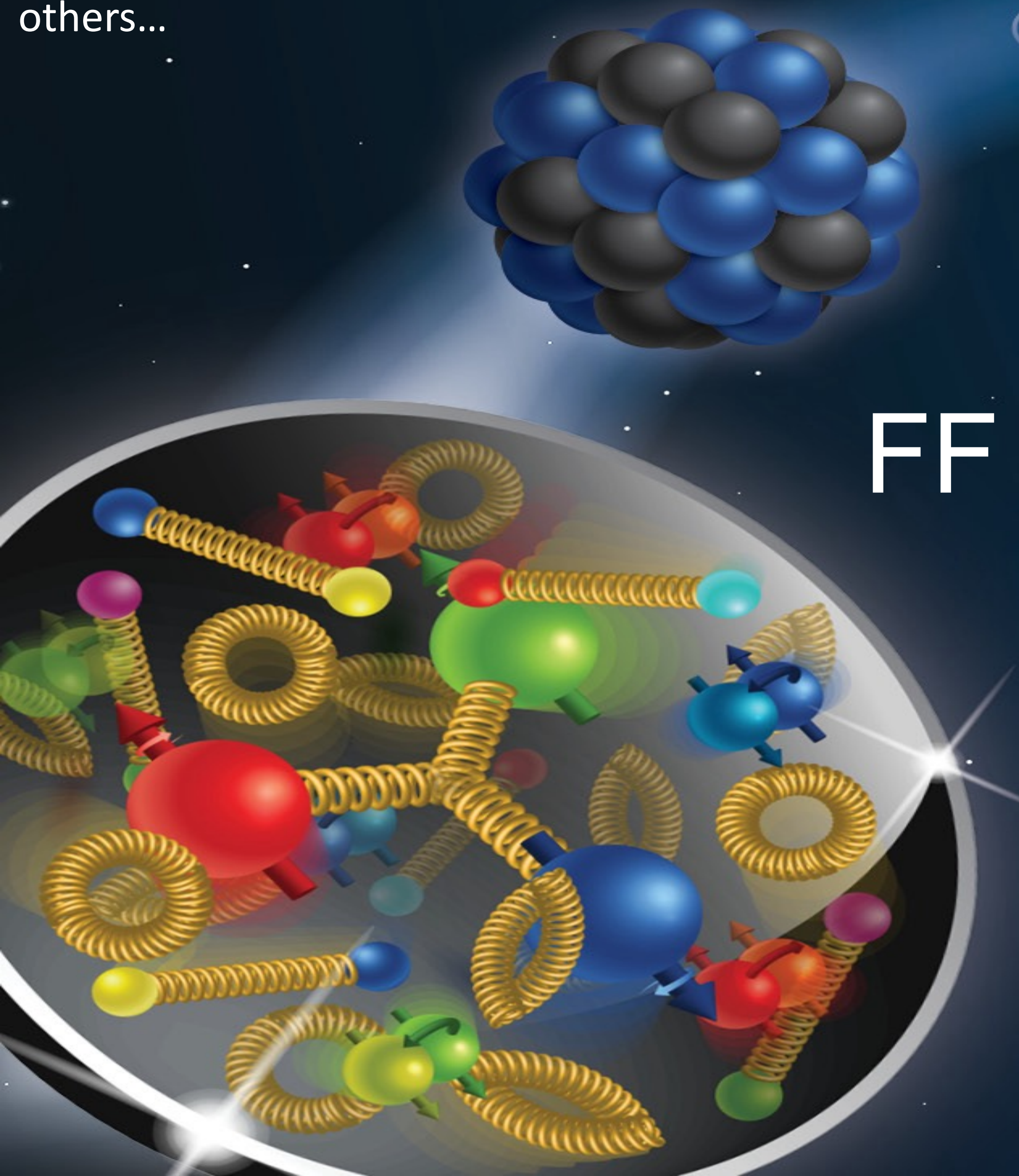
***Slides/drawings/etc., have been produced by Jonathan Smith, Brian Eng, Yulia Furletova, Karim Hamdi, Ron Lassiter, Alex Jentsch, Yuji Goto, and others…



