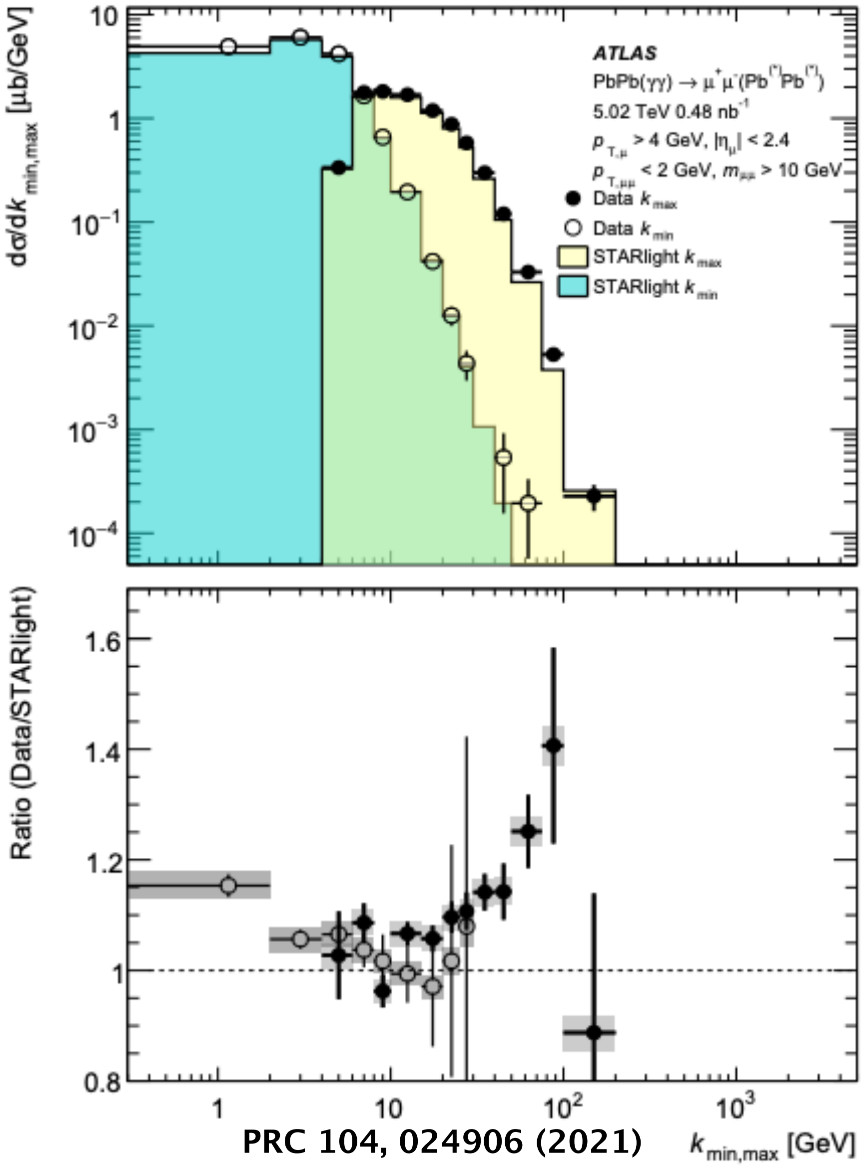
- Dimuon Xsec in $\gamma\gamma$ UPC PbPb at ATLAS
  - Xsec vs $m_{\mu\mu}$, $y_{\mu\mu}$, α, k



PRC 104, 024906 (2021)

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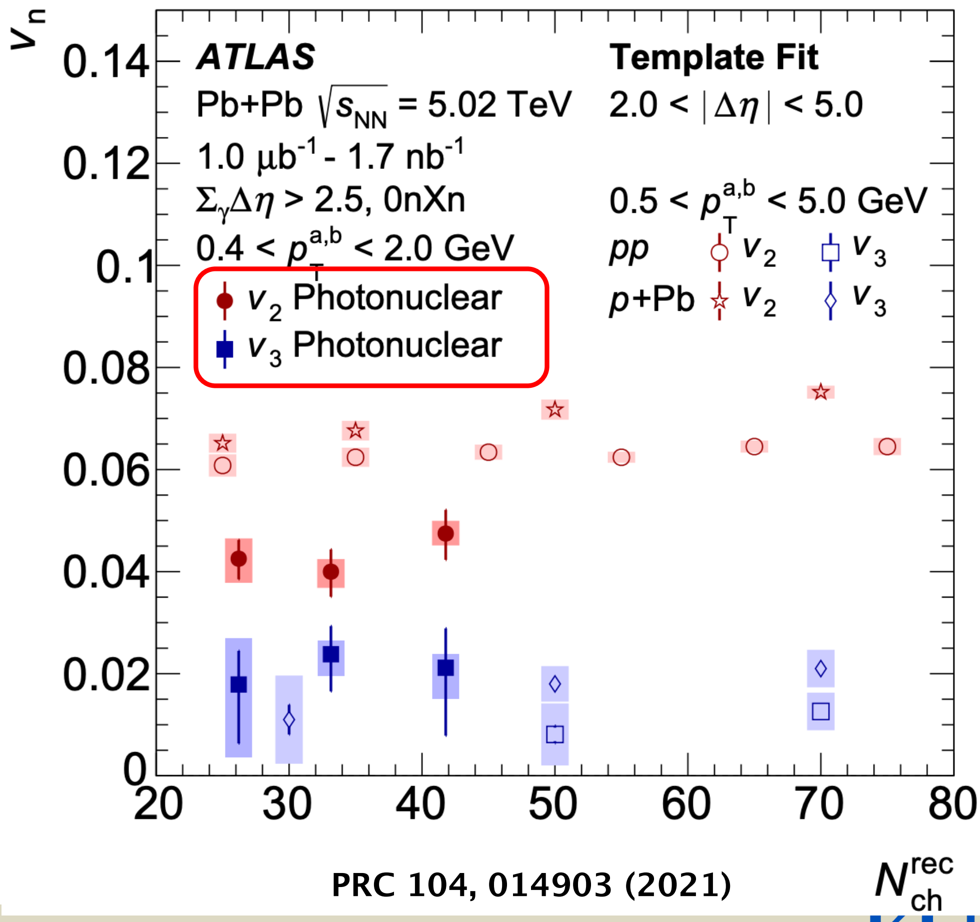
- ➢ V_n harmonics in γPb UPC PbPb at ATLAS



PRC 104, 014903 (2021)

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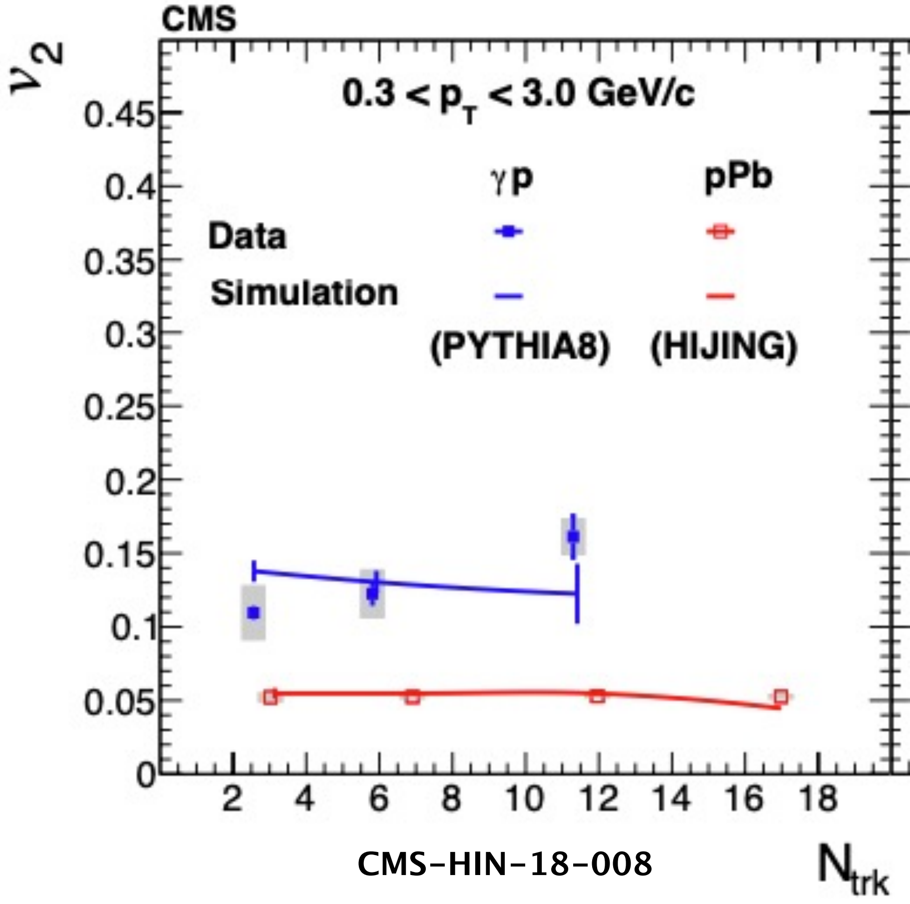
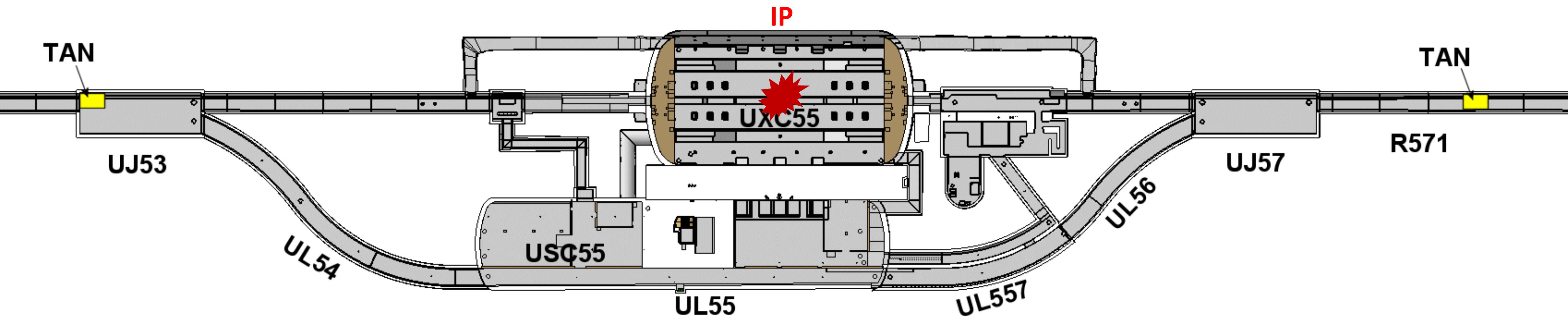
- V_2 harmonic in γp UPC pPb at CMS



