ZDC status

ePIC FF/FB cross-cutting WG meeting

September 5th, 2023

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ZDC status outline

- ZDC design review
  - Crystal calorimeter
  - Imaging EM calorimeter
  - Hadron calorimeter
  - Position (& timing) layer
- ZDC development
  - Radiation requirement
  - Test beam
  - Cooling & support
- ZDC integration
  - Interference

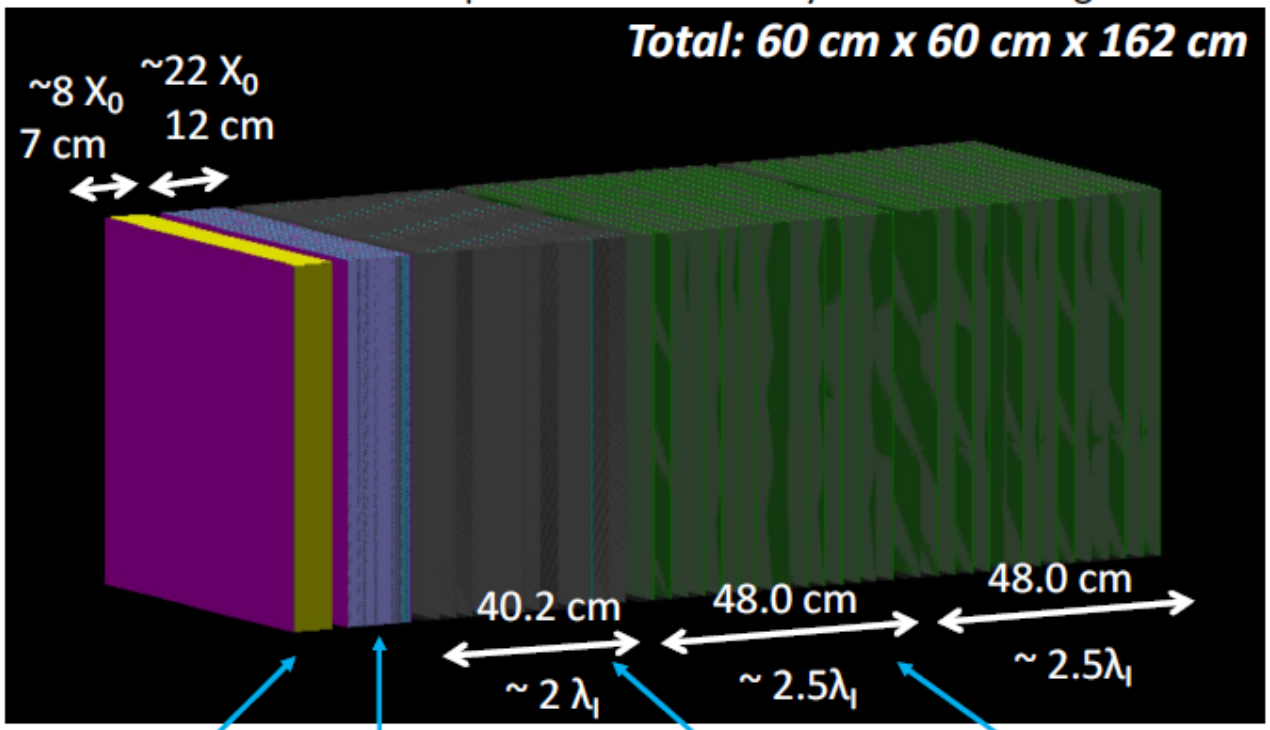
ePIC ZDC group

- Japan
  - RIKEN
  - Kobe Univ.
  - Shinshu Univ.
  - Univ. of Tsukuba
  - Tsukuba Tech. Univ.
- Taiwan
  - NCU
  - Academia Sinica
- Korea
  - Sejong Univ.
- USA
  - Kansas Univ.
  - PNNL

ePIC-ZDC 1st design

Current ZDC design

*note: space for readout may extend the longitudinal length.



Crystal ($PbWO_4$) + Silicon Pixel layer

W/Si calo. 3 Pixel layers are inserted.

Pb/Si calo.

Pb/Sci. calo.