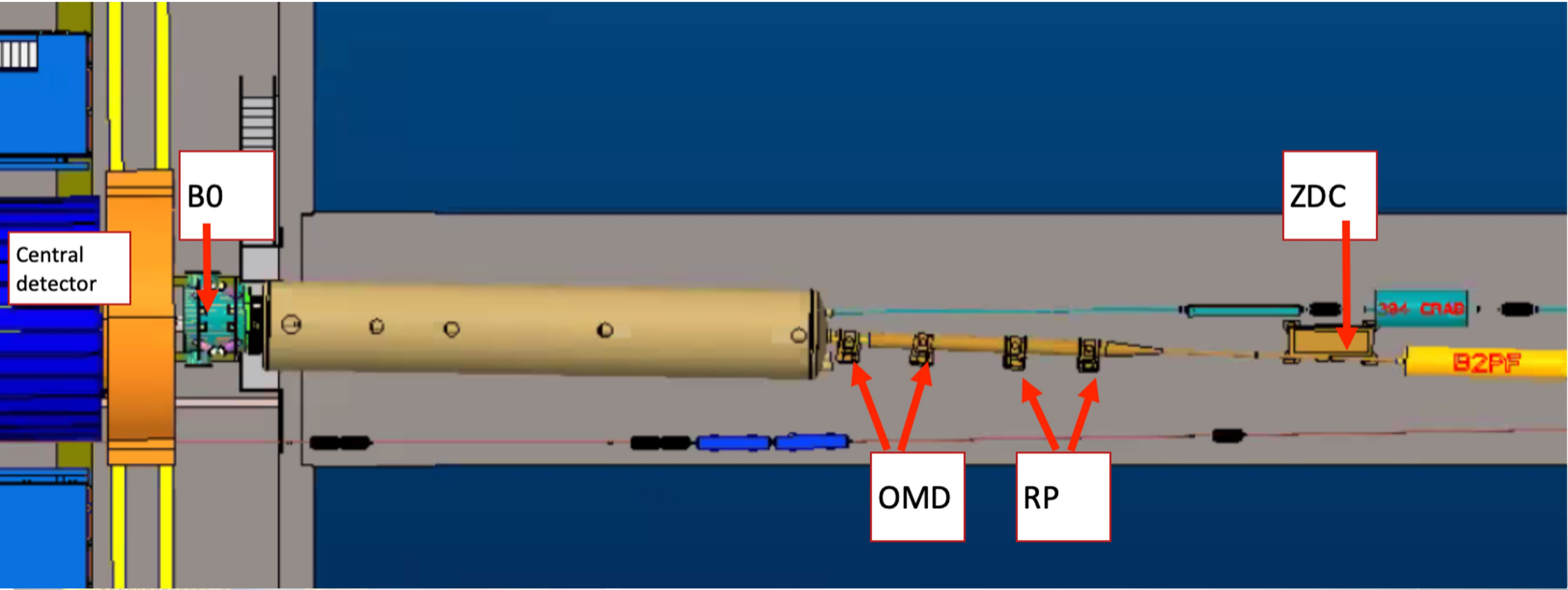
FF Technical Integration Status

Alex Jentsch, on behalf of the FF DSC***

ePIC TIC Meeting
June 26th, 2023

BROOKHAVEN NATIONAL LABORATORY Jefferson Lab U.S. DEPARTMENT OF ENERGY Office of Science

Full CAD Layout



Institutions

B0 Detector

➢ **Silicon Tracker**
- Tel Aviv University, Israel
- Hebrew University of Jerusalem, Israel

➢ **EMCAL**
- Ben Gurion University of the Negev, Israel

Roman Pots and OMD

- Brookhaven National Lab, USA
- IJCLab, Orsay, France
- OMEGA, France
- IRFU/CEA-Saclay, France

Zero-Degree Calorimeter

- RIKEN, Japan
- Kobe University, Japan
- University of Kansas, USA

Pacific Northwest National Lan, USA

➢ **Crystal EMCAL**
- Tsukuba, Japan
- NCU and Academia Sinica, Taiwan

➢ **Sampling HCAL**
- Sejong, South Korea

Charge from TIC

- how is your system integrated with the overall ePIC design, i.e., what is the envelope occupied, is there possibly overlap with other subsystems, and is the design consolidated, …

—> Primary envelopes understood for 2 subsystems → work needed on several fronts for FF subsystems and beamline.

- how are the services integrated, i.e., readout, cooling, support structure, etc?

—-> Susbystem dependent, discussion enclosed.

- does the present technical design and implementation fulfill the YR requirements, i.e., will it stand a technical design review, and if not what is the strategy to mitigate?

—-> YR: Yes, and re-design of various components is being done with care given to the physics topics of interest (detector work is also done by interested physicists).

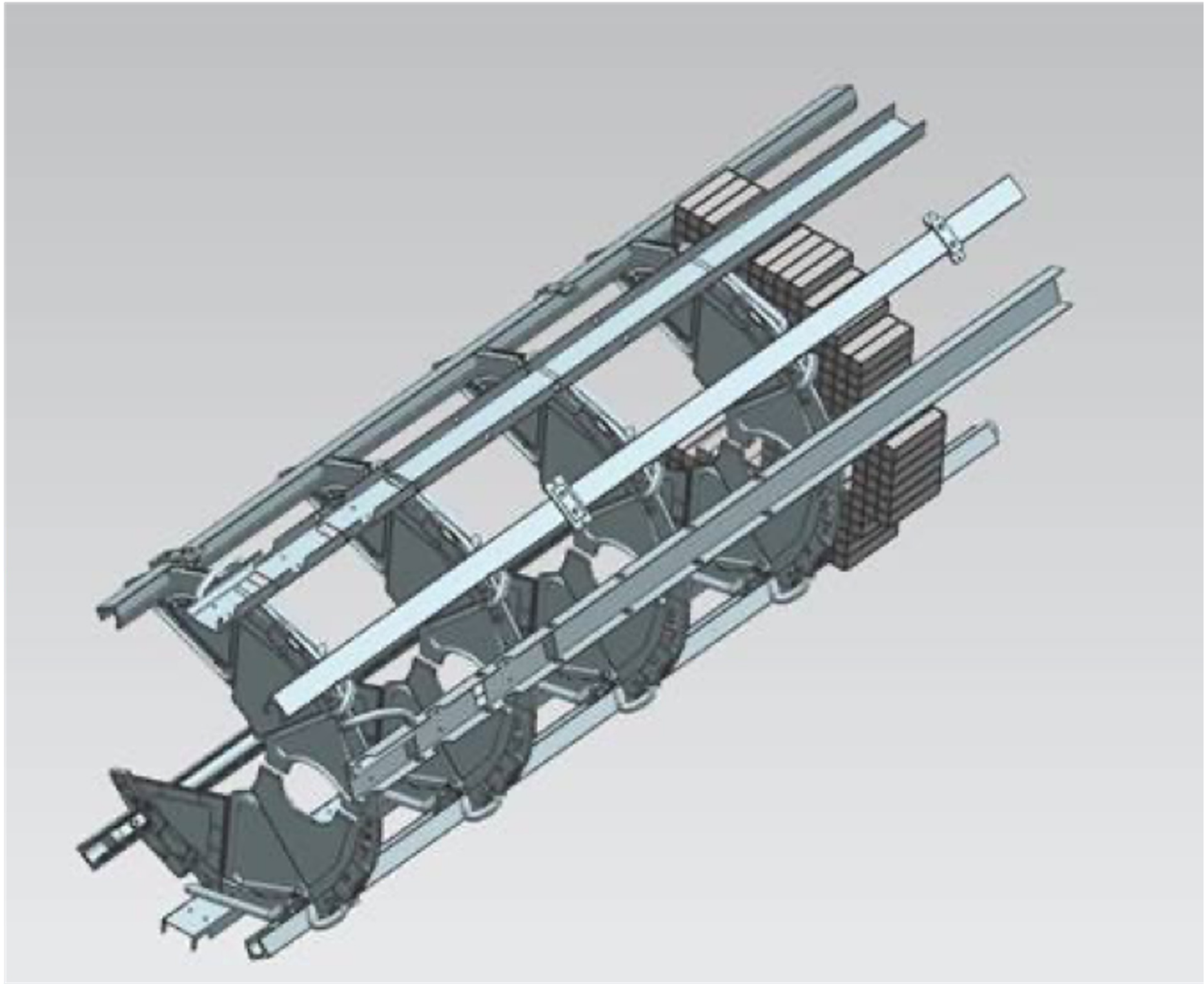
—-> **Technical review: by end of summer, yes. The integration issues are not minor ones.**

