ePIC CyMBaL tracker environment

CYlindric Micromegas BArrel Layer

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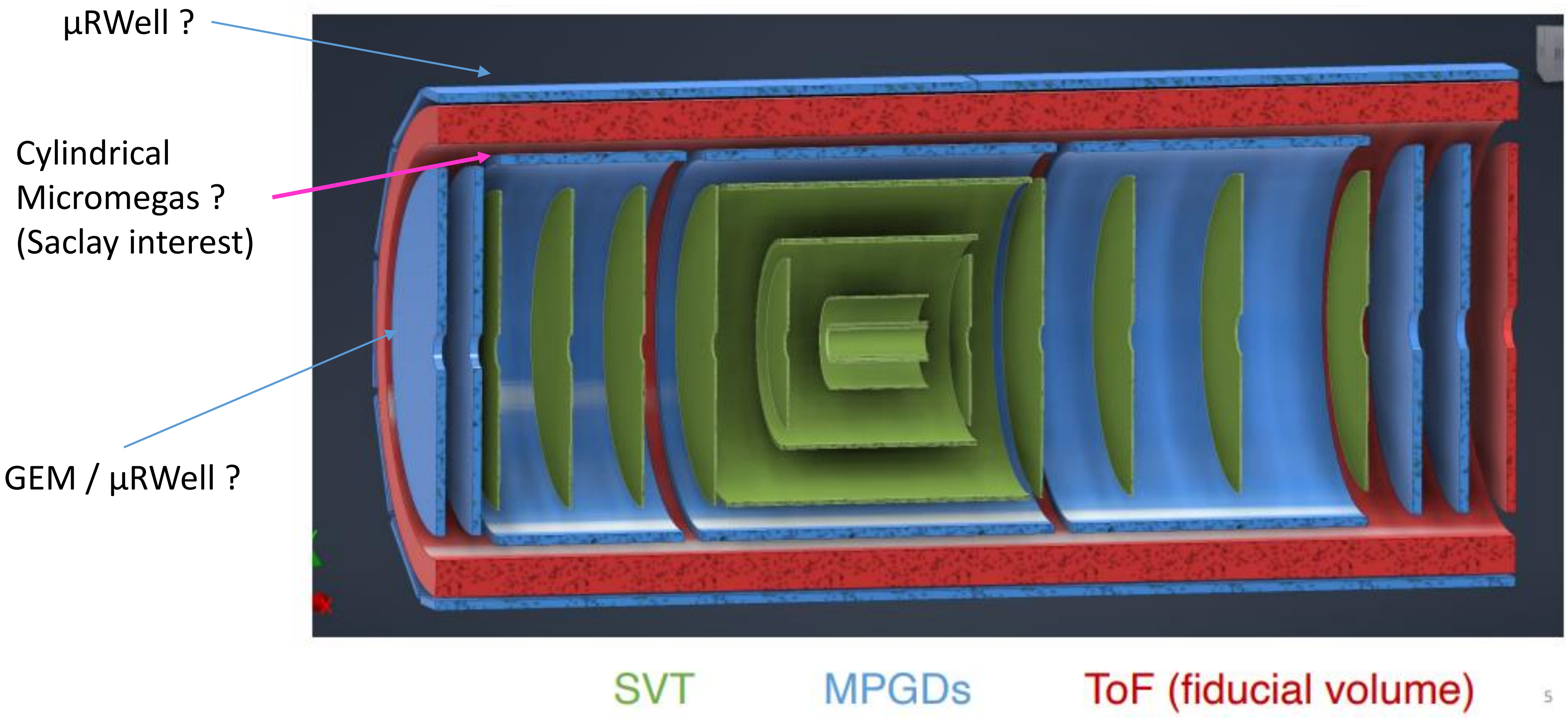
Space

Recent update of ePIC tracking configuration

- [ePIC Tracking Working Group Meeting (15 juin 2023) · Indico (bnl.gov)](#)



Recent update of ePIC tracking configuration

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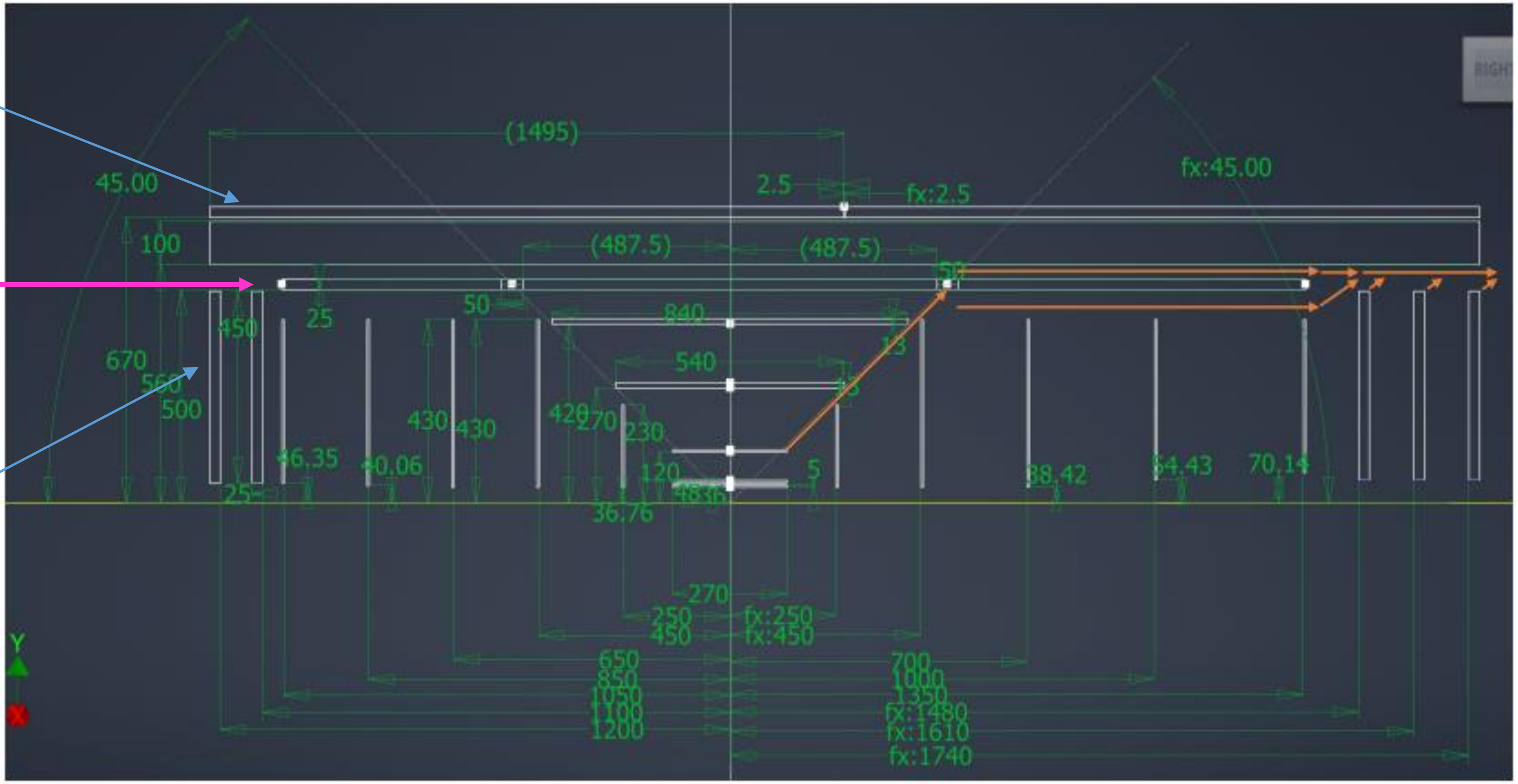
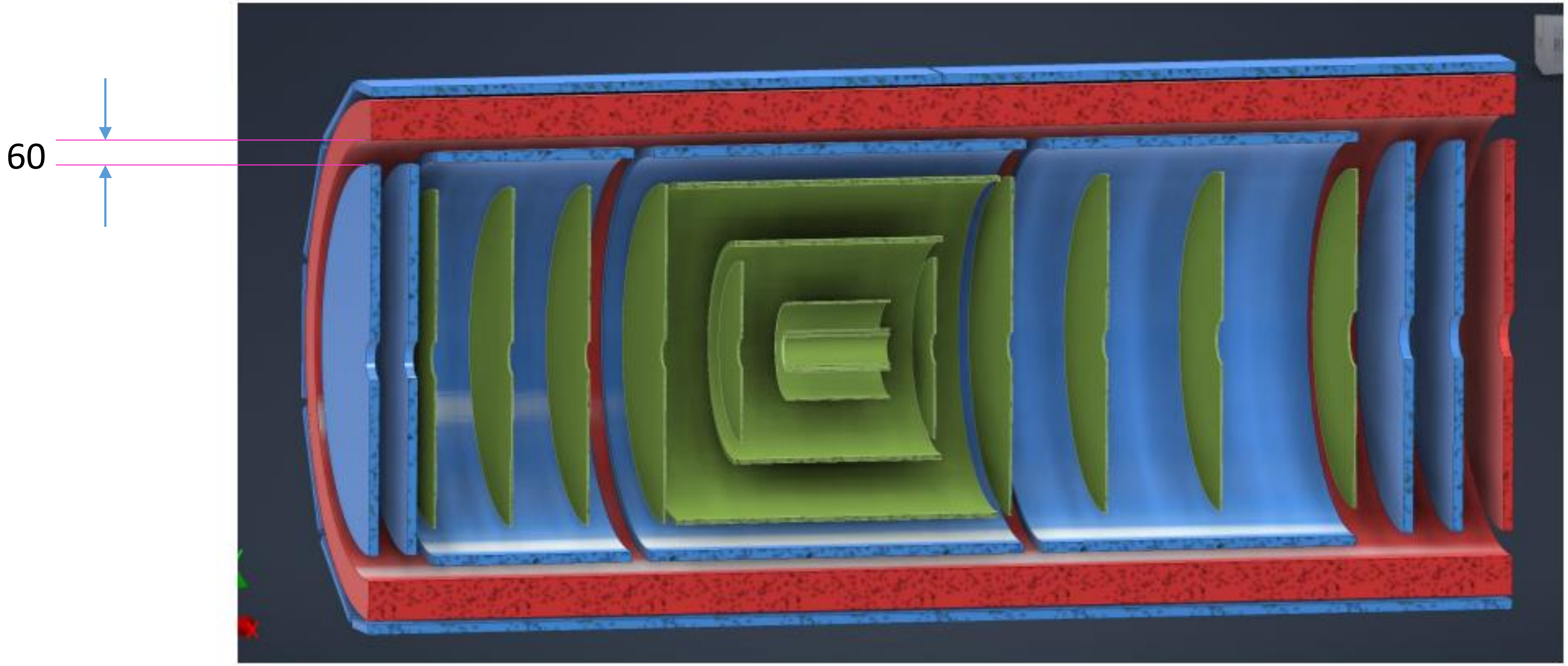