CMS-HIN-18-008

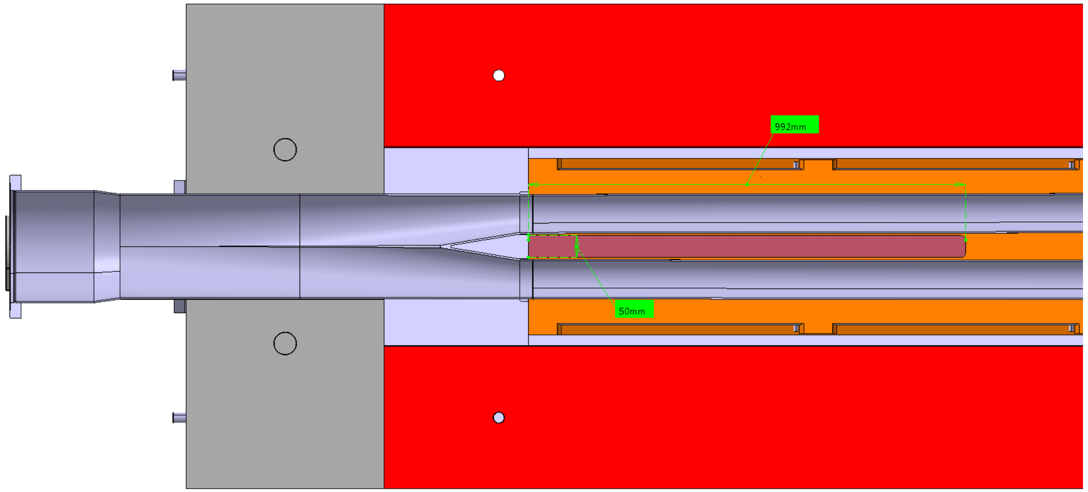
ZDC Detector at LHC

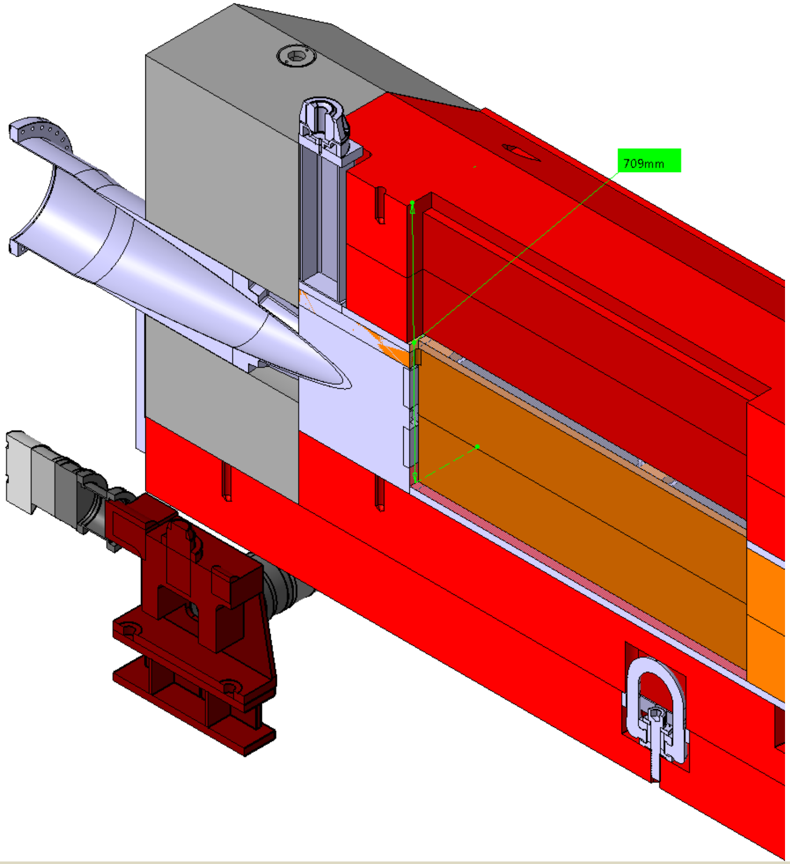
- ZDC is 140m away from IP, inside TAN
- ZDC is installed only for Heavy Ion data taking



ZDC Detector at LHC

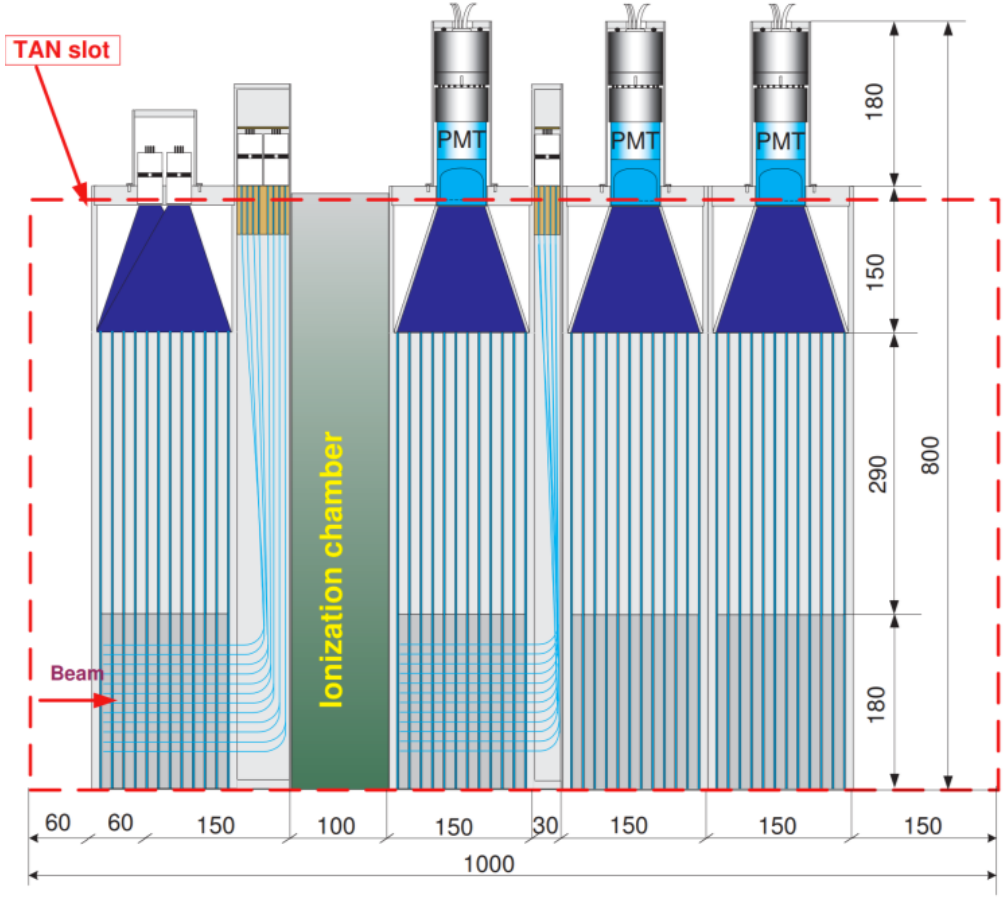
- ZDC is 140m away from IP, inside TAN
- ZDC is installed only for Heavy Ion data taking
- HL-LHC Run 4 (2029–)
  - 127m away from IP
  - Limited space at TAN (TAXN)