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ZDC design review

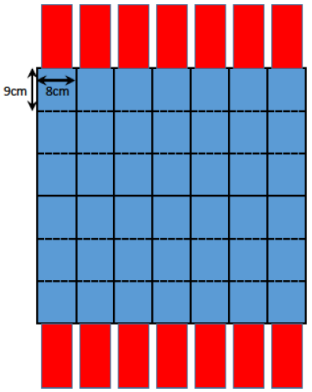
- Crystal calorimeter
  - 1st design: 60cm x 60cm PWO crystal $8X_0$
  - Design update option:
    - Smaller lateral dimension, 60cm x 60cm necessary to cover lateral hadron shower leakage (EM shower leakage smaller)
- W-Si imaging calorimeter
  - 1st design: 60cm x 60cm W-Si $22X_0$ (22 layers)
  - Design update option:
    - Smaller lateral dimension, e.g. ALICE-FoCal-E Pad size 9cm x 8cm $\rightarrow$ 6 x 7 = 54cm x 56cm
    - Smaller number of layers, e.g. $1X_0$ x 22 layers $\rightarrow$ $2X_0$ x 11 layers?
- Hadron calorimeter
  - 1st design:
    - Pb-Si $0.16\lambda_I$ x 12 layers (40cm)
    - Pb-Scintillator 10cm x 10cm x 48cm ($2.5\lambda_I$) tower, 10 x 10 x 2
  - Design update option:
    - No imaging (Pb-Si) layers
    - Pb-(Scintillator + Fused silica) 10cm x 10cm x 48cm tower 4 x 4?

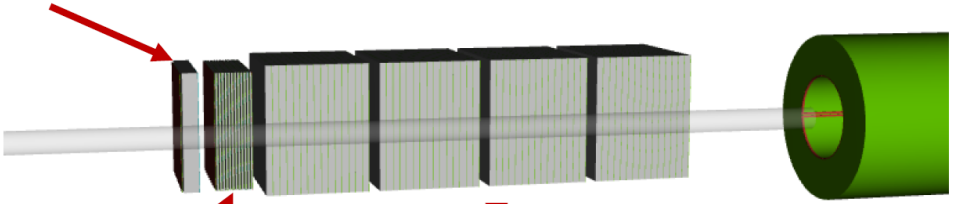
ZDC design review

- More cost effective design
  - Smaller EMCAL
  - Pb-Si HCAL removed
  - By Po-Ju Lin

➢ 1st Silicon & crystal calorimeter:
  - Smaller lateral dimension (x, y) = (56, 54) cm.

➢ Silicon Pixel lateral size (x, y) = (4, 3) mm



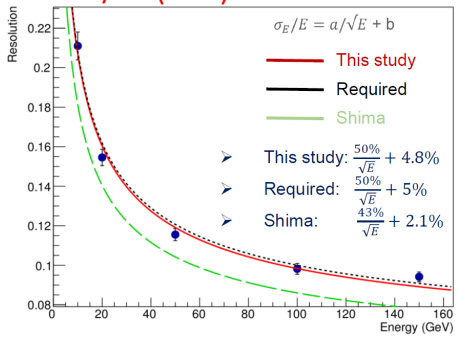


➢ W-Si imagine calorimeter
  - Smaller lateral dimension (x, y) = (56, 54) cm.
  - Smaller number of layers $1X_0 \times 22 \rightarrow 2X_0 \times 12$ layers

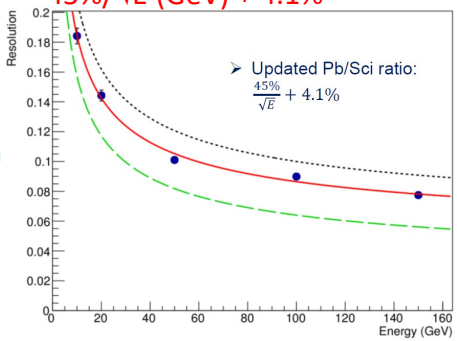
➢ Pb-Scintillator + fused silica
  - Towers of 10cm x 10cm x 48cm, each module is 60cm x 60cm x 48cm
  - 4 modules
  - Not yet have the implementation of fused silica – only scintillator now