- A solid base for detector and readout definition
  - → Need to achieve quickly the same maturity as for Athena CyMBaL tracker
    - https://indico.bnl.gov/event/13103/contributions/55234/attachments/37448/61701/210930_EicAthena_Cymbal_v3.pdf

Spatial constraints for inner barrel cylindrical tracker

- Space is stringent: 6 cm

  → Detectors, gas pipes, HV cables



SVT MPGDs ToF (fiducial volume)

→ What about on-detector frontend electronics:

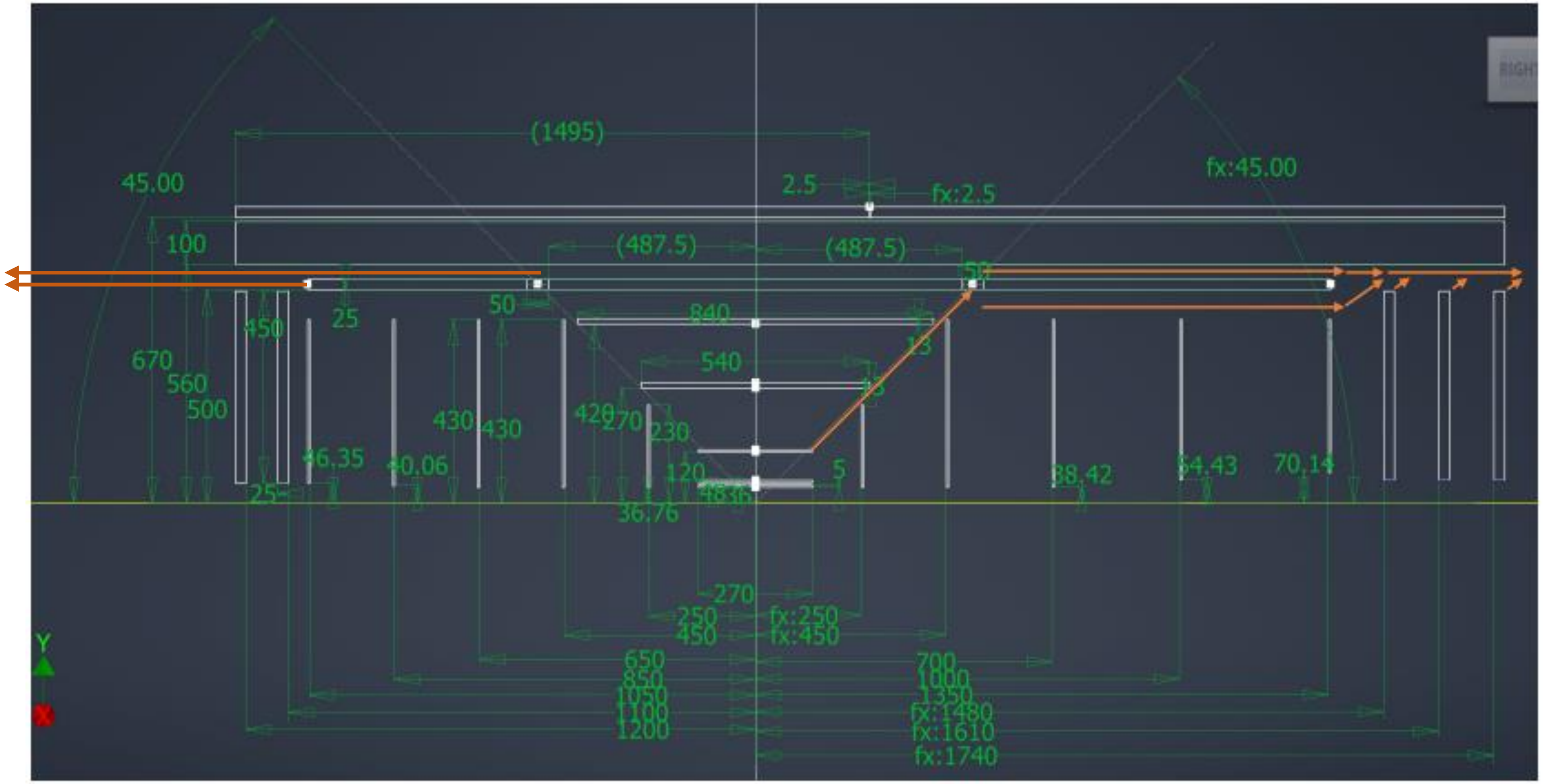
- FEBs + LV distribution + RDO interface cabling + cooling
- Will it fit within the space and material budget envelopes

Where to get information about available space for electronics?