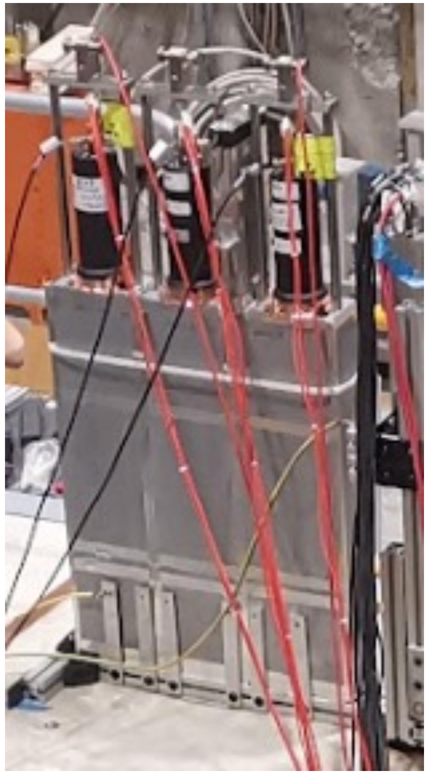


ZDC at ATLAS

- **EM**, **HAD** sections

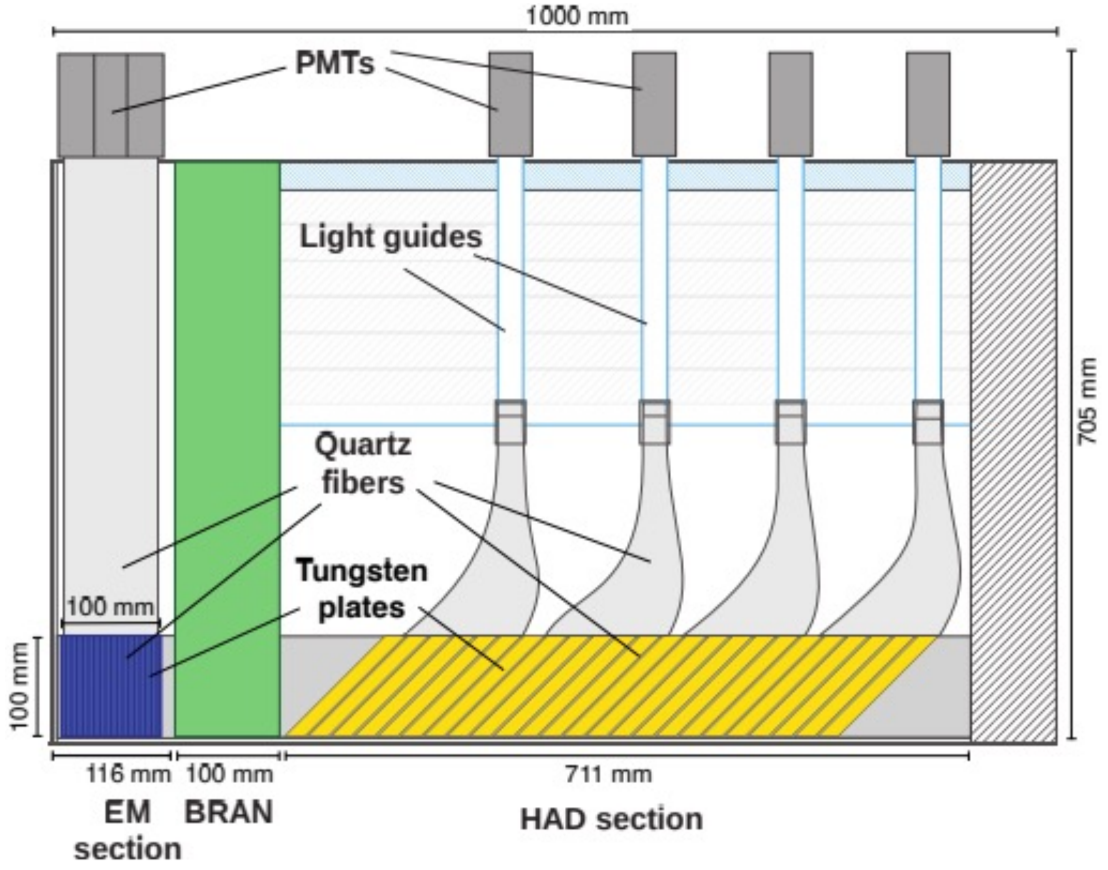


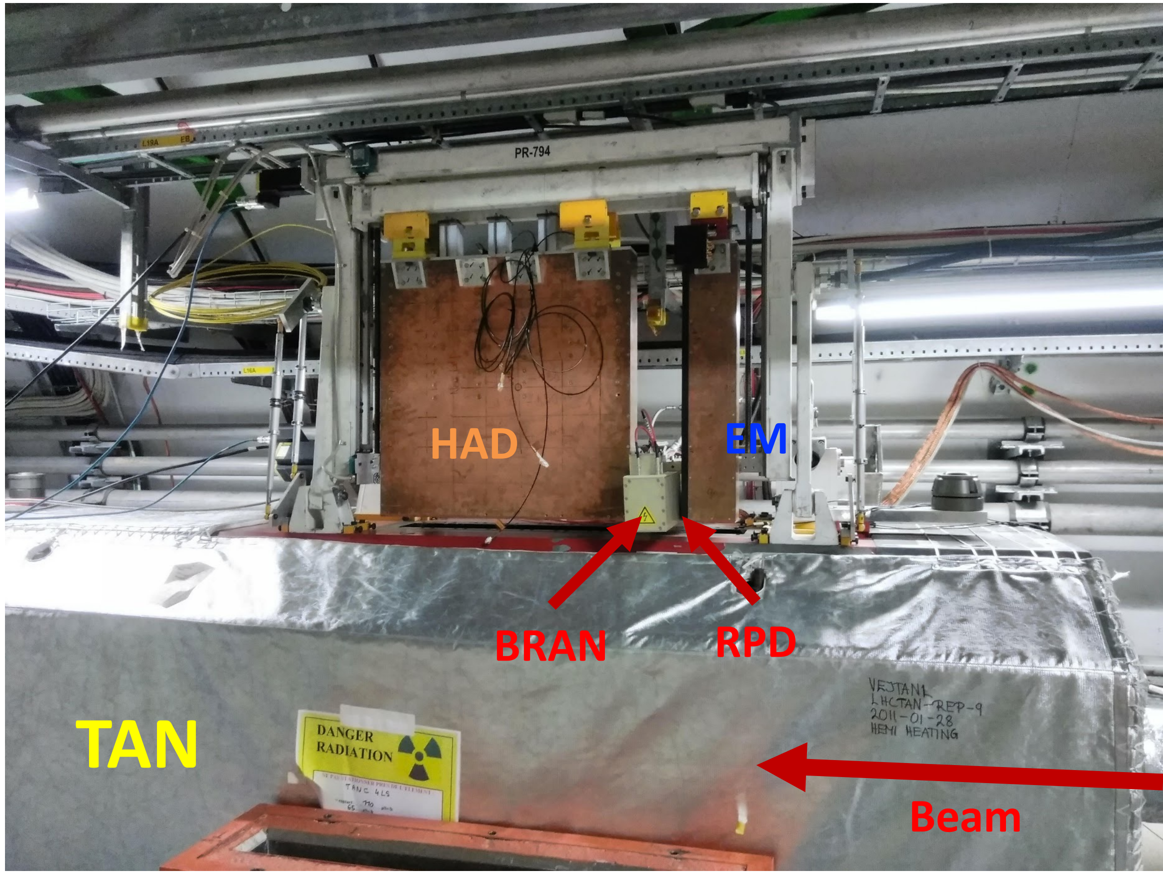
EM **HAD**



ZDC at CMS

- ZDC consists of **EM**, **RPD** and **HAD** sections
- **RPD**, reaction plane detector





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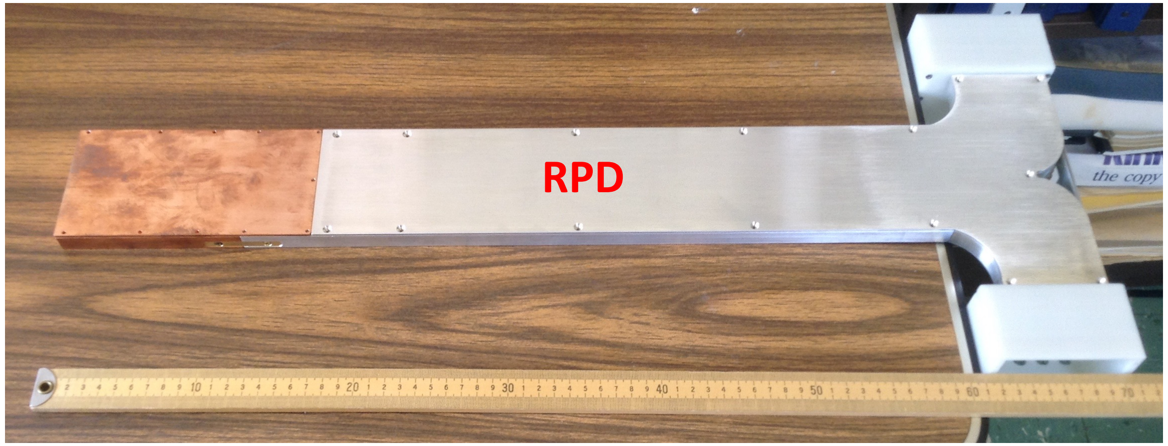
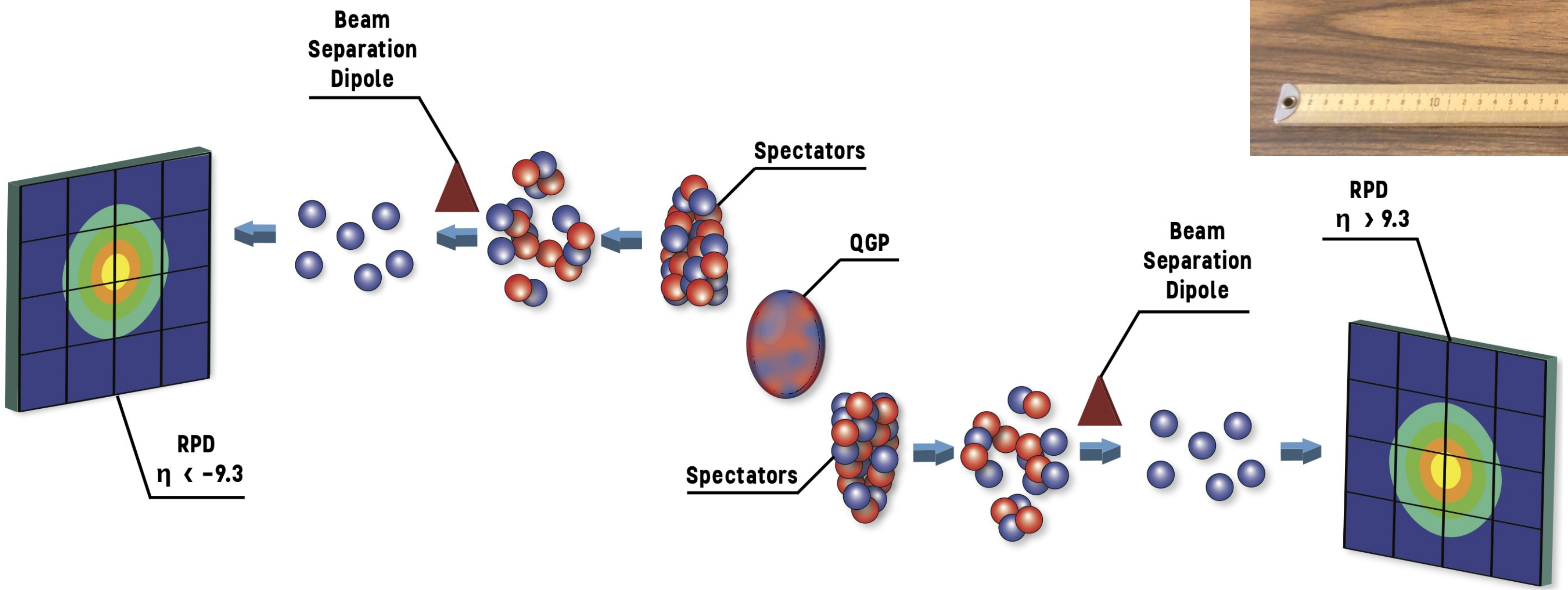