General Integration Comments

- FF subsystems do not overlap physically with other ePIC subsystems at all.
    - Integration issues independent of ePIC (except B0 - ePIC material produces secondaries which irradiate B0).
- Our main integration concerns are with regards to the hadron beam line (vacuum, magnets, etc.).
- 4 subsystems with unique integration issues.

B0 Integration

- Silicon tracking detectors + crystal EMCAL installed into combined function B0pf magnet.
  - Contains both hadron beam and electron beam + quadrupole and shielding.
- Integration includes support structure + installation rails, readout and power cabling.
- Main problems are longitudinal space, transverse acceptance, and radiation loads in the B0 (rather high compared to most of ePIC).
- Preliminary solutions in place, but much remains to be designed.

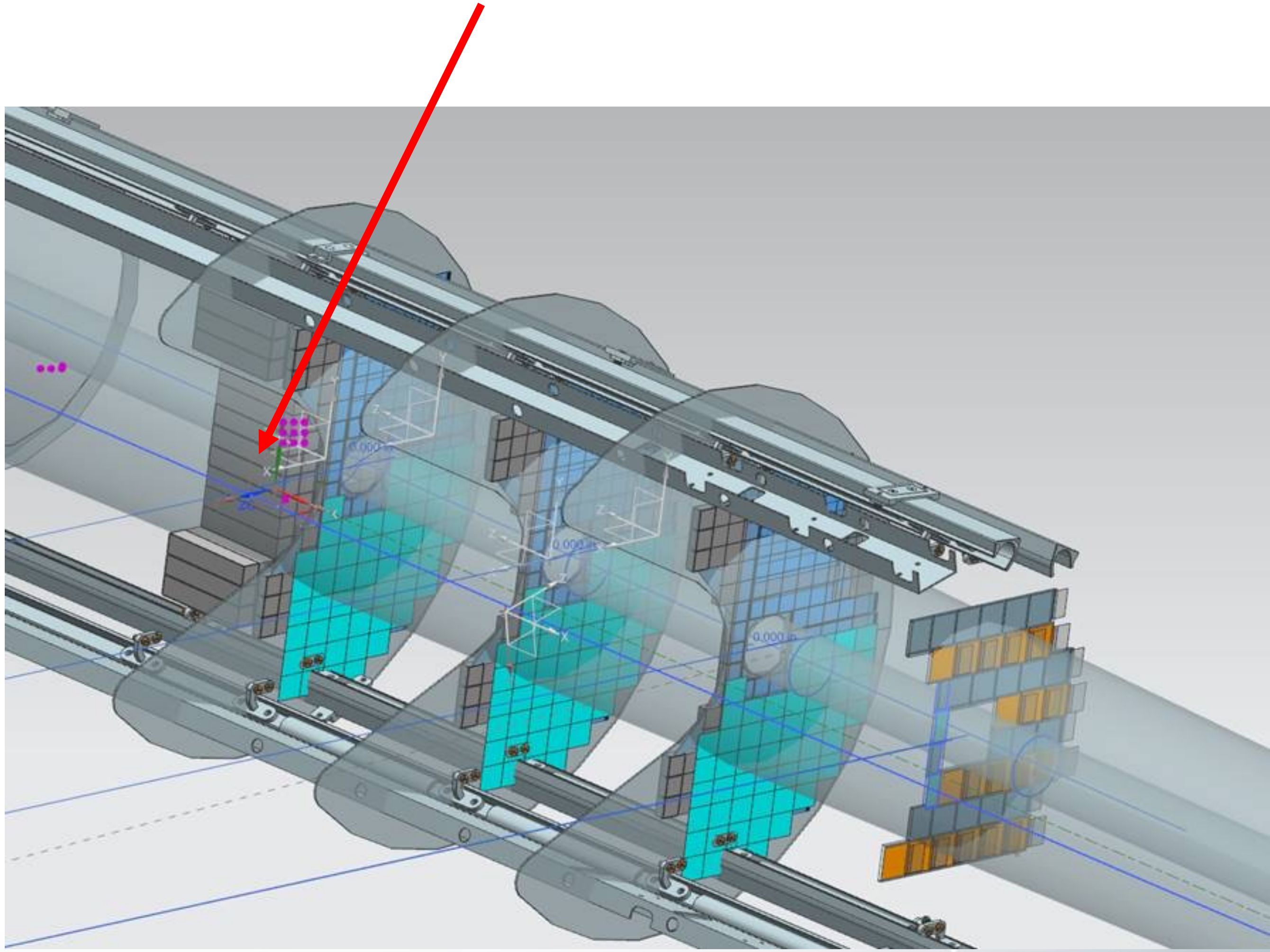


Karim Hamdi and Ron Lassiter

B0 Integration

- Crystal EMCAL weight is ~50kg (for $PbWO_4$) → **support system and installation procedure for the blocks needs to be designed.**
  - Readout? → SiPMs optimal for size, but radiation loads in B0 substantial.
  - Access to B0 system requires removal of pump in front of magnet (see next slide) → not easy to simply reach in and replace PMTs.