- Assuming off-detector FEB for space and material budget restrictions

Electron side

Hadron side

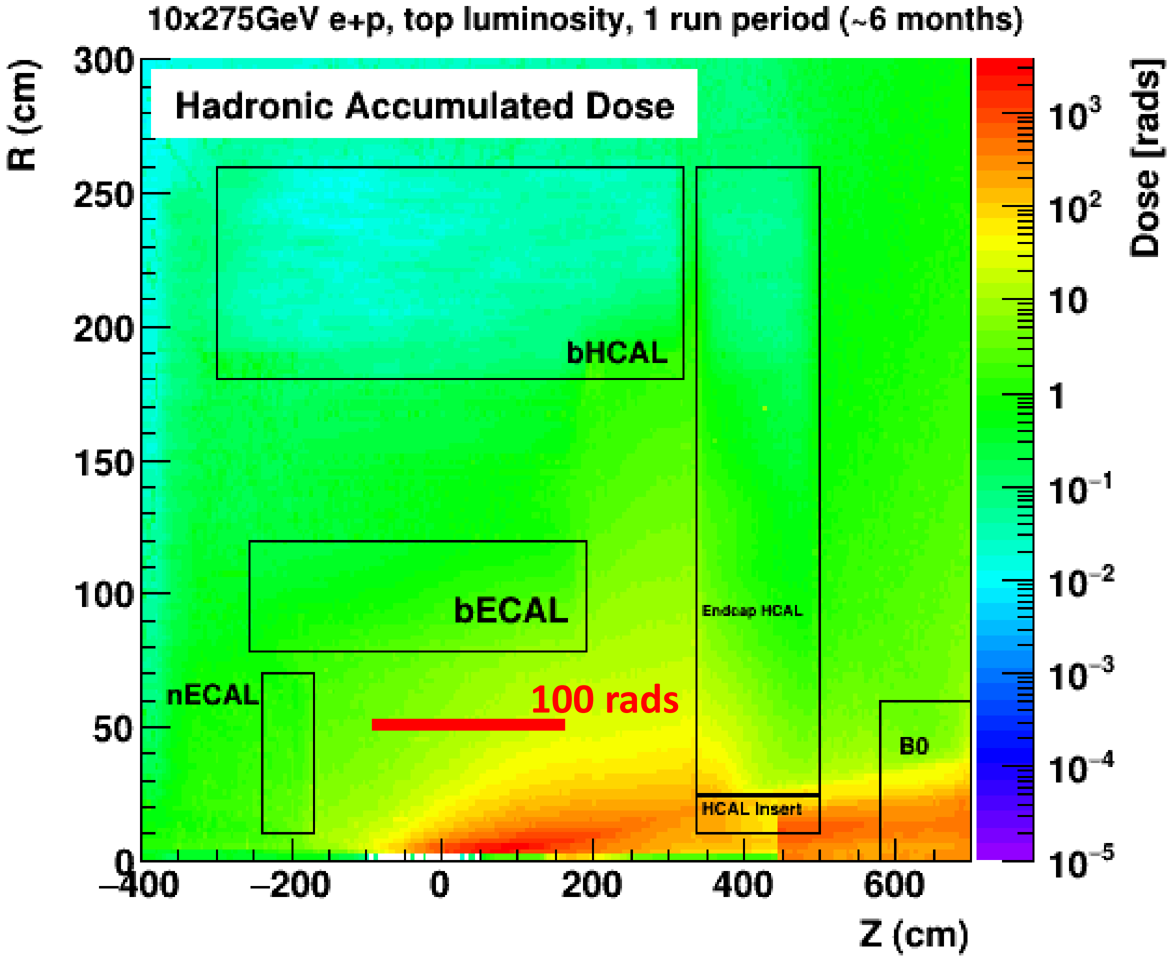


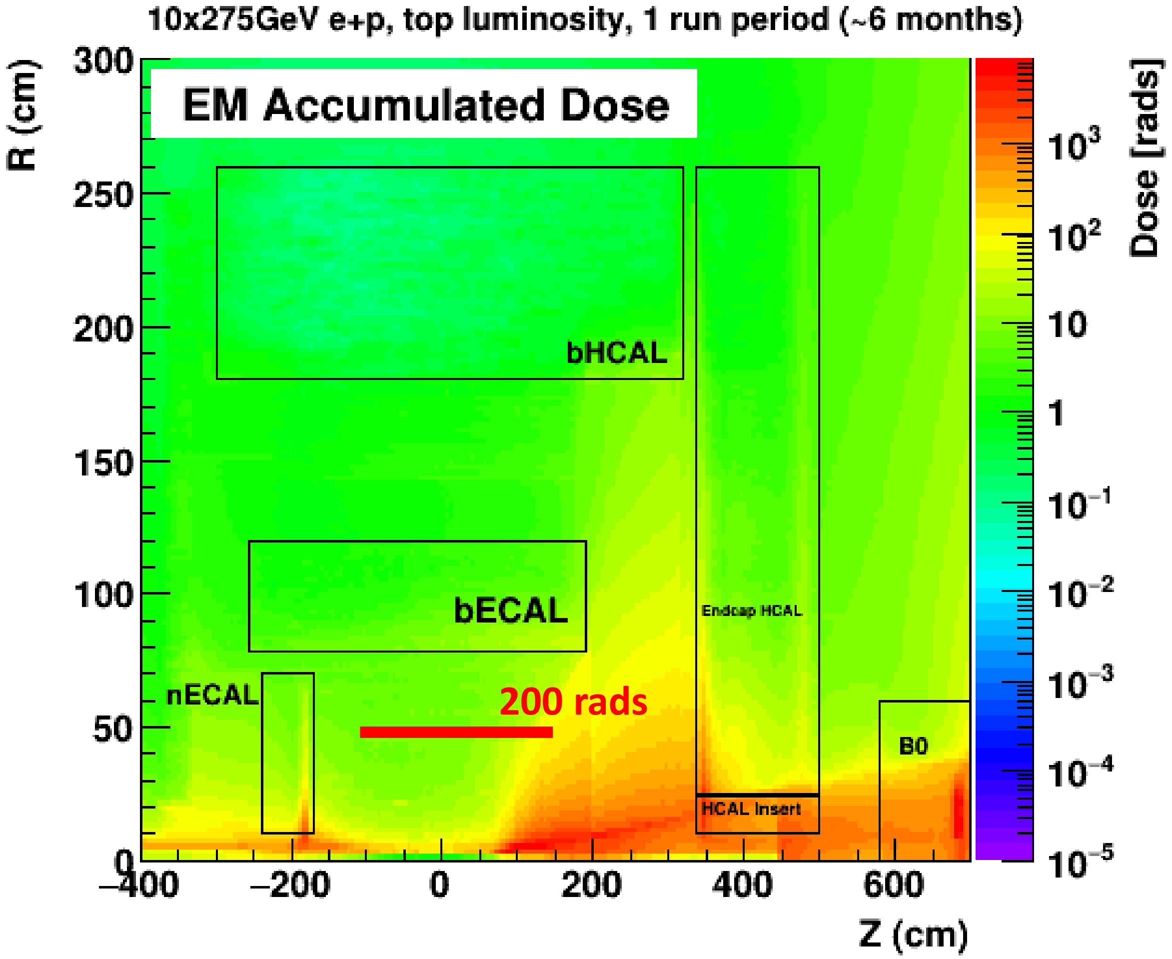
- Place FEBs (hence corresponding RDOs) on both sides: hadron and electron
  → Detector cable length ~2 m
- FEB and RDO: magnetic field ?

Radiation

Total ionization dose (TID) due to e + p events

- Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)





- Should one conclude that annual dose (after 6 months of operation) will amount to 300 rads?
  - → *i.e.* TID of 3 krad over 10 years
  - → Is the space-grade radiation tolerance enough for electronics?

Total ionization dose: TID

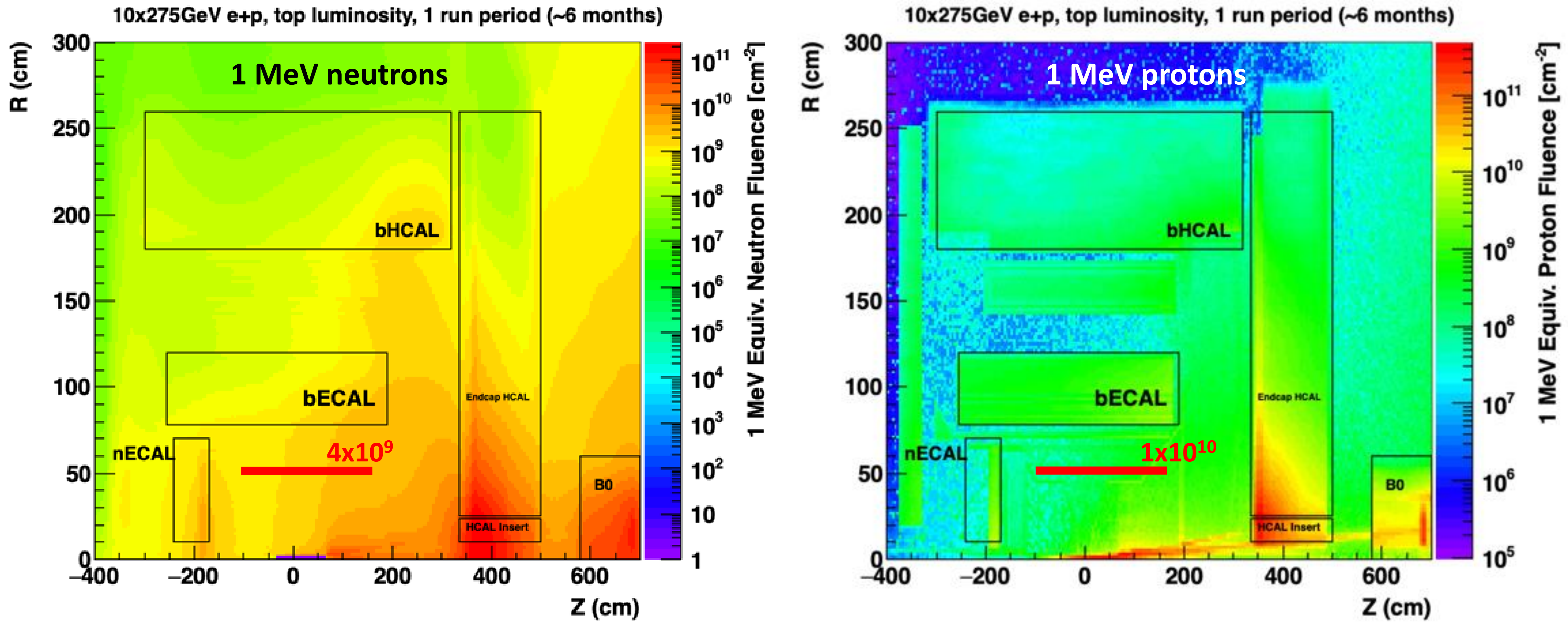
- Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)