➢ Pb-Si modules removed

HCAL Pb : Scint = 15 : 1
Neutron energy resolution
= 50%/√E (GeV) + 4.8%



HCAL Pb : Scint = 4 : 1
Neutron energy resolution
= 45%/√E (GeV) + 4.1%



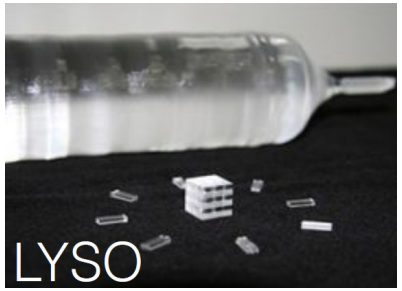
ZDC design review

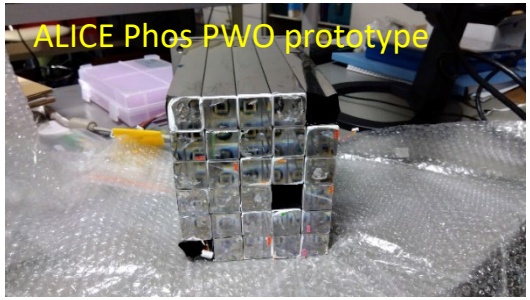
- Position layer
  - 3mm x 3mm required
- Open question yet
  - ALICE FoCal-E pixel layer (MAPS)
    - Too good position resolution
  - Smaller pad layer
  - AC-LGAD (position & timing layer)

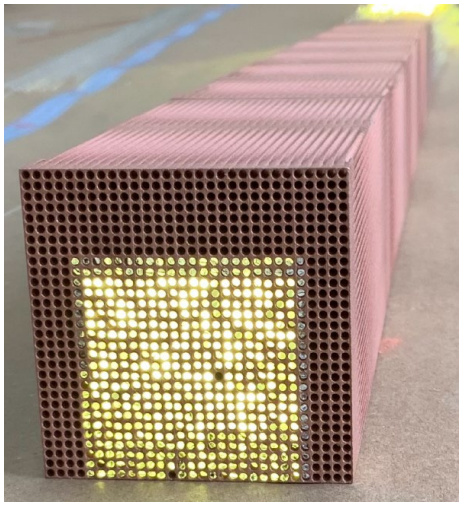
ZDC design review

- Crystal calorimeter
  - PbWO4 vs LYSO
    - Small prototype to be tested & evaluated @ Tohoku-ELPH in this winter
  - LYSO crystal by Taiwan group (from CMS)
    - More light yield
    - More stable for radiation
    - But higher cost
  - Cooperation with B0 EMCAL started

	X_0	LY (ph/MeV)	T dep. of LY (%/K)	Decay time (ns)	λ_{em} nm
$PbWO_4$ (CMS)	0.89 cm	200	-1.98	5 (73%) 14 (23%) 110 (4%)	420
LYSO	1.14 cm	30,000 (market standard)	-0.28	36	420
SciGlass	2.4-2.8 cm	>100		22-400	440-460







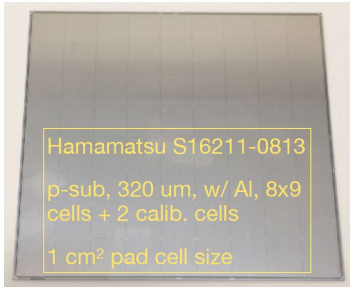
- HCAL
  - Korea group
  - Dual-readout calorimeter