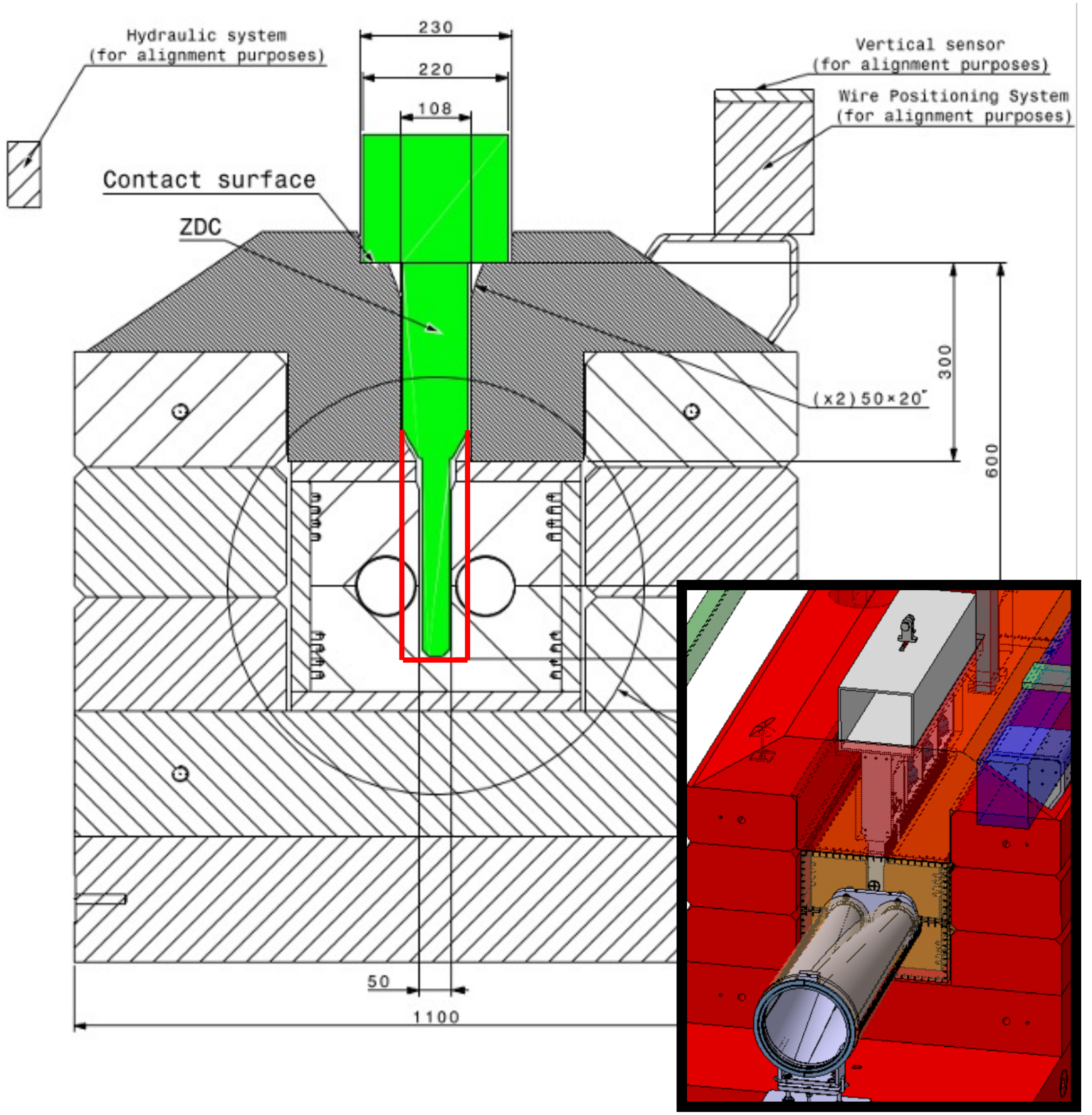


ZDC Key Design Criteria

- Large dynamic range <1n, to ~100n
  - Clean separation between 0 and >=1n [diffractive vs hadronic]
  - Good γ/n separation
  - Provide trigger decisions
- 1n peak crucial for energy calibration
  - Beam energy neutron
- Measure spectator event plane angle
  - Neutron orientation

ZDC Key Design Criteria at HL-LHC

- Performance requirement
  - ❑Highly radiation hard
  - ❑Stable over Run 4
- Operation requirement
  - ❑Compatible with TAXN
    New beam optics (92mm→46mm)
  - ❑Easy installation/cabling (RP)