Radiation sources	EM rad / year	Hadron rad / year	Total rad / year
10 x 275 GeV e + p	100	200	300
275 GeV p beam + gas	2	10	12
10 GeV e beam + gas	500		500

- Should one conclude that annual dose (after 6 months of operation) will be less than 1 krad?
  → *i.e.* TID of 10 krad over 10 years
  → Is the space-grade radiation tolerance enough for electronics?

1 MeV equivalent neutron / proton fluences due to e + p events

- [Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)](#)



- Should one conclude that annual fluence (after 6 months of operation) will be < 1 x 10^{10} n_{eq}/cm^2?
  - → *i.e.* 1 x 10^{11} n_{eq}/cm^2 over 10 years
  - → In the CMS barrel EM calorimeter region we qualify ASICs to stand fluences of 10^{13} - 10^{14} n_{eq}/cm^2

1 MeV equivalent neutron / proton fluences

- [Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)]

Radiation sources	Neutron / cm² / year	Proton / cm² / year
10 x 275 GeV e + p	4×10^9	1×10^{10}
275 GeV p beam + gas	5×10^8	1×10^9

- Should one conclude that annual fluence (after 6 months of operation) will be ~ 1×10^{10} n_{eq}/cm^2 ?

→ *i.e.* 1×10^{11} n_{eq}/cm^2 over 10 years

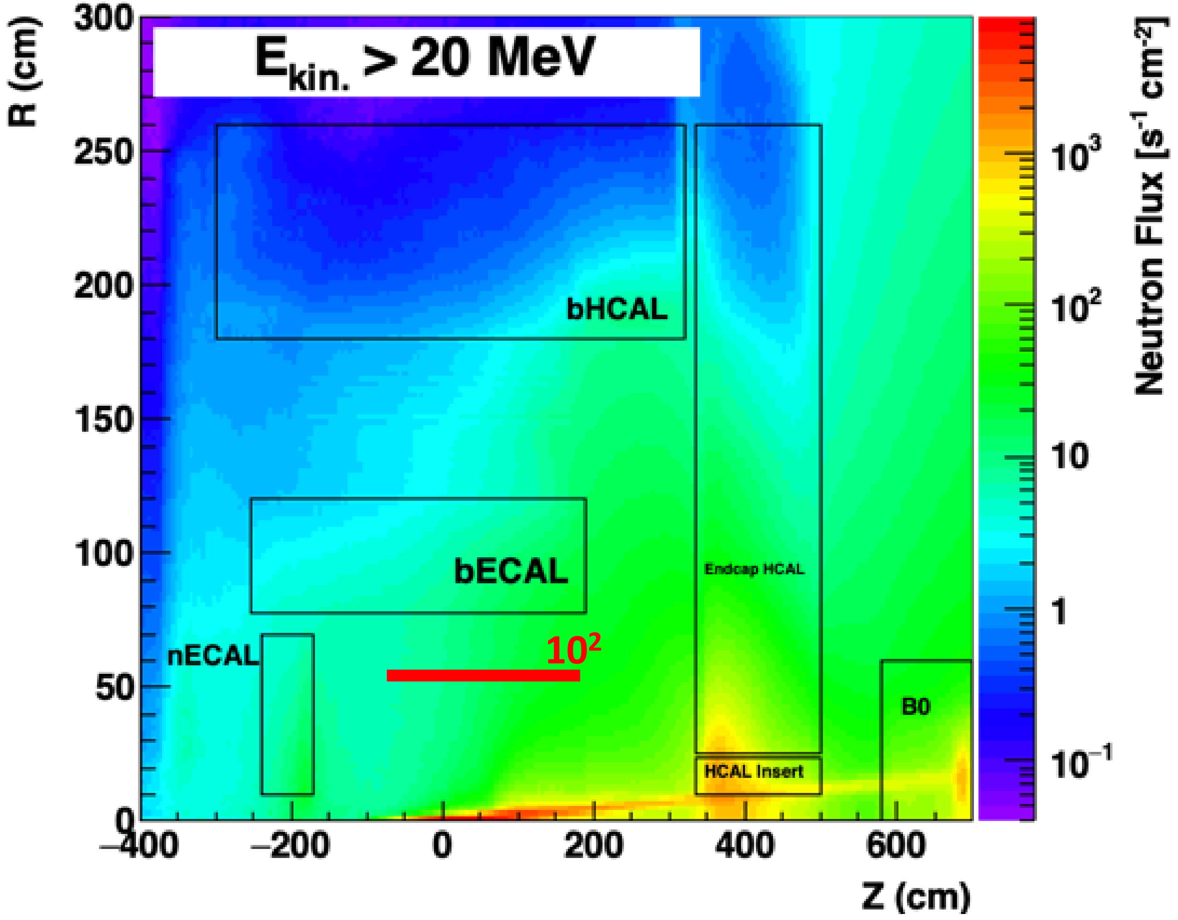
→ In the CMS we qualify ASICs to stand much higher fluences

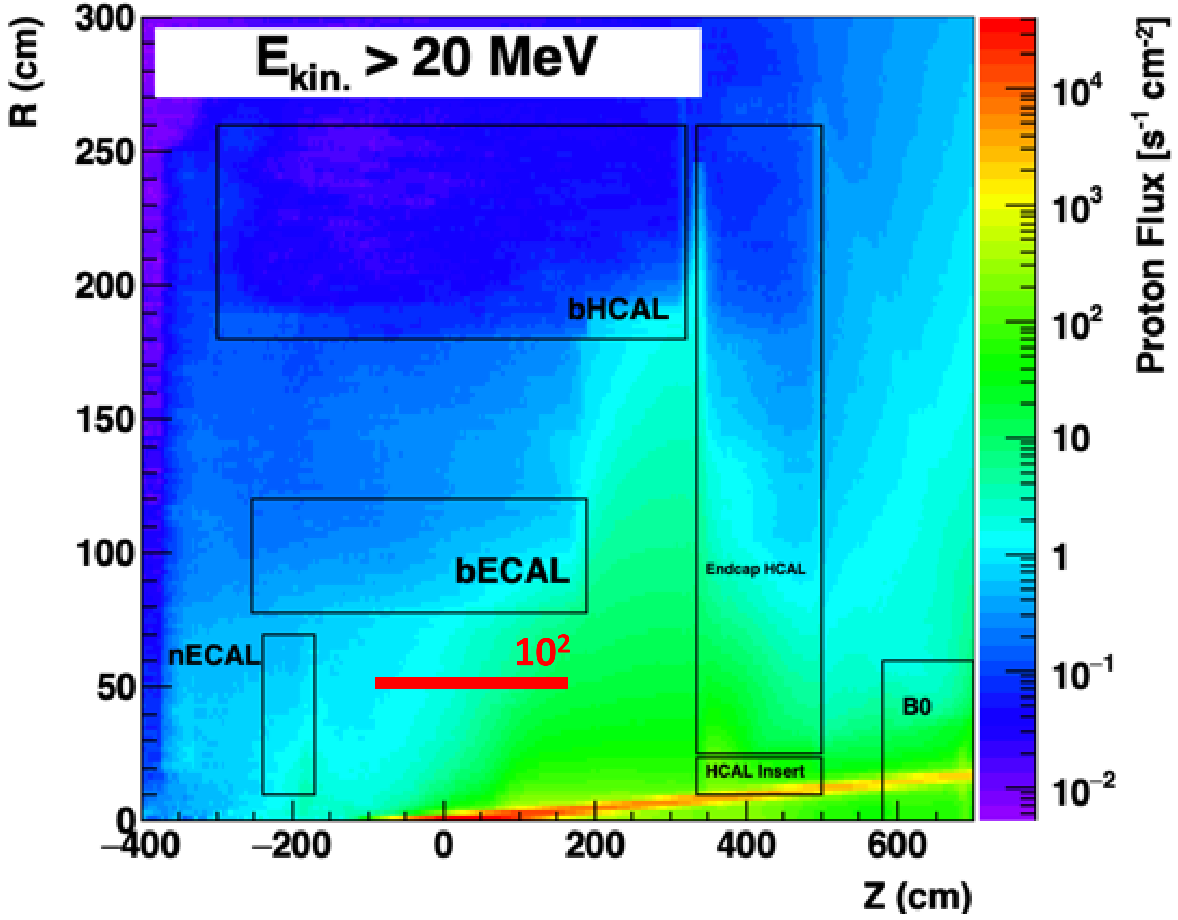
  - 10^{13} - 10^{14} n_{eq}/cm^2 in barrel EM calorimeter region
  - 10^{15} - 10^{16} n_{eq}/cm^2 in endcap high granularity calorimeter region