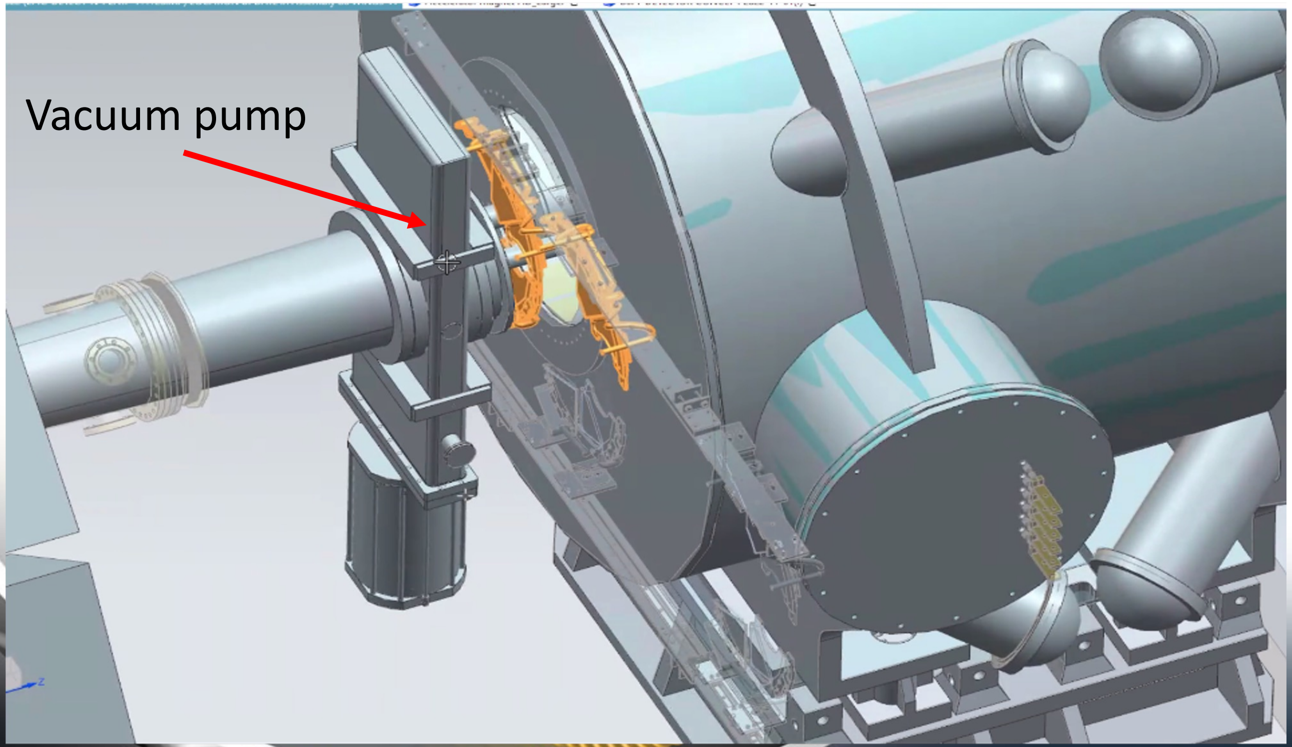
EMCAL at back of the B0pf bore

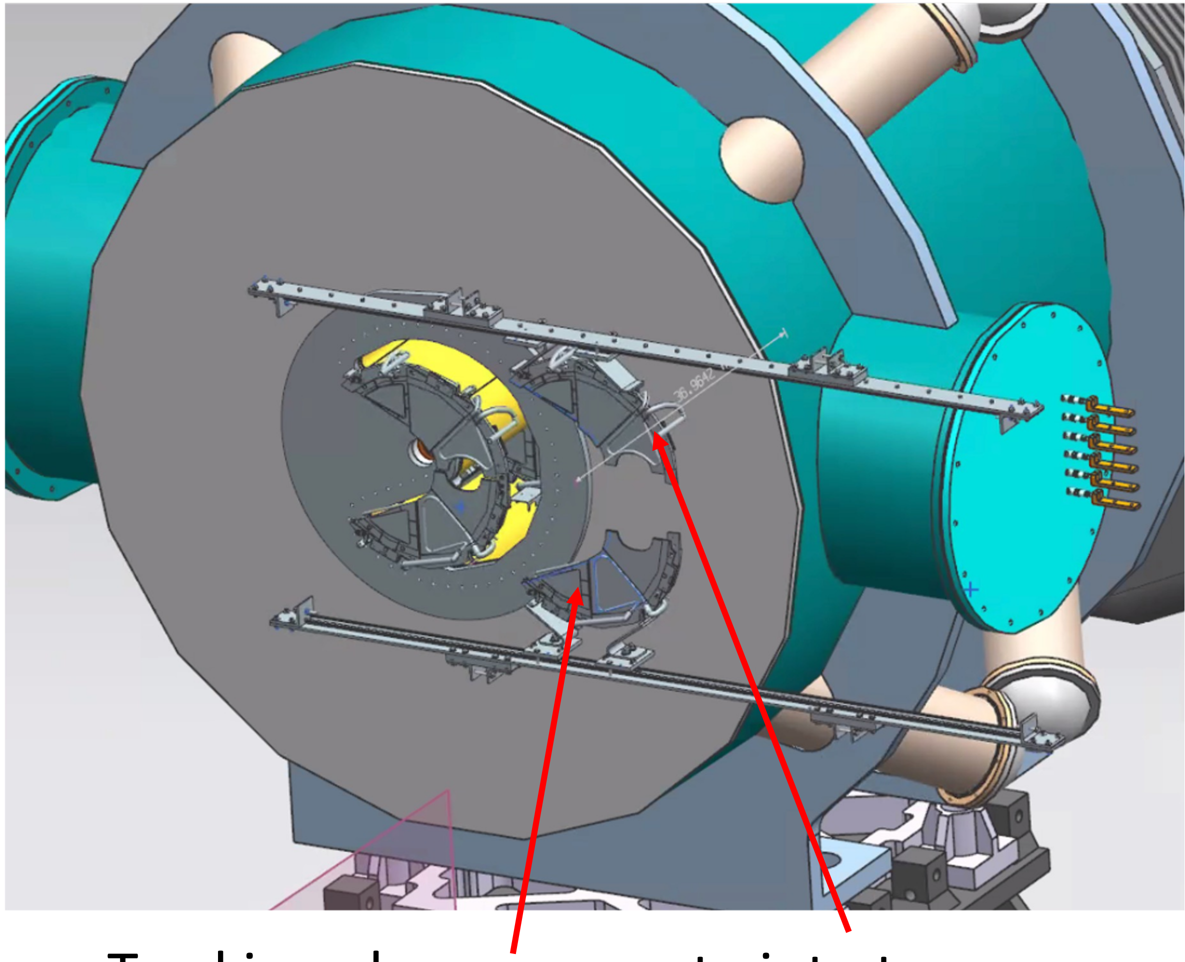


B0 Integration

Ron Lassiter

- Pump in front of detector package - only 13cm of space between pump and detector.