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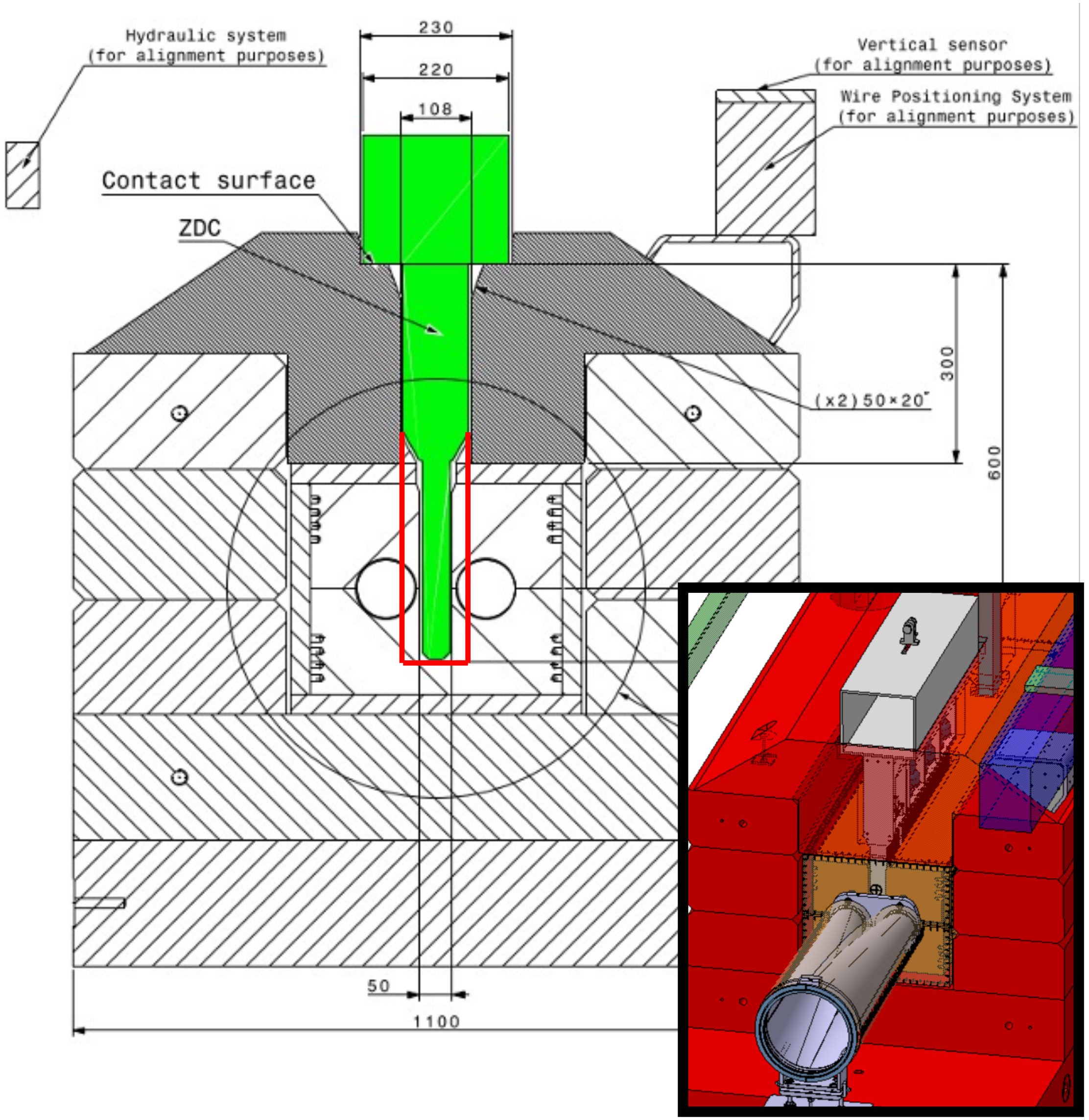
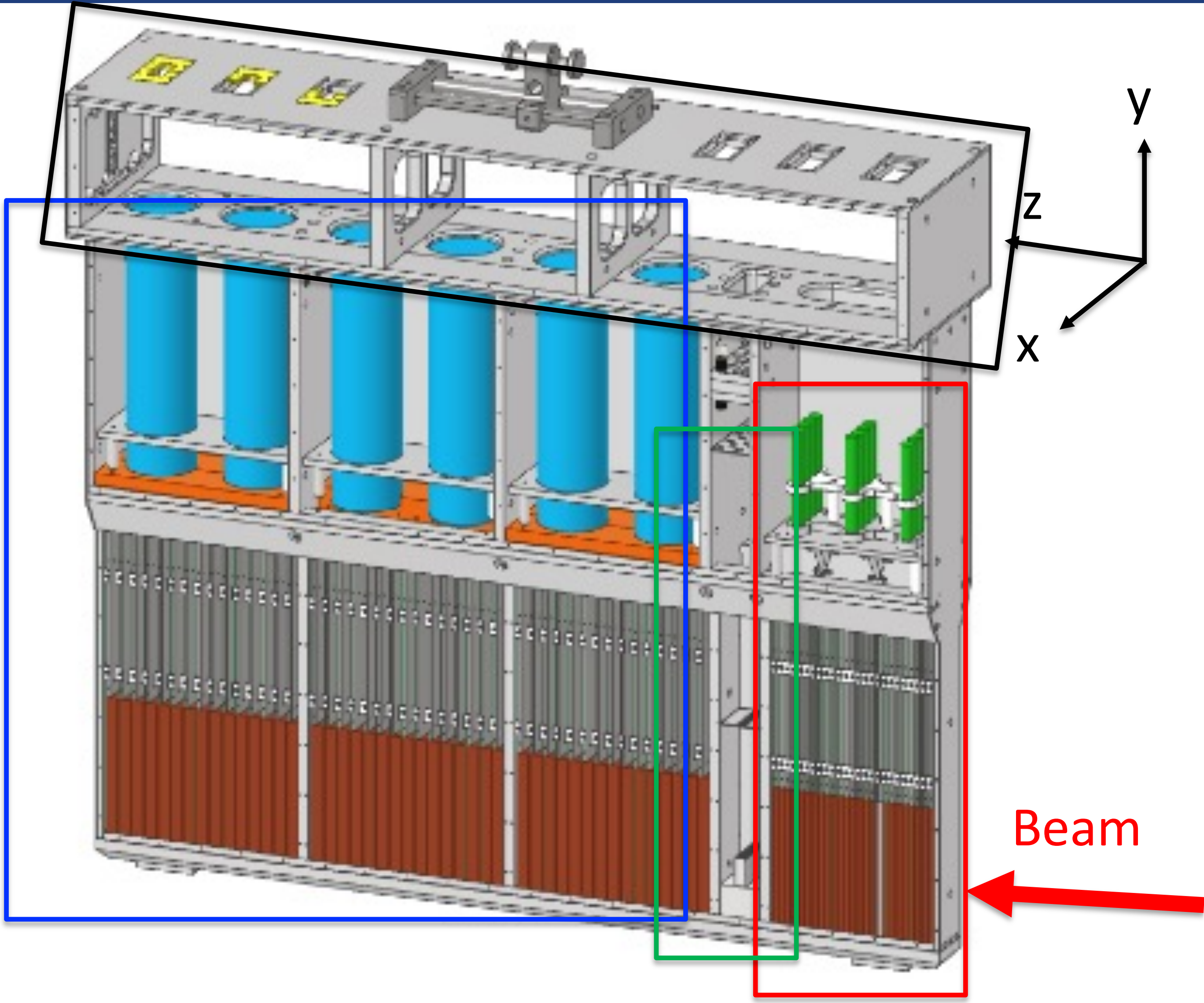
- ➢ ***J***oint ***Z***ero degree ***Ca***lorimeter ***P***roject
  - ❑ ATLAS and CMS



Zero Degree Calorimeter for HL-LHC

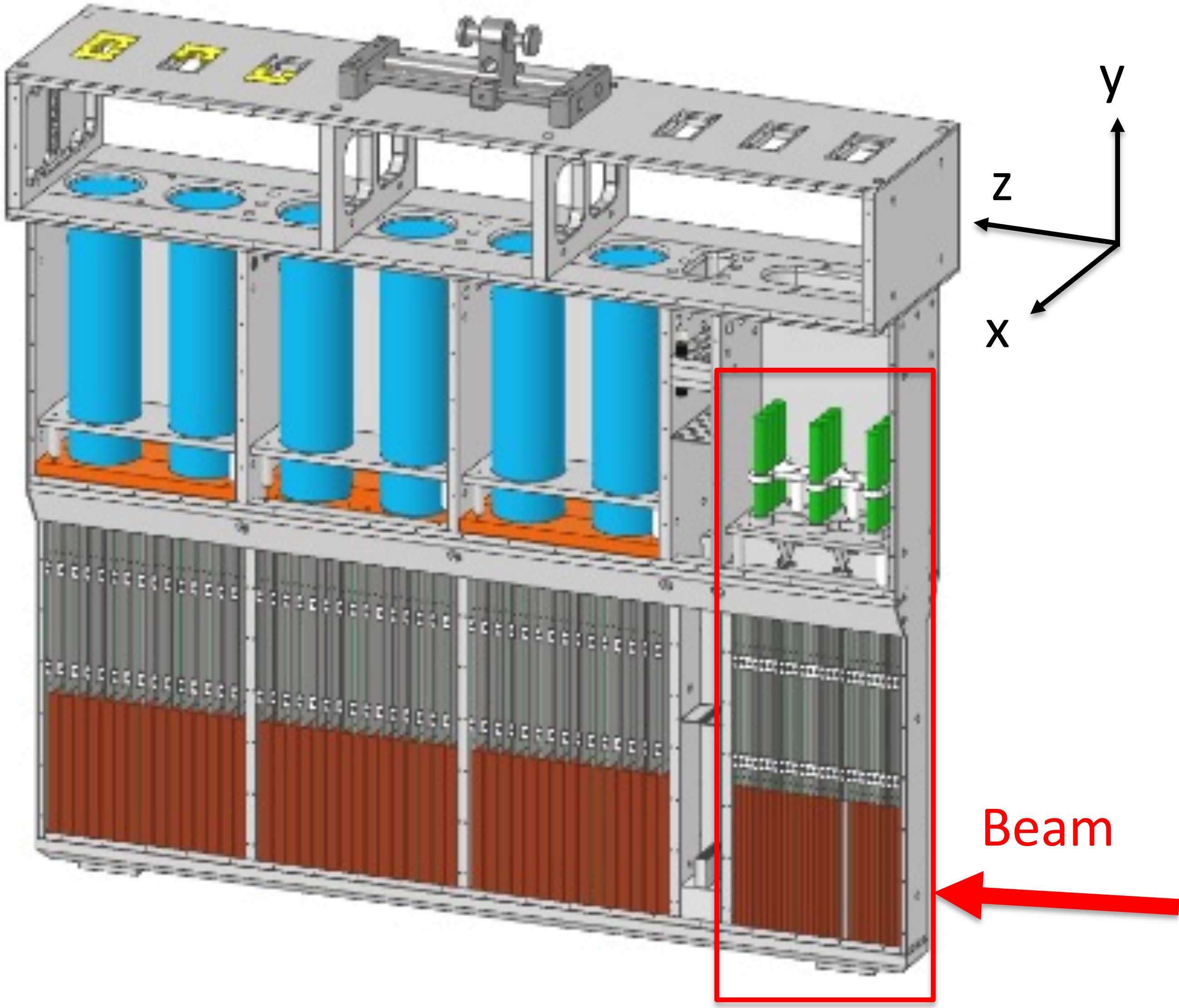
- Detector design
  - **Electromagnetic [EM] section**
  - **Hadronic [HAD] section**
  - **Reaction Plane Detector[RPD]**
- Operation requirement
  - Single piece structure
  - Easy access **patch panels**
- Specs
  - 46mm X 766mm
  - 120-125 kg
  - 5.5 λ_{int} of W