→ Need to check ratings of commercial components

>20 MeV neutron / proton fluxes due to e + p events

- [Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)]





- Should one conclude that the flux is ~100 particles / cm^2 / s?
  → In the CMS barrel timing layer we estimate SET at fluxes of 10^5 particles / cm^2 / s

>20 MeV neutron / proton fluxes

- Radiation Doses - Electron-Proton/Ion Collider Experiment (bnl.gov)

Radiation sources	Neutron / cm^2 / s	Proton / cm^2 / s
10 x 275 GeV e + p	100	100
275 GeV p beam + gas	1	<<1

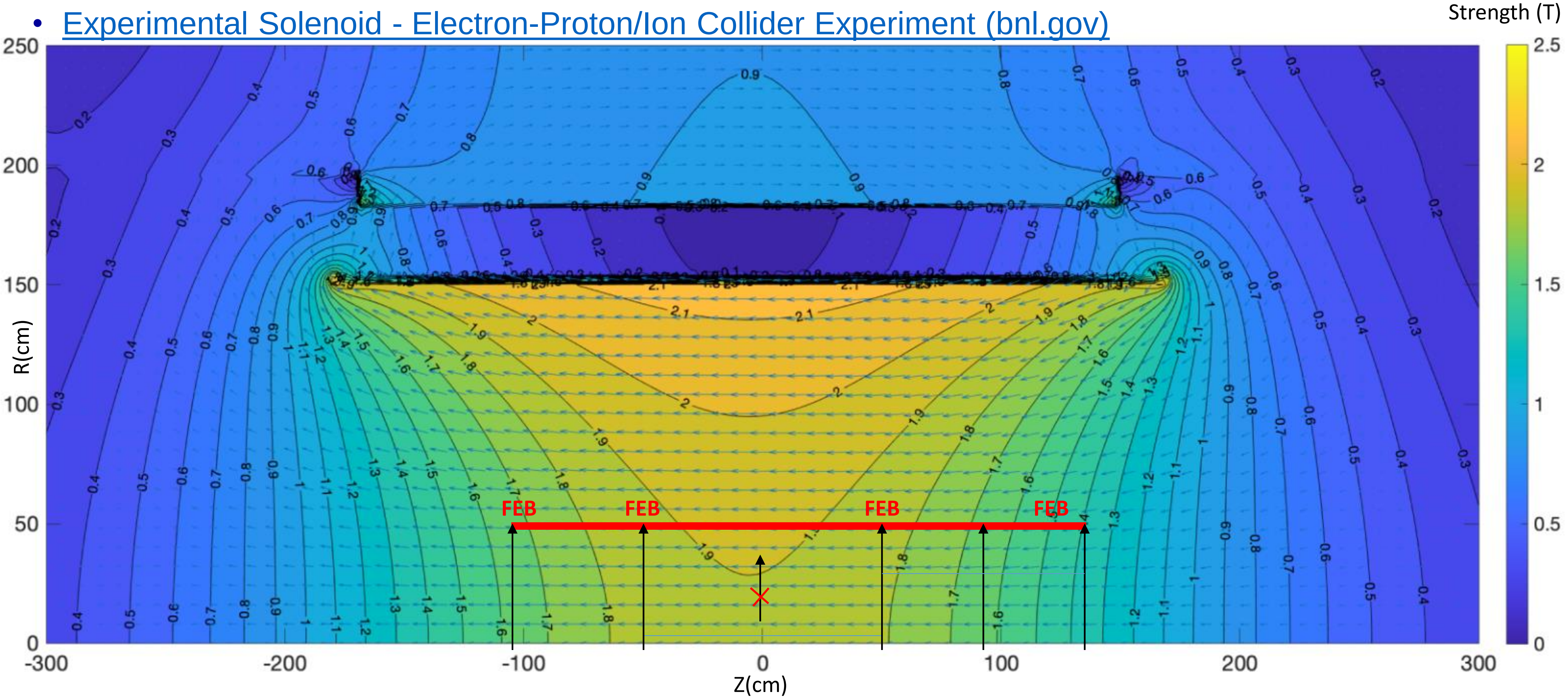
- Should we estimate SET probabilities for 100 particle cm^2 / s fluxes ?
  → In the CMS the figures of merit are
    - 10^5 particles / cm^2 / s in barrel timing layer
    - Mean of 2 x 10^6 particles / cm^2 /s in endcap high granularity calorimeter region

  → Need to check ratings of commercial components

Magnetic field

2T solenoid magnetic field map

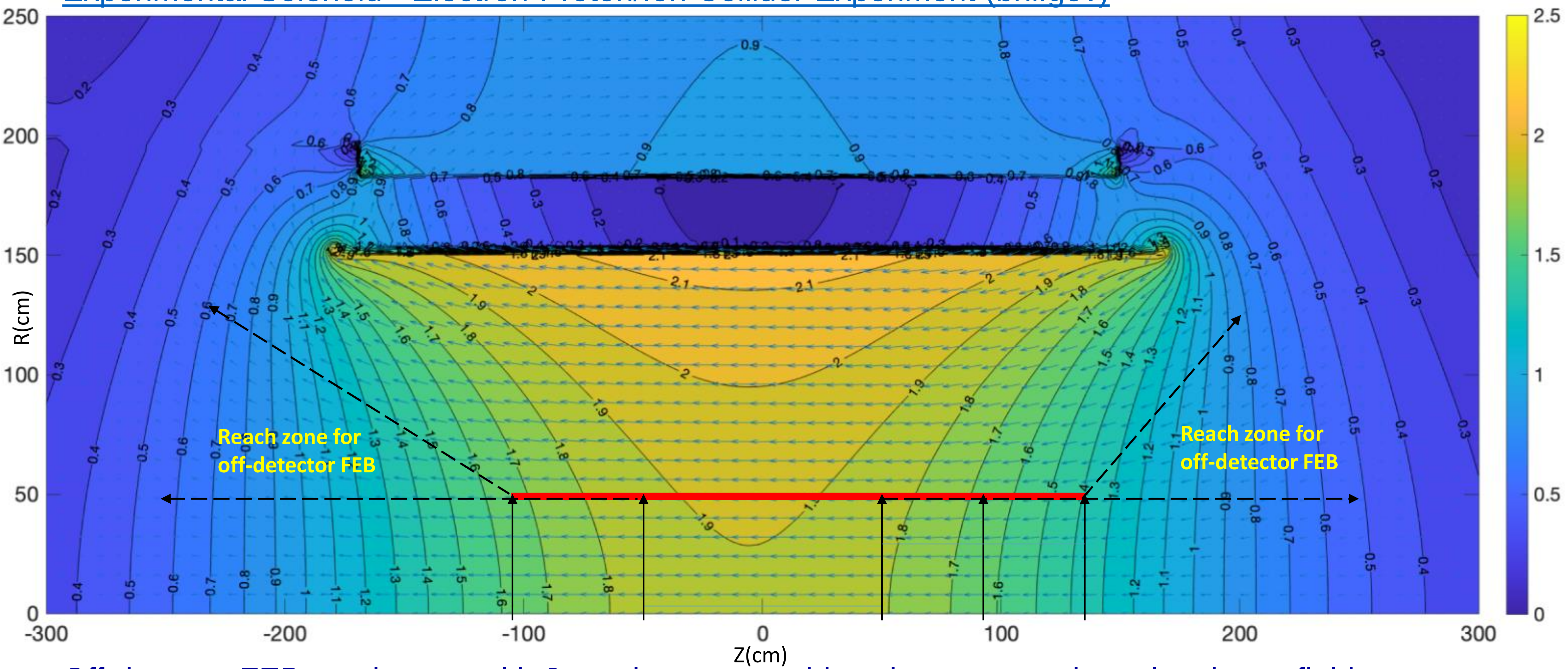
- Experimental Solenoid - Electron-Proton/Ion Collider Experiment (bnl.gov)