- Not currently in DD4HEP geometry - another source of secondaries (impact to be evaluated).





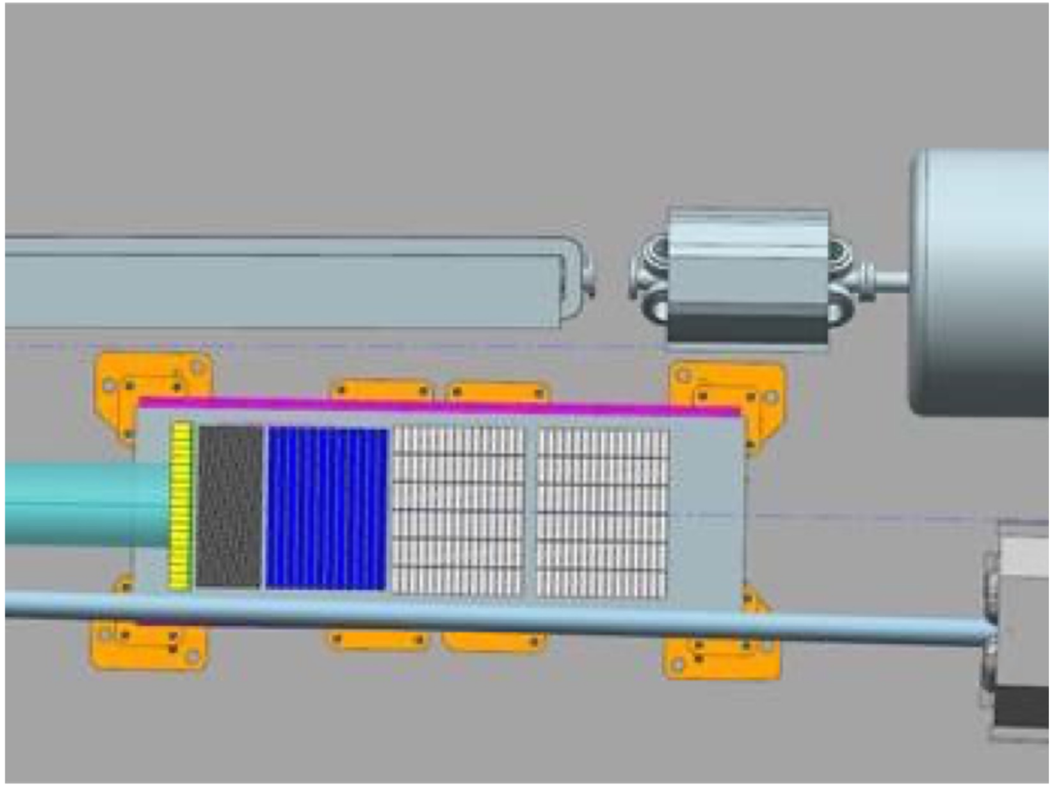
- Tracking planes separate into two pieces - top and bottom - for insertion into bore.
- Need concept for EMCAL.