Zero Degree Calorimeter for HL-LHC

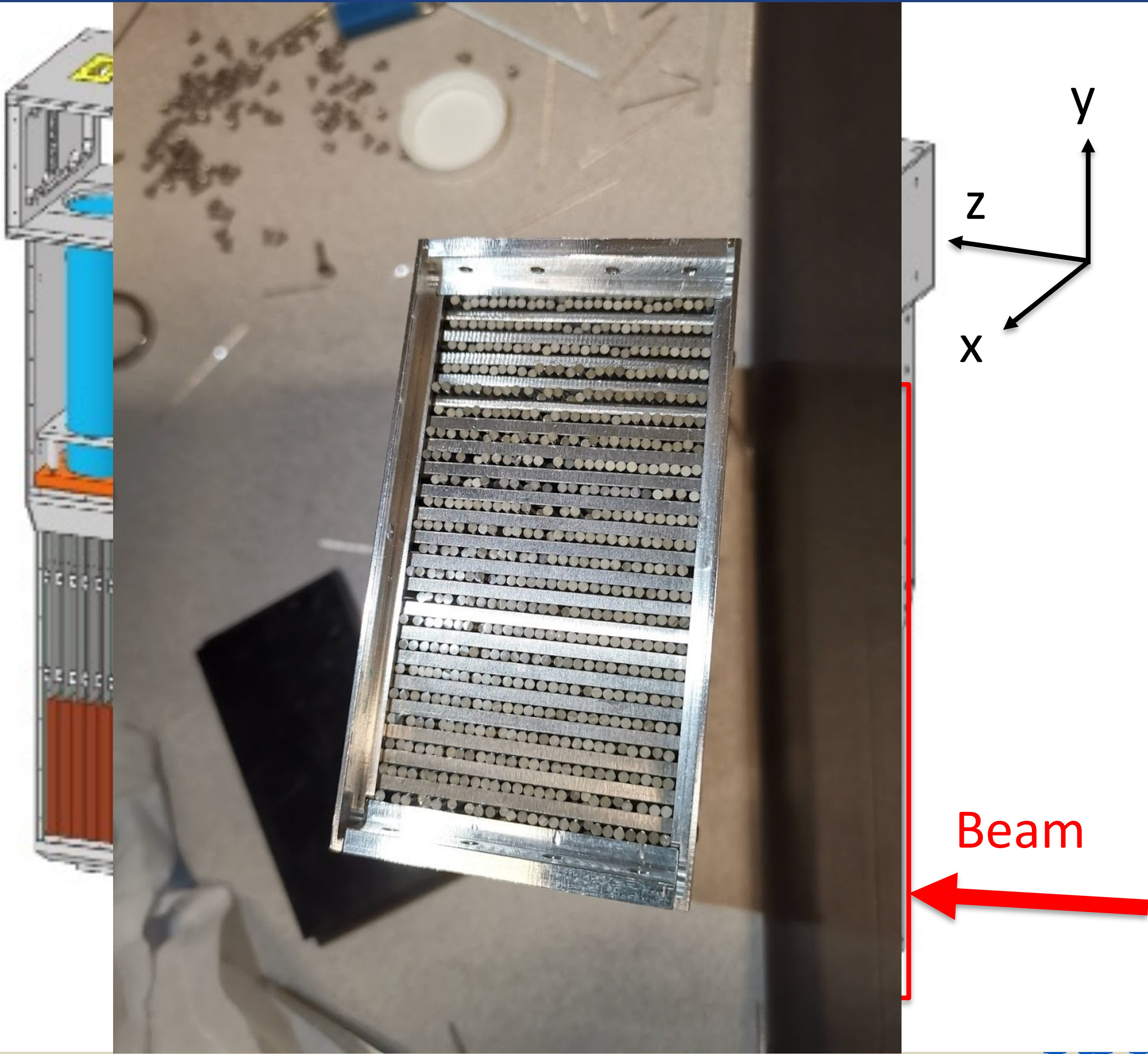
➢ EM section

- ❑25 tungsten plates [42mm X 120mm X 4mm]
- ❑15 fused silica rods per layer [ϕ1.5mm]
- ❑~30 X_0
- ❑4x3 [X-Z] segmentations
- ❑Winston cone light-guide
- ❑Hamamatsu R2496 [ϕ10mm]
- ❑Beam test in 2019/2021



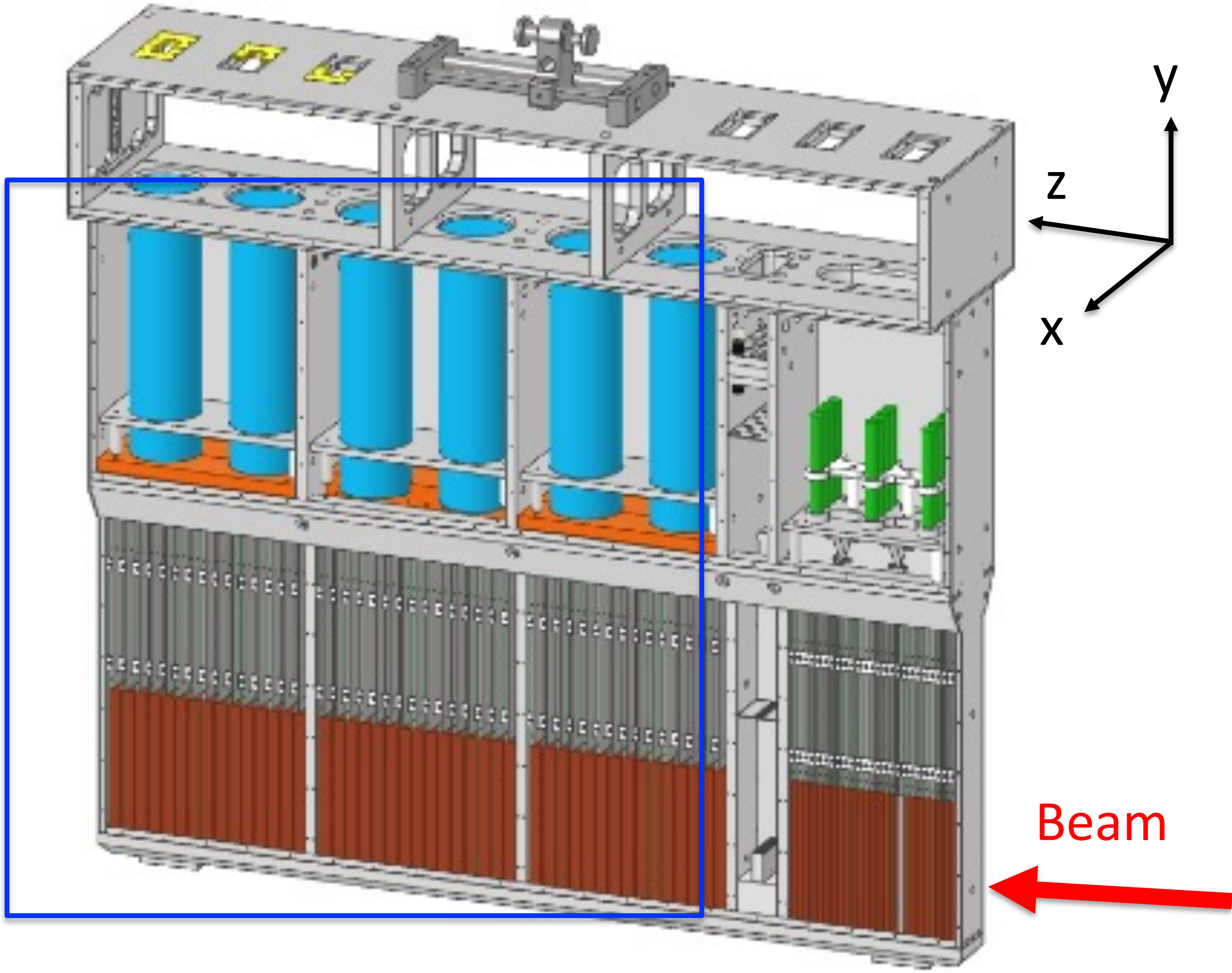
Zero Degree Calorimeter

- **EM section**
  - 25 tungsten plates [42mm X 120mm X 4mm]
  - 15 fused silica rods per layer [ϕ1.5mm]
  - ~30 X_0
  - 4x3 [X-Z] segmentations
  - Winston cone light-guide
  - Hamamatsu R2496 [ϕ10mm]
  - Beam test in 2019/2021