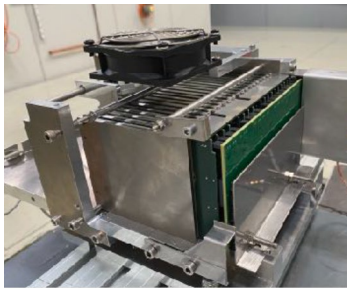
ZDC Development

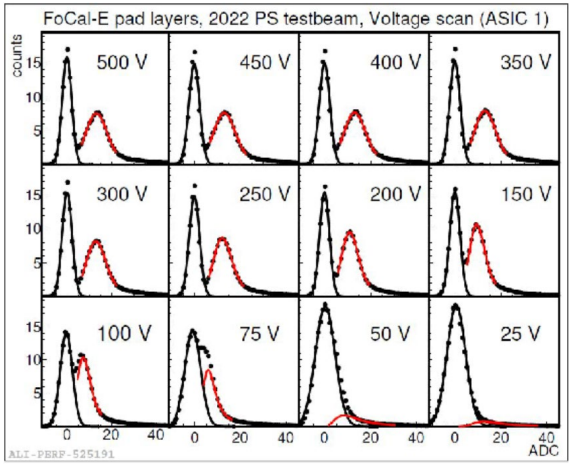
- Radiation requirement
  - Based on FLUKA simulation by V. Baturin, et al., we assumed 10^{14} neutron/cm^2 lifetime fluence, but this seems be too high.
  - 10^{13} neutron/cm^2 or lower would be appropriate estimation, but it still require radiation hard technology for the ZDC, especially upstream EM calorimeter and even Hadron calorimeter close to the zero degree region.
- Test beam
  - ALICE FoCal-E test beam @ Tohoku-ELPH & CERN-PS/SPS done
  - Crystal calorimeter prototype test beam @ Tohoku-ELPH will be performed in Feb. 2024
- Cooling & support
  - For imaging calorimeter, Taiwan group is going to produce a draft CAD figure based on ALICE FoCal-E design

Test-beam studies

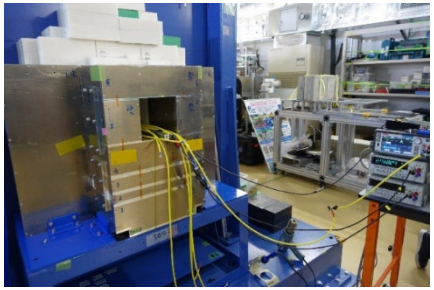
- ALICE FoCal-E test beam @ Tohoku-ELPH & CERN-PS/SPS
  - p-sub sensor, HGCROC v2 for readout
  - Clear MIP peaks observed for almost all channels and layers
  - Reaching full depletion voltage around 300 V