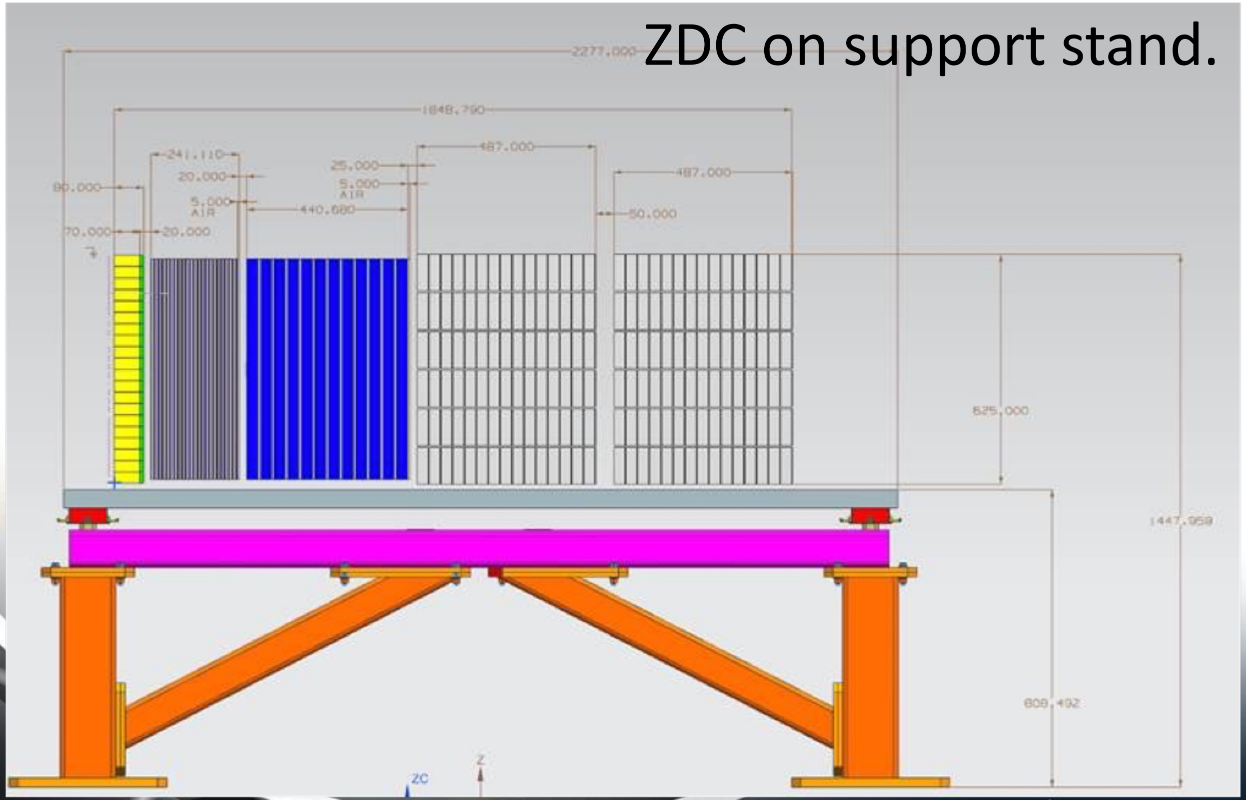
B0 technology

- Originally planned to use ITS3 MAPS + AC-LGADs (single layer).
  - **This solution won't work because of the integration time.**
- Now looking at a completely AC-LGAD system, or a TimePix4(3) + AC-LGAD(1) system (decision coming in the next few weeks).
  - Doesn't change much in terms of support system and integration - mostly alters performance.
  - Layout of sensors also affected, but options already laid-out (thanks to Jonathan Smith).
  - Need answers on radiation tolerance for TimePix4 so we can make a final decision.
  - Momentum reconstruction performance of various options already studied by Alex Jentsch (https://indico.bnl.gov/event/19620/)
- EMCAL was originally proposed to be PbWO4.
  - Challenging to maintain constant temperature + other issues.
  - Looking at LYSO as well.
- Radiation tolerance needs to be part of the discussion – B0 region among the "hottest" in ePIC (per year: 1 MeV neturon eqiv. Fluence ~ 10^{12} cm^{-2}; radiation doses > 10 krad - Current dose calculations)

ZDC Integration

- 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.





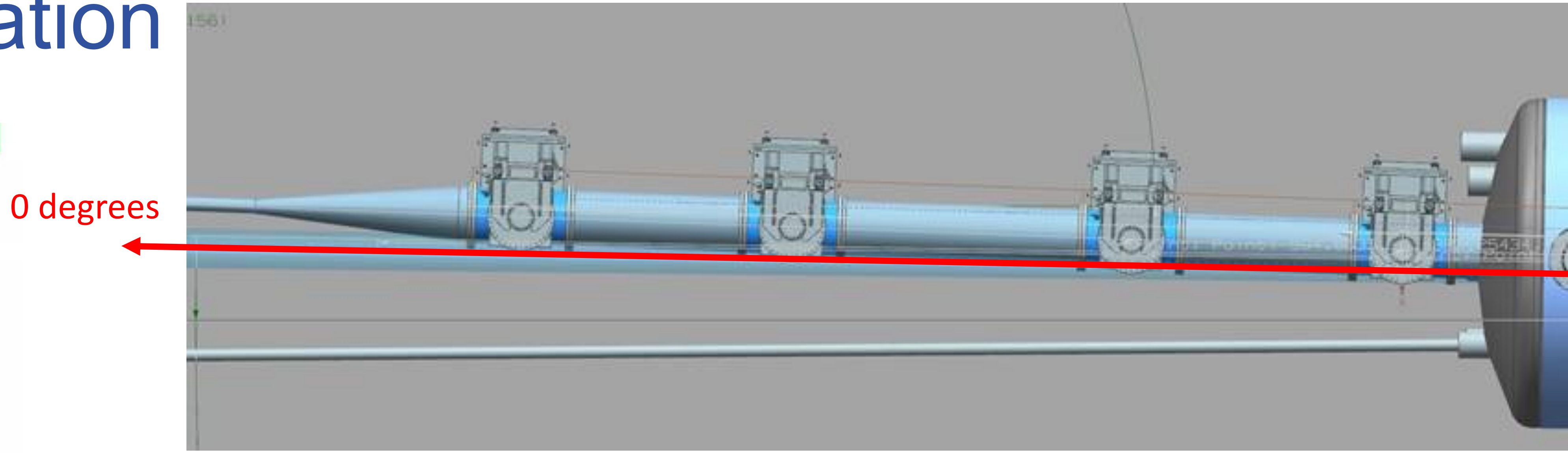
ZDC on support stand.