Zero Degree Calorimeter

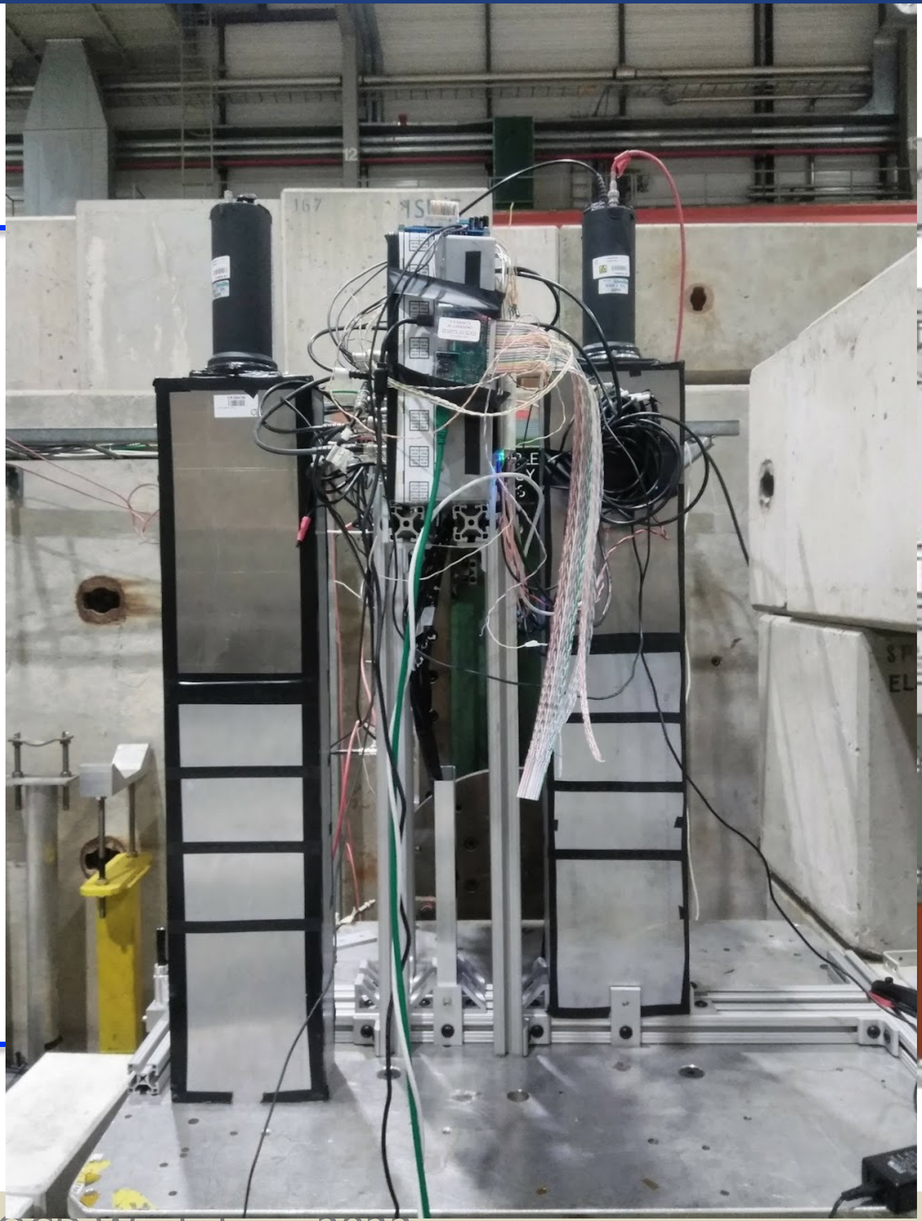
- **HAD section**
  - 45 tungsten plates [42mm X 120mm X 10mm]
  - 15 fused silica rods per layer [ϕ1.5mm]
  - ~4.5 λ_{int}
  - 6 [Z] segmentations
  - Trapezoidal light-guide
  - Hamamatsu R2059 [ϕ51mm]
  - Beam test in 2018 at SPS



Zero Degree Calorimeter

➢ HAD section

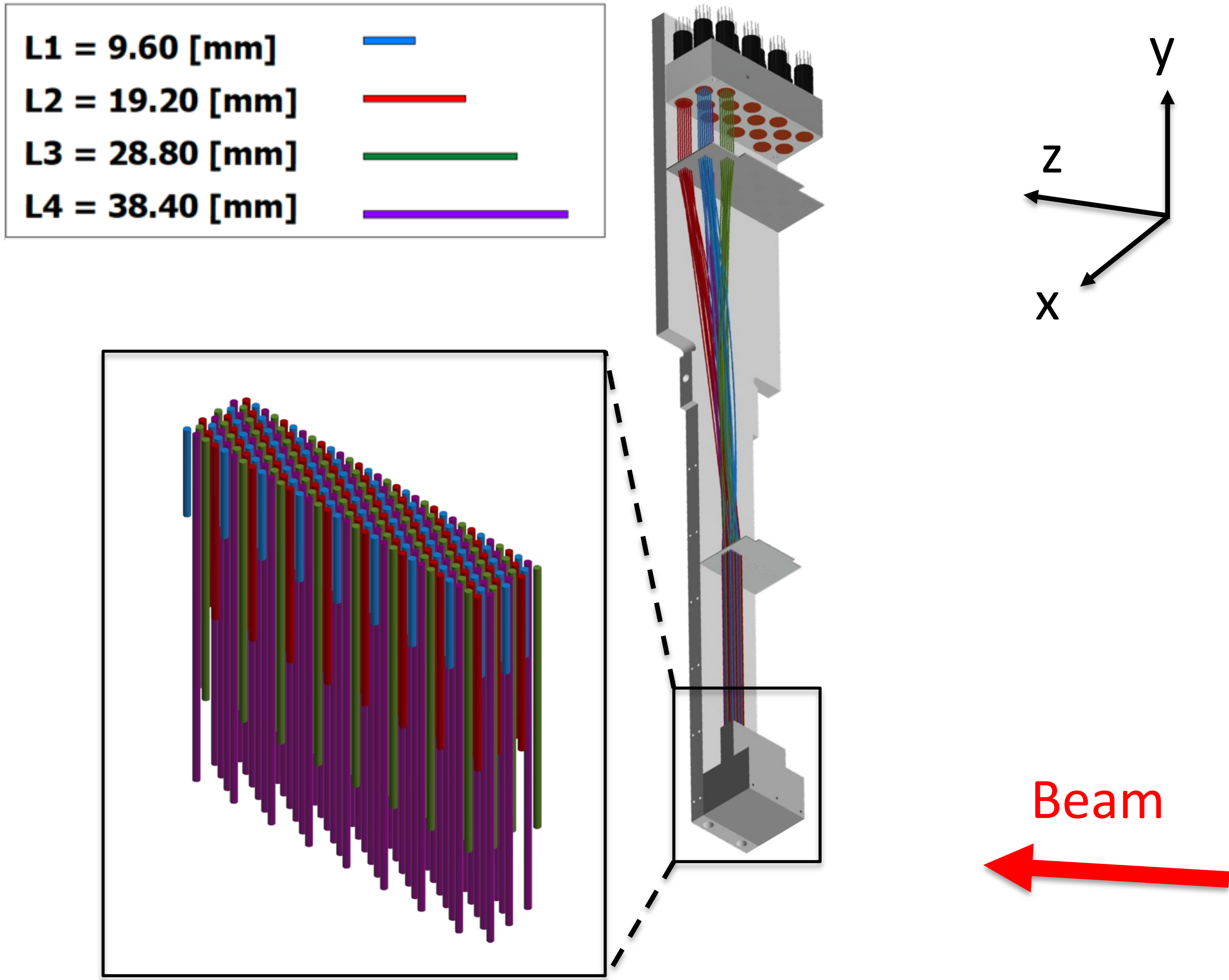
- ❑ 45 tungsten plates [42mm X 120mm X 10mm]
- ❑ 15 fused silica rods per layer [ϕ1.5mm]
- ❑ ~4.5 λ_{int}
- ❑ 6 [Z] segmentations
- ❑ Trapezoidal light-guide
- ❑ Hamamatsu R2059 [ϕ51mm]
- ❑ Beam test in 2018 at SPS



Zero Degree Calorimeter

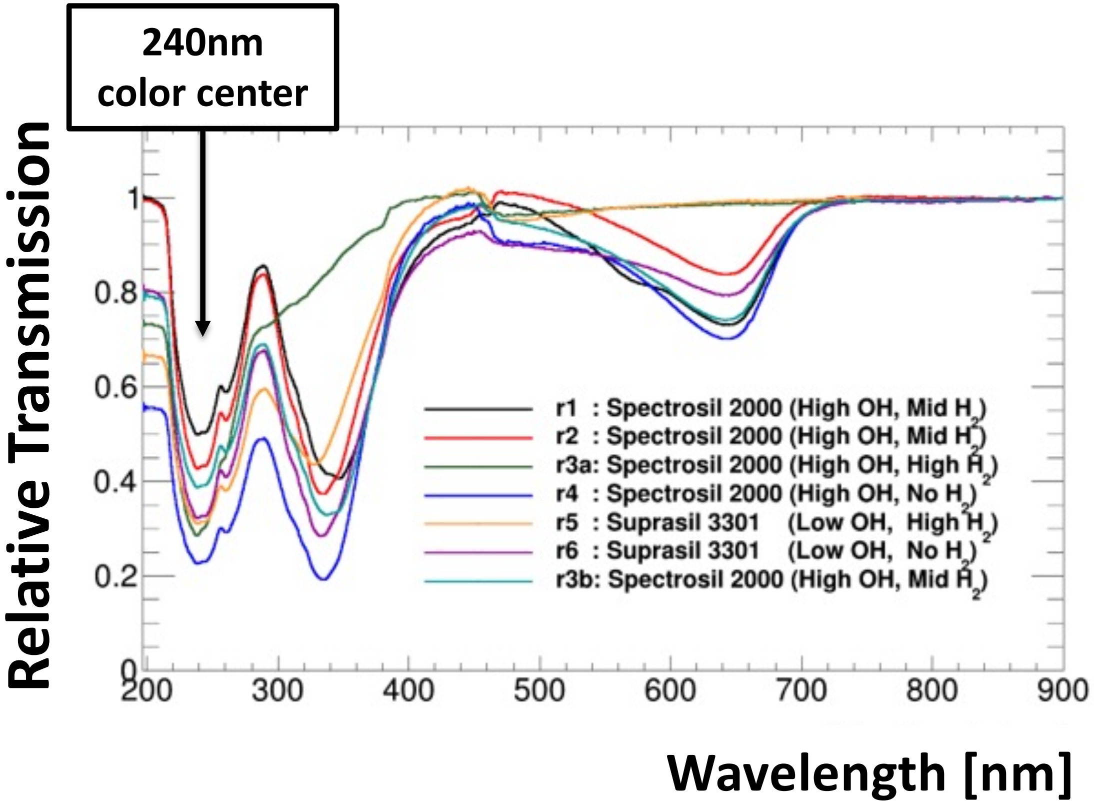
➢ RPD section

- ❑ "Pan flute" design
- ❑ Fused silica core and polyamide buffer
- ❑ 4X4 [X-Y] segmentations
- ❑ Machine learning algos
- ❑ Hamamatsu R2496 [ϕ10mm]
- ❑ Beam test in 2021 at SPS