- On-detector FEBs must stand at least 1.9T magnetic field, say 2T
  - → 1.7T solenoid: tolerance of at least 1.6T

2T solenoid magnetic field map

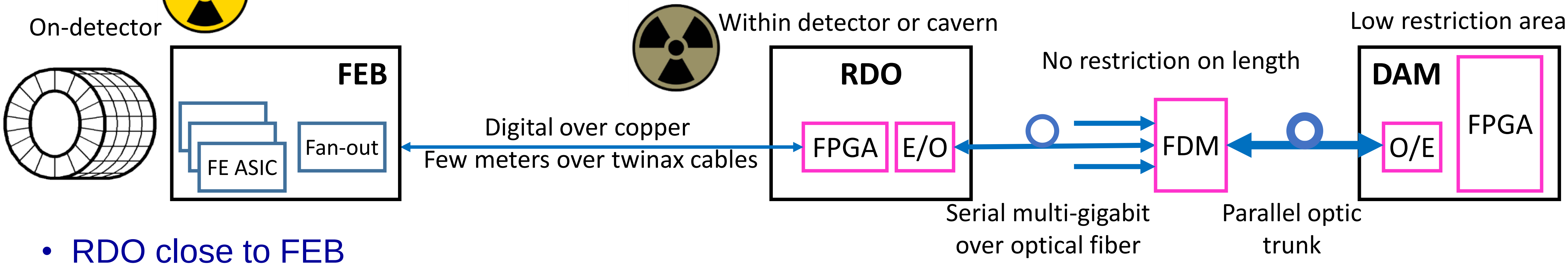
- [Experimental Solenoid - Electron-Proton/Ion Collider Experiment (bnl.gov)]



- Off-detector FEB reach zone with 2 m micro-coax cables shown approximately – lower field
  → 1.7T solenoid: probably < 1T tolerance for off-detector FEBs

FEB components

FEB location: on-detector



FDM – fiber distribution module (patch panels, etc.)

- RDO close to FEB
  - → Moderate radiation environment, space & power stringent
- RDO ↔ FEB
  - → Clock & synch commands – on FEB fan-out or multi-drop
  - → I2C – daisy chain
  - → Test
  - → Data – single or several uplinks per ASIC
- FEB
  - → No on-board intelligence, no board-level data aggregation
  - → High fidelity fan-out can be the Rafael ASIC or a development based on EICGENR&D_2022_06
    - Used solely for clocks and commands; not for I2C
- On detector FEB: best option for S/N
  - → Difficult for all the rest

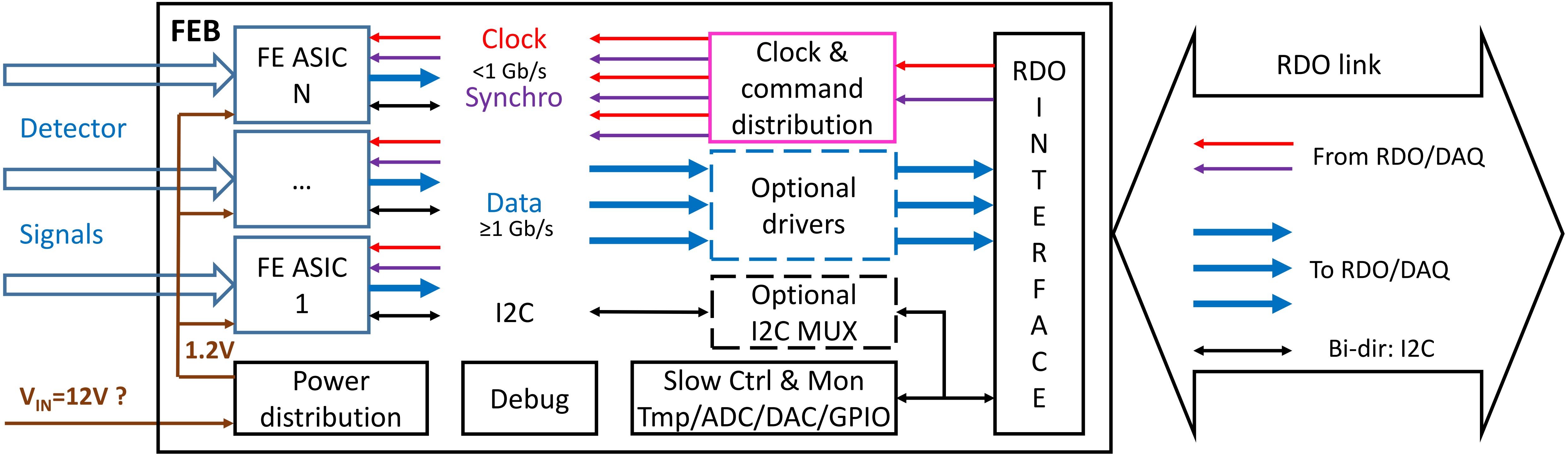
RDO ↔ FEB

Rafael

65nm PLL

A typical digital FEB with no on-board intelligence

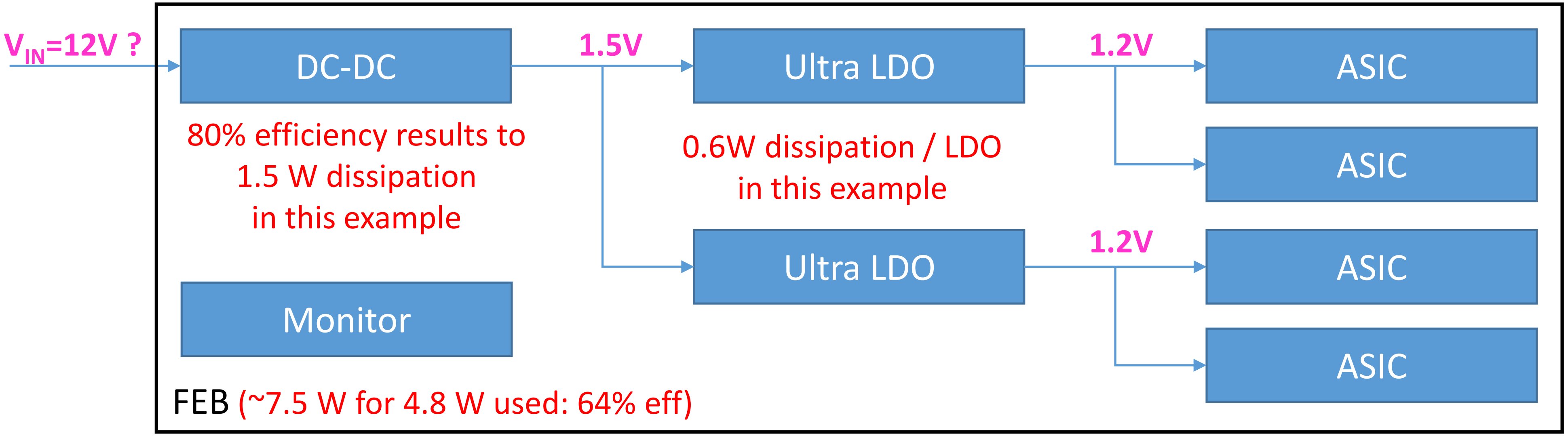
- Number of ASICs per FEB to be adapted according to detector modularity and space constraints
  → Possibility to have a separate PCB with an ASIC or a small number of ASICs can be envisaged
    - Needs a clock/synchro pair, a data line per ASIC, a common I2C and power
    - Price to pay for space limitation: multiplication of boards and interconnects



- For a possible MPGD data collection protocol see for example:
  → https://indico.bnl.gov/event/18118/contributions/72179/attachments/45781/77366/221221_MpgdDataCol_IM.pdf