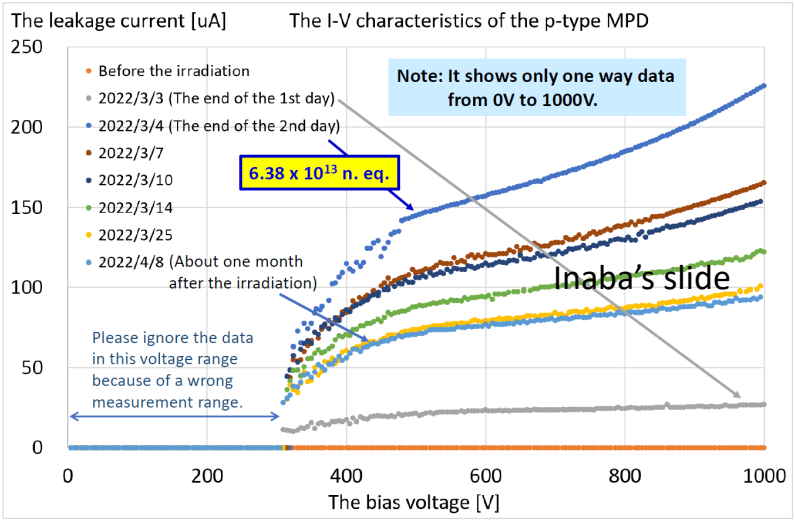






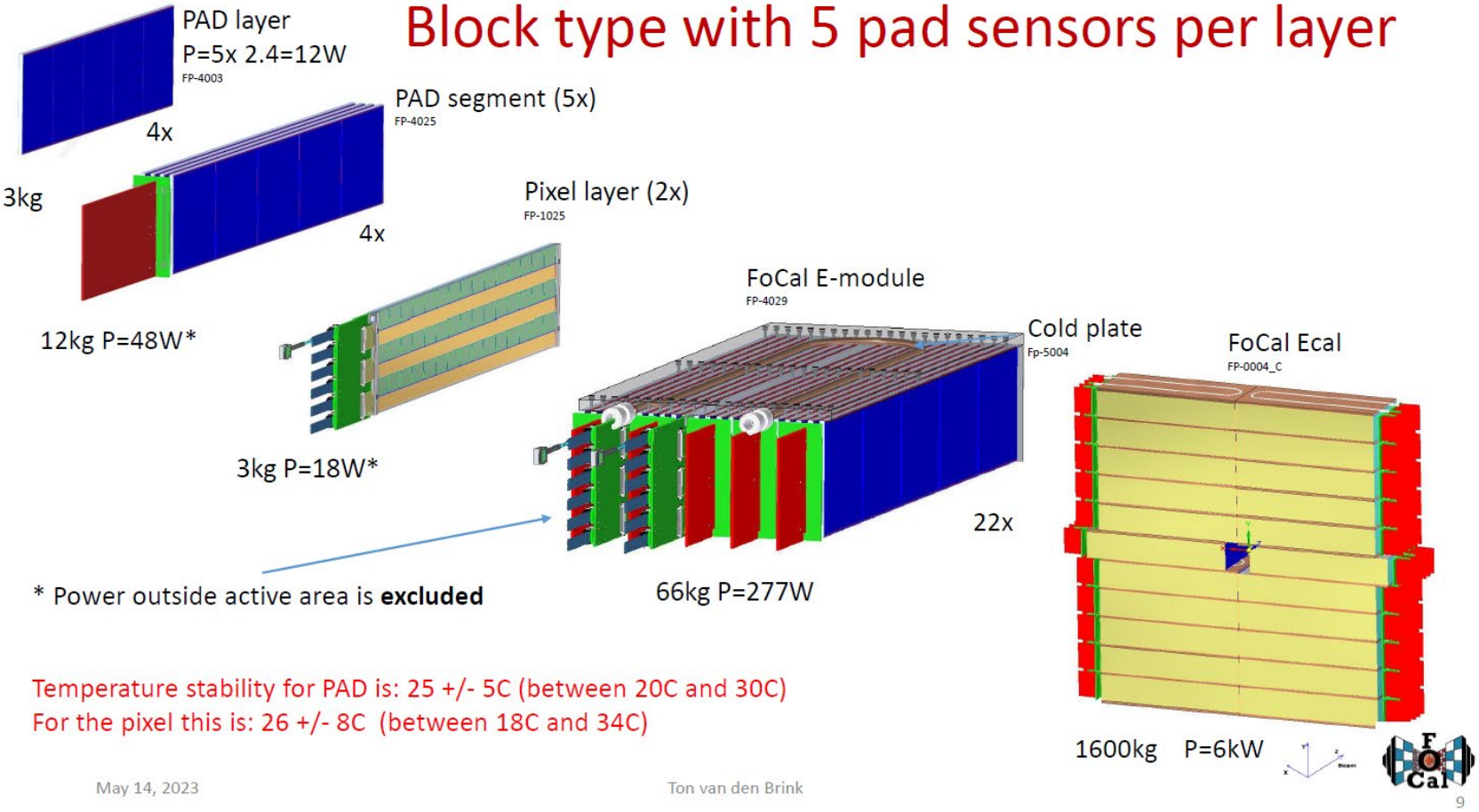
- Neutron irradiation test @ RIKEN-RANS
  - Sensor, photodetectors, chips, cables
  - For FoCal-E, sPHENIX, ePIC-ZDC
  - Up to ~10^{14} neutrons/cm^2