Fused Silica Radiation Hardness

- Radiation hard fused silica rods used as Cherenkov radiator
  - Various fused silica rods irradiated by BRAN group in TAN during Run 2



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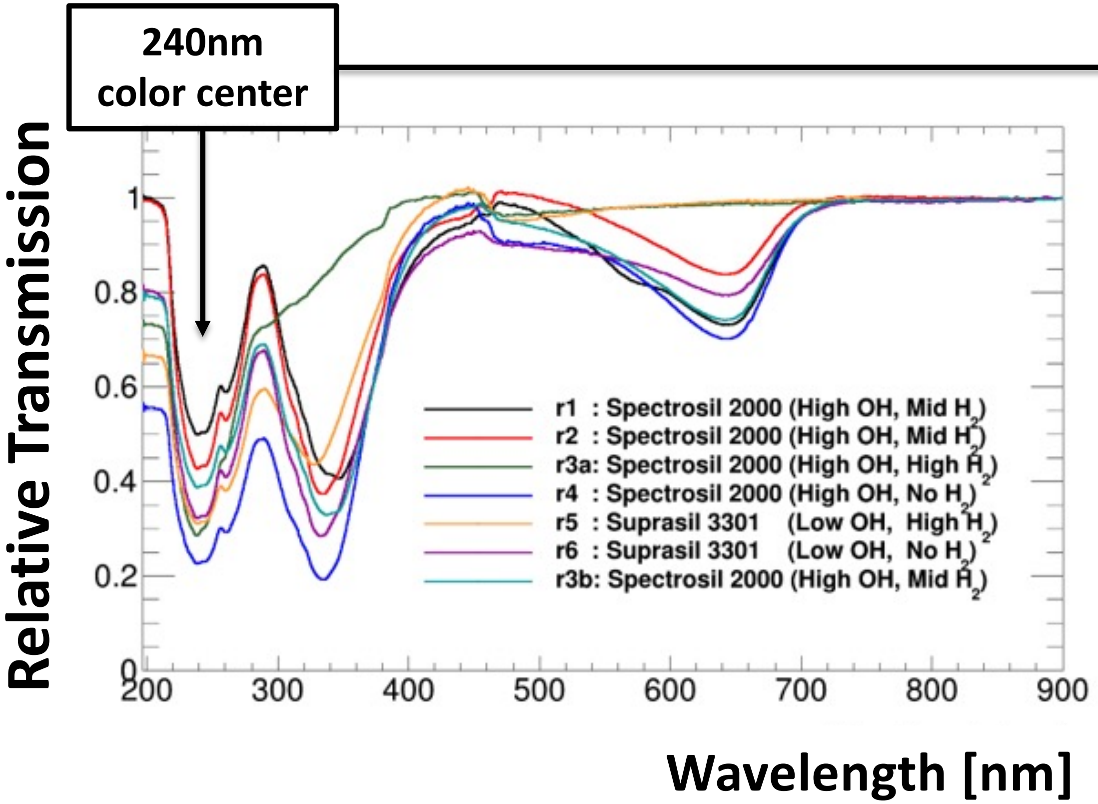
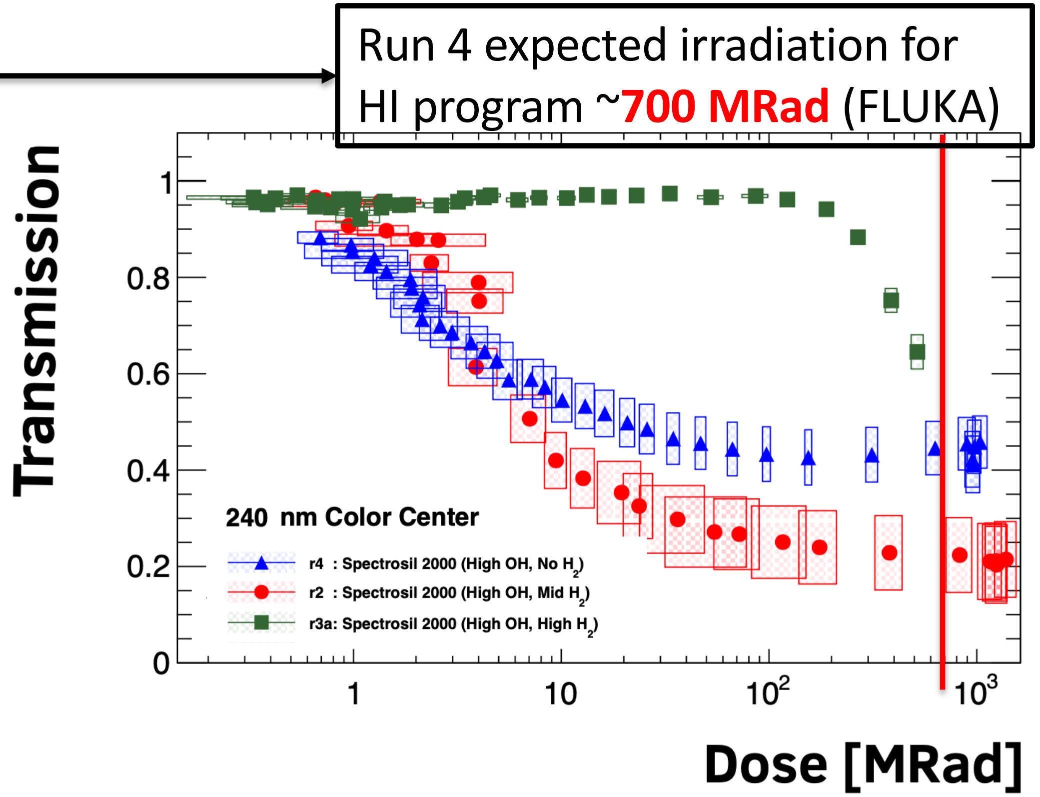
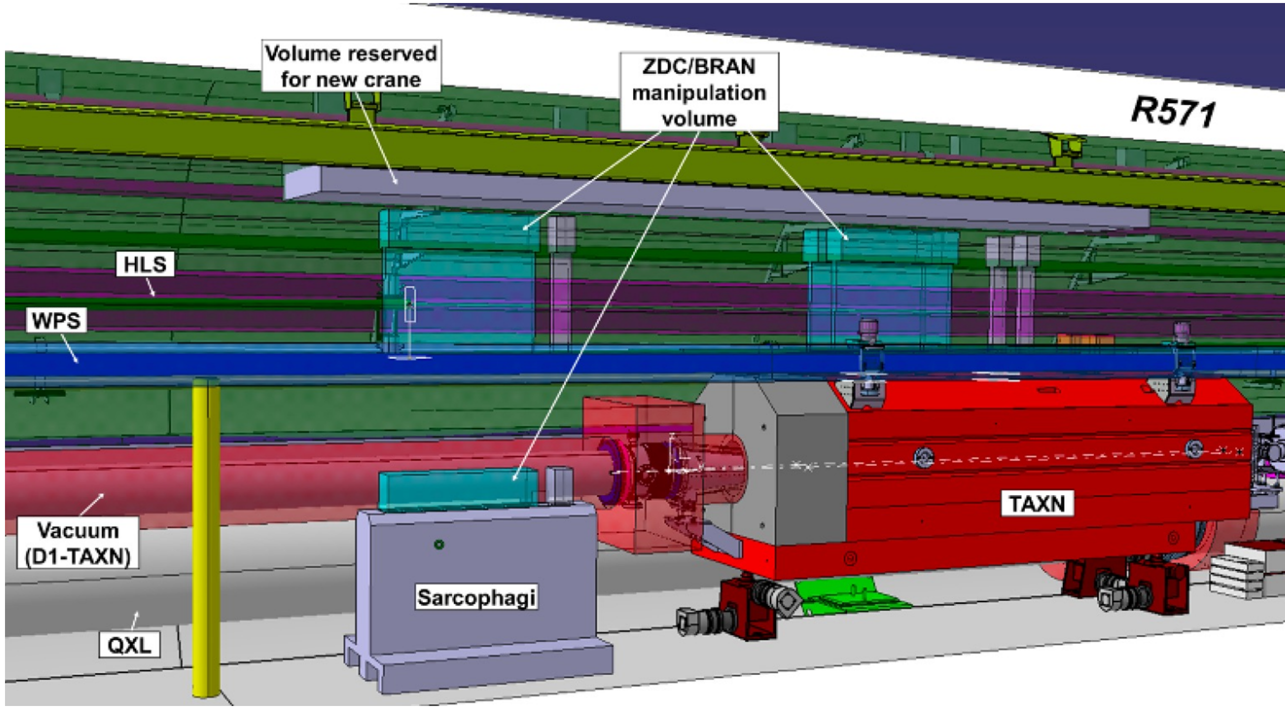




Things Not Covered

- PMT considerations
  - Radiation hardness, diameter, rising time
- LED gain monitoring system
  - Online calibrations
- HL-LHC integration
  - Installation, RP
- Experiment integration
  - Readout, DAQ, DCS, monitoring
  - Software



Summary

- ZDC is important to overall Heavy Ion program at LHC
  - Better energy resolution and γ/n separation
  - Reaction Plane Detector for neutron orientation measurement
- Radiation hard and compact ZDC design for HL-LHC
  - Radiation tolerance for increased luminosity in Run 4
  - Compatible with TAXN modification
- Beam tests
  - 2018, 2019, 2021
- Well defined schedule