- 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.

ZDC Integration

- 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!

ZDC Integration



- <u>Neutral particle cone faces two issues:</u>
  - 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).**

ZDC Technology

- Crystal EMCAL in front, followed up with W/Si imaging EMCAL, Pb/Si imaging HCAL, Pb/Sci sampling HCAL.
  - Complex design → re-work in-progress to simplify and highlight neutron reconstruction capabilities (current highly non-uniform design worsens neutron energy resolution).
  - Optimization needed on absorber + active layers to get correct ratio (4:1 absorber/active for Pb) for compensation.
  - Optimization of efficient use of imaging layers to improve angular resolution also in-progress.

ZDC Technology

- The technology choice does not really impact the integration.
  - Group is aware space is limited on the sides of the detector due to presence of beam pipes - readout needs to be from the top.
  - Longitudinal space limited to ~ 2 meters.
  - Work being done to potentially reduce the transverse size (< 10%) of the detector from 60cm x 60cm to provide necessary safety margin for beam pipes.

ZDC Technology

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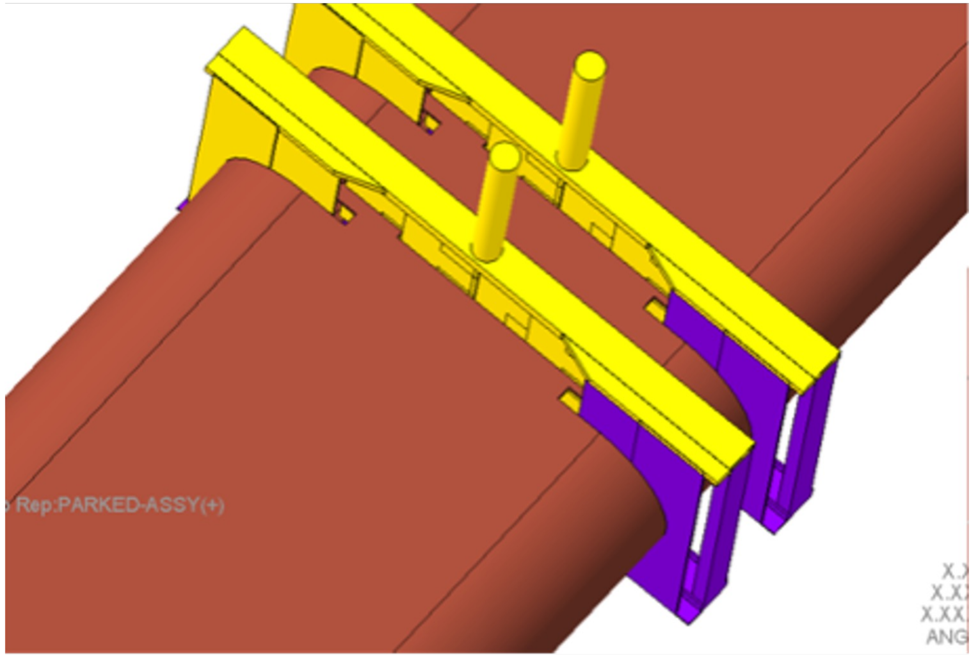
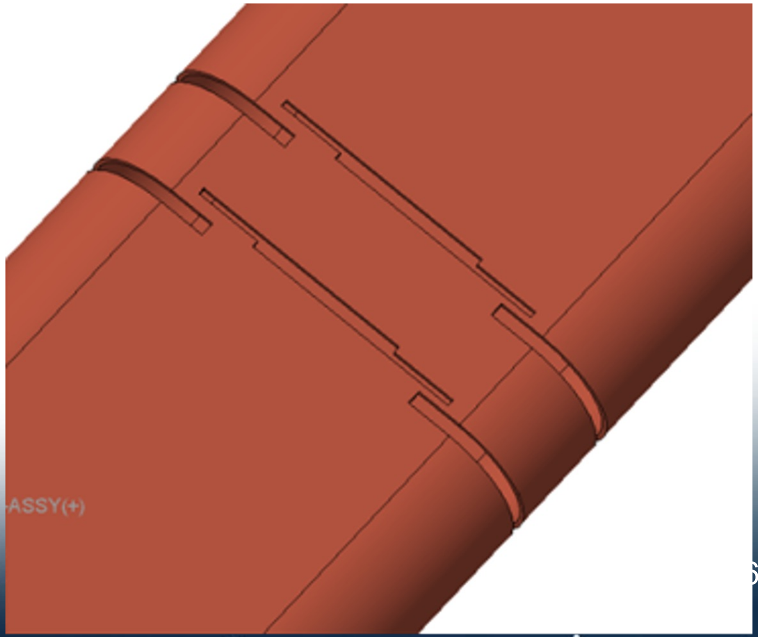
  - Group is aware space is limited on the sides of the detector due to presence of beam pipes - readout needs to be from the top.
  - Longitudinal space limited to ~ 2 meters.
  - Work being done to potentially reduce the transverse size (< 10%) of the detector from 60cm x 60cm to provide necessary safety margin for beam pipes.
    - Not a problem for photons → transverse extent of neutral cone limited to ~ 30cm x 30cm by aperture (smaller if ZDC is closer to neutral exit).
    - Need to establish loss of neutron energy resolution as a function of transverse size of detector → detector could have overall slightly projective shape → transverse size grows with depth.