ALICE-FoCal structure

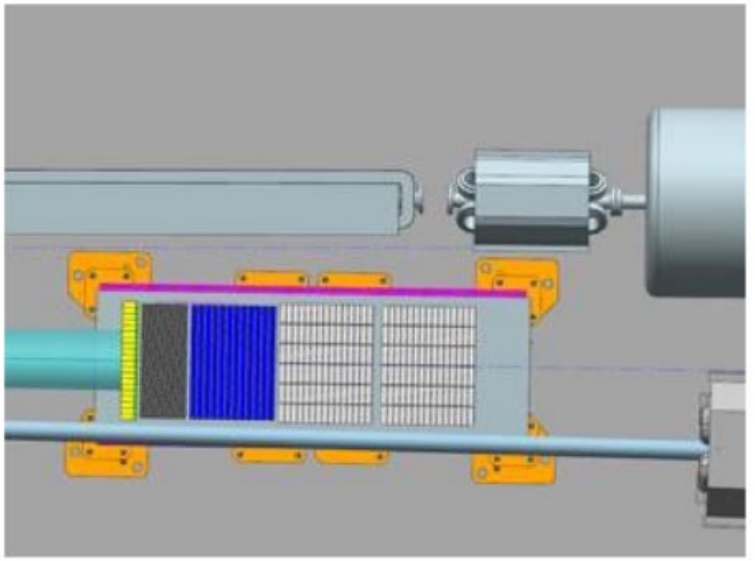
- Including cooling & support

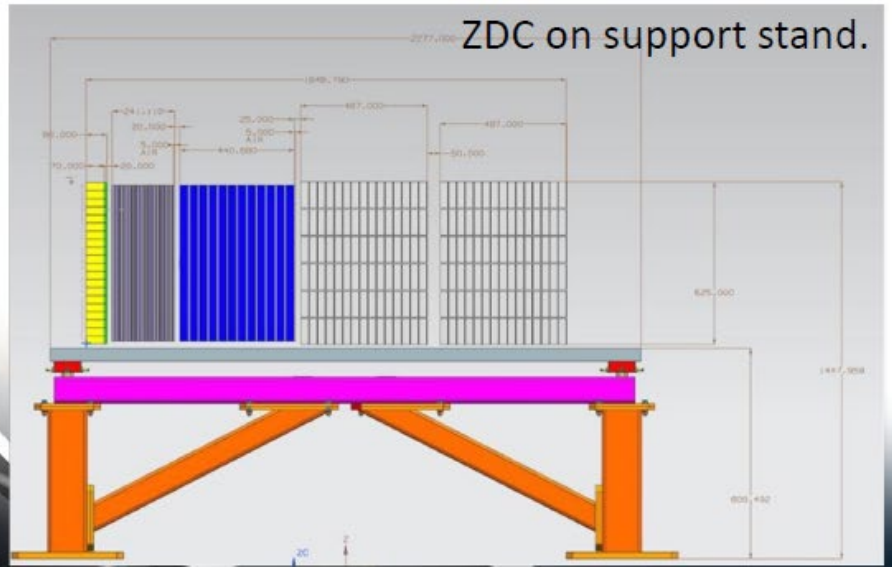


ZDC integration issues

Integration Issues

- ZDC sits outside of the beampipe - main integration issue is keeping it clear of magnet cryostats, crab cavity on electron side, and hadron beam pipe.





- Potential interference with hadron beamline → needs some follow-up with hadron beamline experts.
  - Need 2-3cm clearance between ZDC components and beam pipe, but this needs follow-up.

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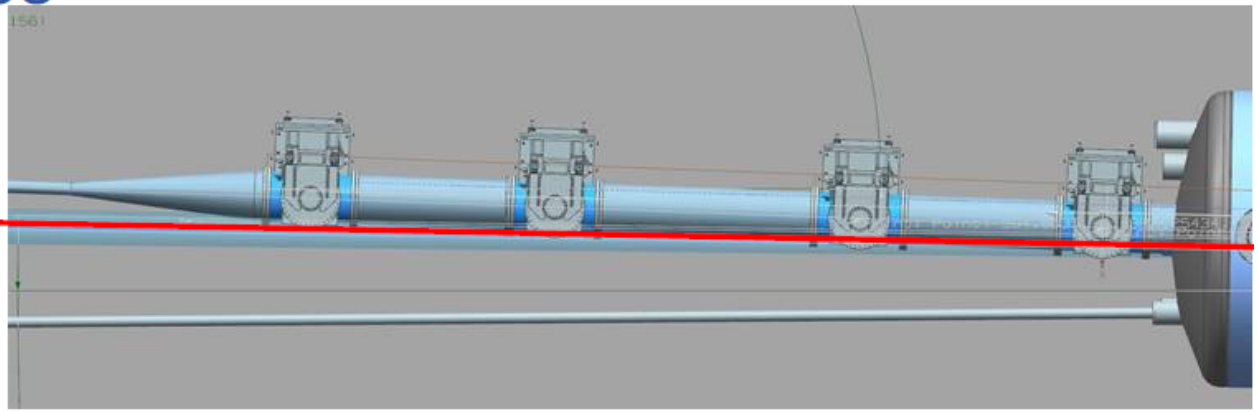
Slide shown by Alex Jentsch in Warsaw meeting in July

ZDC integration issues

Integration Issues

0 degrees



- Neutral particle cone faces two issues:
  - Exit from beampipe at very shallow angle (~ 22mrad) → effective material length O(10cm) for 2mm thick beam pipe wall!
  - With inclusion of OMD/RP support - interference of zero angle neutrals with flanges/support components!
- **This needs some major optimization (underway).**
  - **The present beampipe design was done by Alex Jentsch as a placeholder back in 2021 - we are in need of an engineer to advance the design and aid in optimization (project is aware – in progress).**

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Slide shown by Alex Jentsch in Warsaw meeting in July