FEB powering within magnetic field

- Assuming 64-channel Salsa with ~1 W power consumption @ 1.2 V
  → For simplicity, 1 A per ASIC
- Clean power will require a radiation hardened ultra LDO linear regulator
  → *e.g.* commercial TPS7H1101A-SP from TI - https://www.ti.com/product/TPS7H1101A-SP - space grade
  → *e.g.* community LDO used for CMS HgCal frontends - https://cds.cern.ch/record/2797683 - HL LHC grade
  → Or whatever other subsystems propose
- Power distribution requires magnetic field tolerant high efficiency DC/DC regulators
  → *e.g.* community bPOL12V from CERN – HL LHC grade and 4T tolerance
    - Microsoft Word - bPOL12V_V6 datasheet V1.6.docx (cern.ch)



- Question: is there a common effort for LV distribution?
  → A centralized group taking care to provide V_{IN} in a “uniform” way wherever possible
  → And in case CERN components will be the choice, for their inventory and procurement

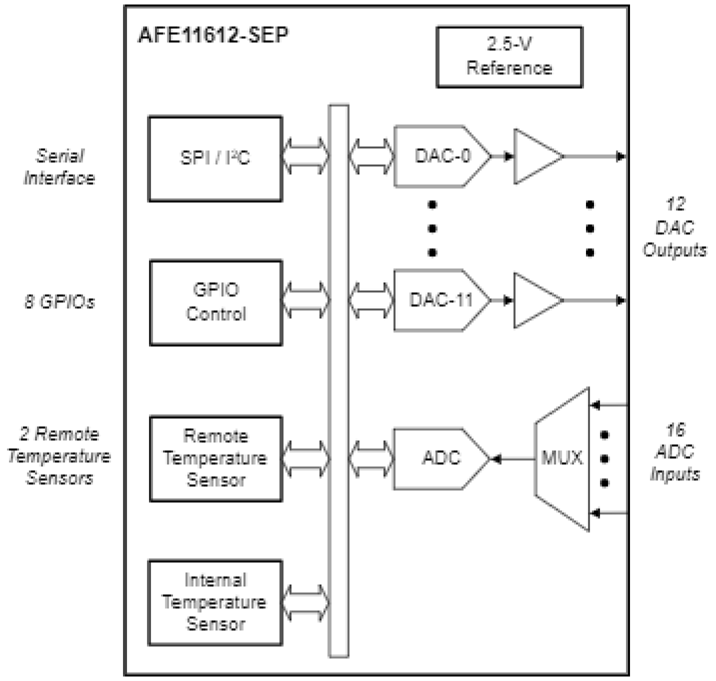
FEB monitoring

- FEB is deeply embedded complex system repeated multiple times
  → Needs at least health monitoring

- Commercial space grade candidate from TI: AFE11612-SEP
  → https://www.ti.com/product/AFE11612-SEP#tech-docs
  → 16 inputs towards a 12-bit ADC
    - For on board generated voltages and current measurements
  → 12 outputs from 12-bit DACs
    - For on board reference voltage settings
  → Up to 8 GPIO
    - For test pulse generation or non-I2C component settings
  → Up to 4 external temperature sensors
  → I2C interface

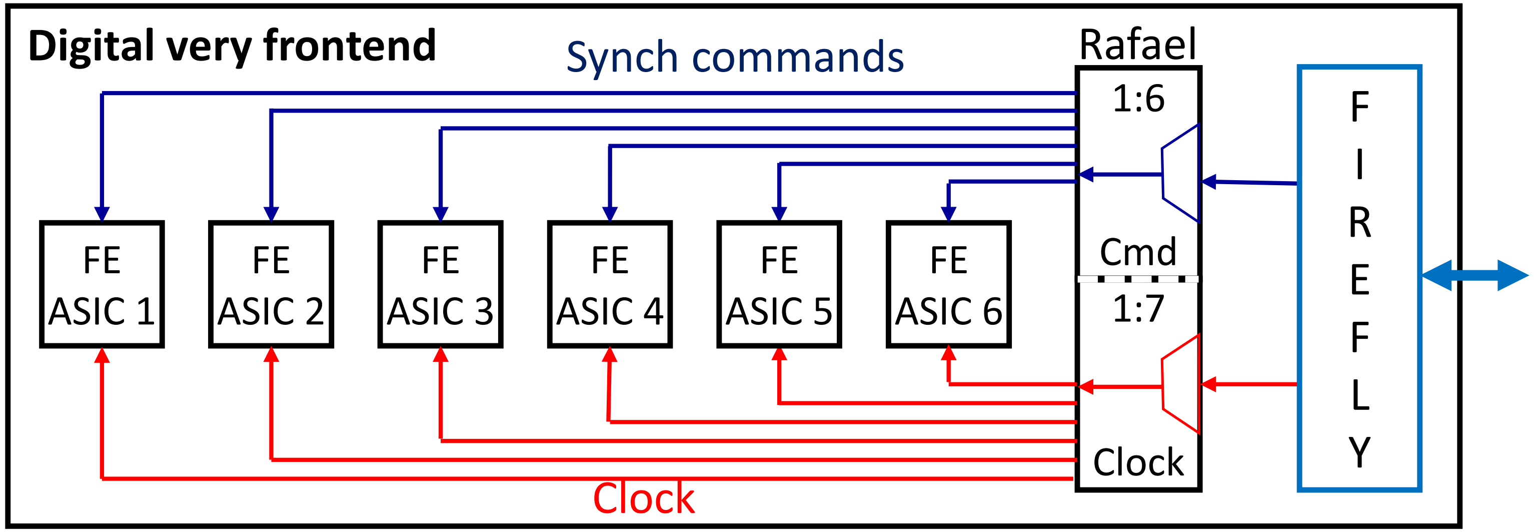
  → Might be too power hungry
    - Detailed information requested
    - Evaluation board exists

  → Check if something lighter does not exists



Clock and fast command distribution example

- Rafael - Radiation-hArd Fan-out ASIC for Experiments at LHC - developed at Irfu, CEA Saclay
  - → 3 inputs and 13 outputs
  - → CLPS signaling: 0.6 V CM voltage; 200-400 mV differential swing
    - ■ Programmable drive and emphasis
  - → Single buffer: any input to 13 outputs
  - → Double buffer
    - ■ Input 1 to 6 outputs
    - ■ Input 2 to 7 outputs
  - → Up to 400 MHz and beyond
  - → Low additive jitter of < 2 ps
  - → HL LHC-level TID, neutron, SEU
  - → 130 nm technology
    - ■ Possibility to embed a PLL
      - If no jitter cleaner PLL in ASICs