Roman Pots/Off-Momentum Detectors

- RP/OMD most-challenging of the FF systems for machine integration.
  - AC-LGAD sensors directly integrated into beamline vacuum → creates issues for detector technology and **beam impedance**.
  - Requires special consideration for **beam pipe design and support system.**





Roman Pots/Off-Momentum Detectors

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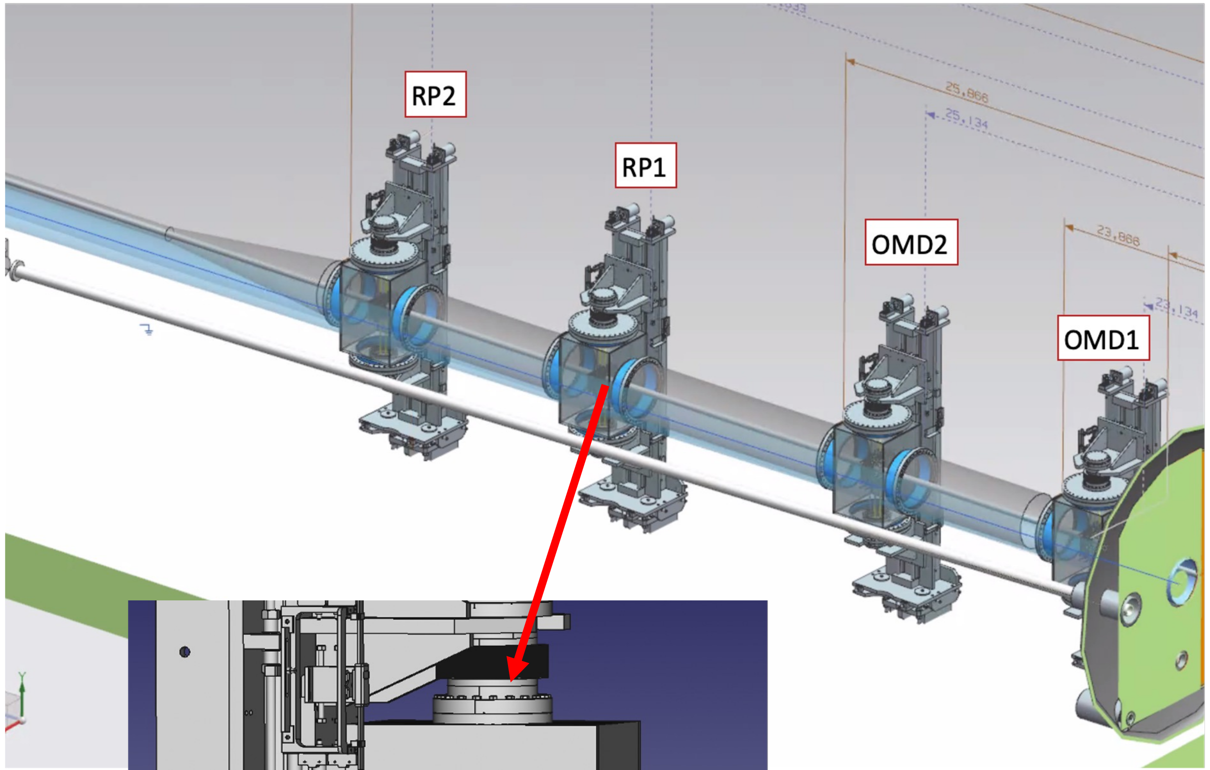
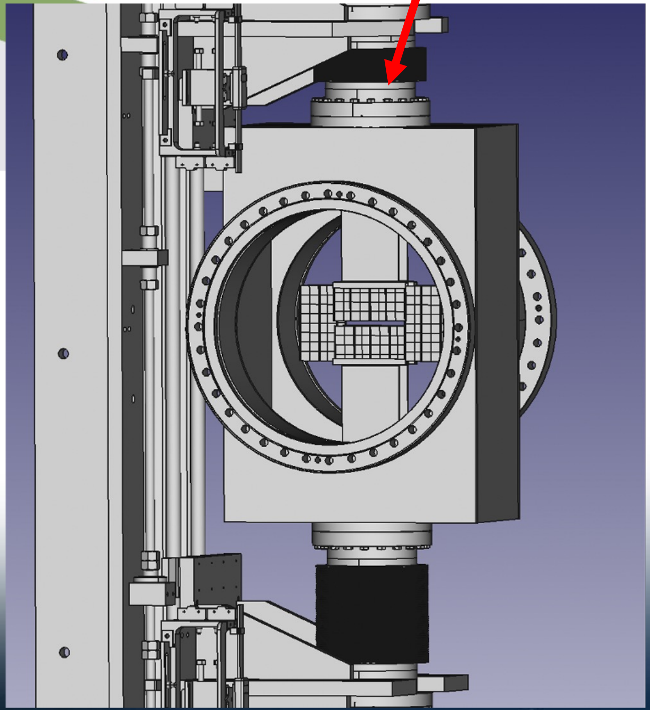
  - AC-LGAD sensors directly integrated into beamline vacuum → creates issues for detector technology and **beam impedance.**
  - Requires special consideration for **beam pipe design and support system.**
- **Current design meets physics requirements from YR.**
  - **BUT → major changes/solutions will be needed to address impedance and integration issues, which could impact physics (especially at acceptance edges/gaps).**
  - **Common issue with beampipe design for the ZDC neutral exit.**





Next steps → What is needed?

- Engineering support to aid in optimization of layout (Fall 2023).
  - Preserving/improving physics performance is the primary goal → Technology choice not the bottleneck!
  - Need vacuum engineer to advance beam pipe design and ensure it can be successfully pumped.
  - Need expertise on impedance to solve issues with RP/OMD.
- Design of RP/OMD cooling system.
  - Preliminary ideas are on the table, but need someone with expertise to advance the conceptual design to something which can be built (need to cool ~100 watts per active plane).
- Iteration with accelerator experts as hadron lattice evolves (ongoing).
- Finalize technology options and alternatives for ZDC and B0 subsystems (next 1-2 months, maximum).