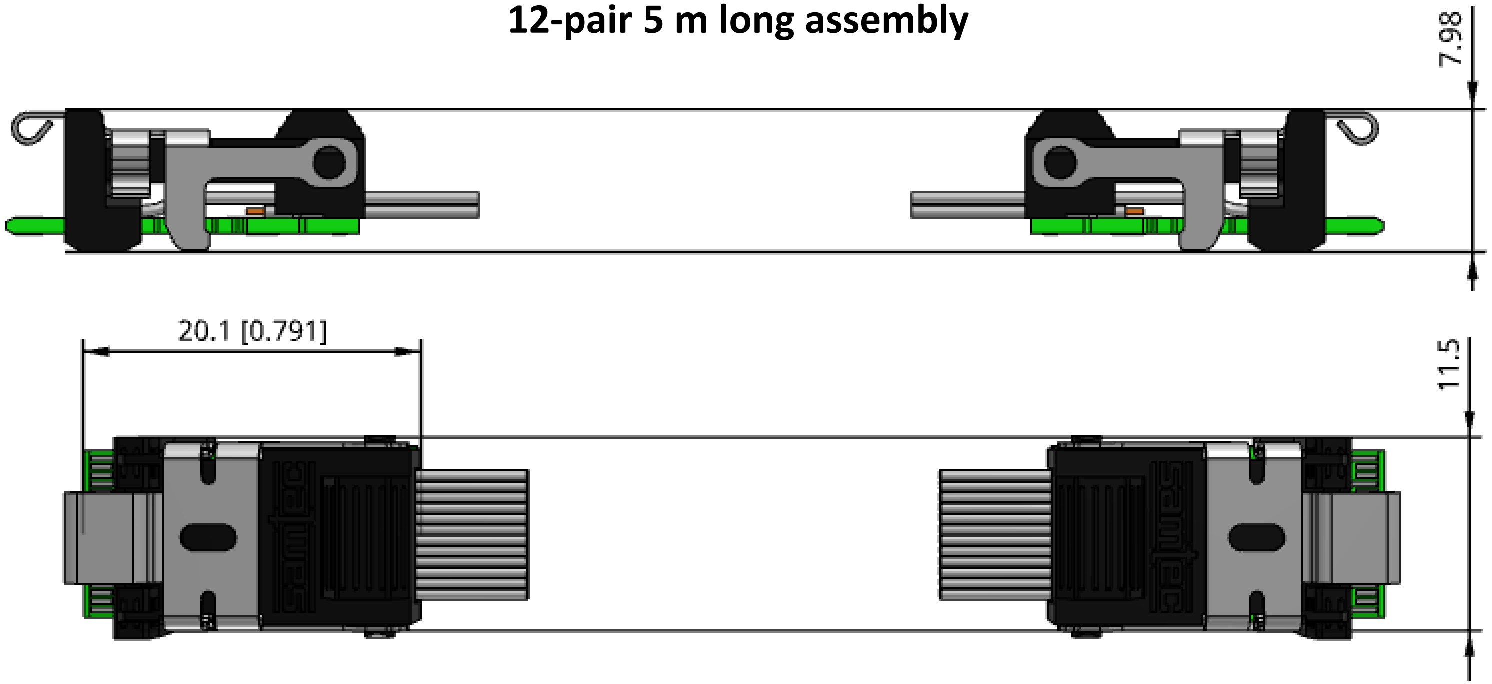


- Possibility to design a new fan-out ASIC based on PRISME IP
  - → on-going development under EICGENR&D_2022_06 call
    - ■ https://www.jlab.org/sites/default/files/eic_rd_prgm/files/2022_Proposals/EIC_RD_Proposal_DigiPLL_vfinal_EICGENRandD2022_06.pdf
    - ■ Jitter cleaner clock synthesizer PLL with phase adjustment
      - To be used in Salsa

RDO interface: passive twinax copper Samtec FireFly

- https://www.samtec.com/products/ecue
- https://suddendocs.samtec.com/catalog_english/ecue.pdf
- Configurable assembly
  - → 8 or 12 pairs
  - → up to 10 m
  - → Low profile fits stringent space
    - Only 8 mm high
- Impressive signal integrity figures
  - → Qualified for 10-50 Gbit/s speeds

Example of configured part number: ECUE-12-500-T1-FF-01-1
12-pair 5 m long assembly



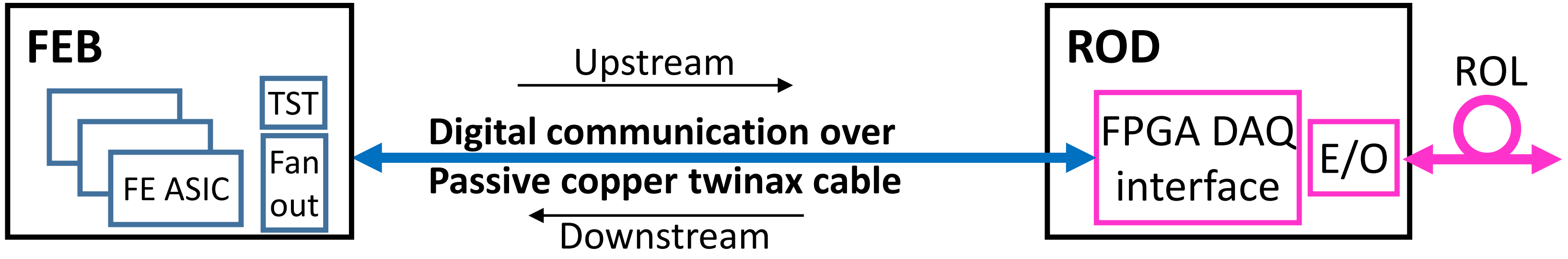
- Max length for O(1 Gbit/s) speed?
  - → Are extra drivers needed?
- Rigidity, weight?
- Flammability?

→ Contact Samtec technical service

→ R&D on data transmission and on clock / synchronous command distribution?

- Intention to validate with the PRISME test bench

FEB-RDO link MPGD example

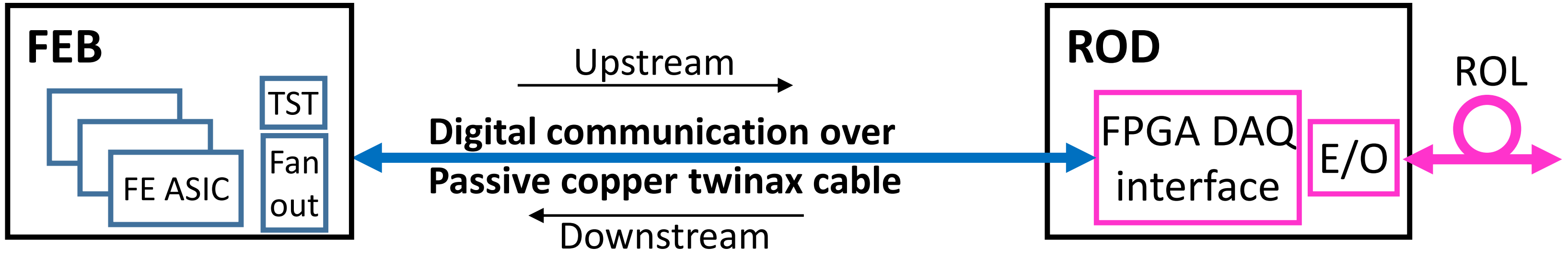


- 512-channel on-detector FEB
  - → 8 64-channel FE ASICs (*e.g.* future SALSA) with
    - ■ 1 Gbit/s output data link
    - ■ Unique system clock
      - On-board 1-to-8 fan-out
    - ■ Synchronous command encoding trigger
      - On-board 1-to-8 fan-out
  - → Bi-directional I2C SDA + unidirectional I2C SDC
    - ■ Chained
  - → Common on-onboard test pulse logic

- Off-detector on-detector interface
  - → 3 downstream lines:
    - ■ Clock, command, I2C SDC
  - → 1 bi-directional I2C SDA line
  - → 8 upstream lines
    - ■ 8 data links
  - → Fits single 12-pair Samtec FireFly copper cable
    - ■ Test sequence may be initiated by I2C over GPIO

- The FEB size (number of channels) to be adapted according to detector segmentation, available space …
  - → Example of 256-channel FEB: use 8-lane FireFly
  - → For other channel counts, some lanes may be ignored

Quick assessment of number of FireFly links for CyMBaL



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  - → 1 bi-directional I2C SDA line
  - → 8 upstream lines
    - 8 data links
  - → Fits single 12-pair Samtec FireFly copper cable
    - Test sequence may be initiated by I2C over GPIO

- Assume CyMBaL of 5 η x 7 φ = 35 detectors of 1024 channels each
- Assume 512-channel FEB
- Requirement: 70 12-laine 10 mm wide FireFly cables
  - → 35 cables distributed over 3 m perimeter on each side of the tracker
    - 1 cm cable every 8.5 cm

Summary

- Radiation levels seem to be low
  - → Compatible with space grade commercial components
    - ■ To be confirmed for CyMBaL and to be checked at other MPGD locations
- FEB design should be robust against magnetic field
  - → Most probably, need to stand for up to 2T
  - → Special attention is needed for efficient powering
    - ■ DC/DC regulators operating in high magnetic field to go down to 2.5-1.5V
    - ■ Ultra LDO linear regulators for sensors @ 1.2V
    - ■ Voltage-current-temperature monitoring
  - → Colling will be needed
    - ■ Should be compatible with material budget
    - ■ A usual cooling-LV-HV interlock needs to be implemented
- FEB on-board clock-synch command distribution should be possible with Rafael
- Copper FireFly from Samtec could be a good candidate for FEB-RDO link
  - → Passive – no constraints from radiation or magnetic field
  - → Low profile, encouraging signal integrity features

Caveat and next steps

- None of the above is fixed
  - → Will evolve with detector design
  - → Choices will depend on ROD locations as well
- Data rates need yet to be estimated
  - → Physics + background
- Assess number of FEB-ROD links according to detector segmentation
  - → Their volume, weight
  - → Find nearest positions to place RDOs
- Number of RODs to be defined
  - → Depends on data constraints
    - ■ How much data can be swallowed by a ROD
  - → Depends on mechanical constraints
    - ■ How many links can be physically aggregated on the ROD
      - Even if small, the FireFly connector has some size
      - It requires 12 differential signals – 24 FPGA IOs
- Profit from shared design with other MPGDs
  - → At least wherever possible
  - → Understand if any common LV distribution system is foreseen
  - → Understand where the LV blocs can be placed in the cavern
- In general, structure integration questions to ask for discussions with integration group