Some thoughts on ND fine grained tracker design

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ND concept design group meeting
July 5, 2017

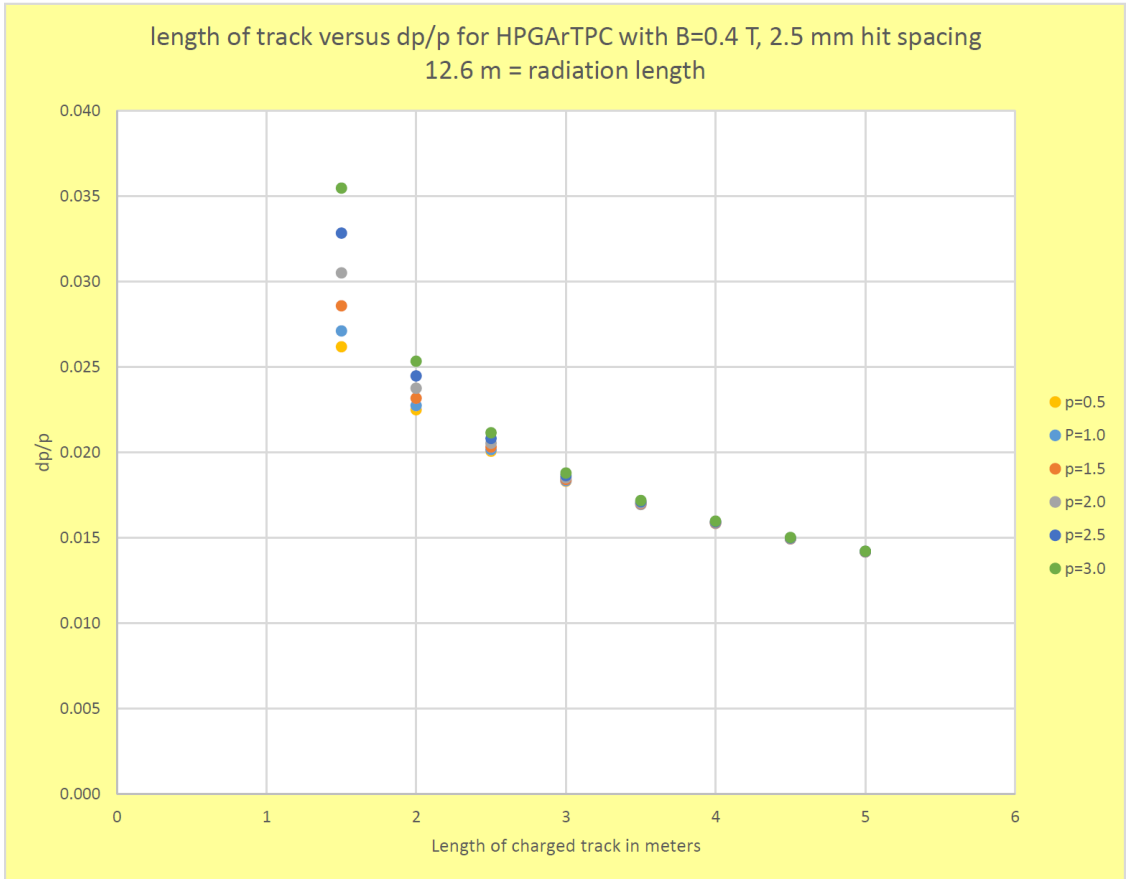
- Looking at very basic tracking performance, mass (statistics), geometry limitations
- Ideas meant to foster discussion of different concepts
- “design A-F” designations just for reference during discussion
- Thoughts predicated on assumption of LArTPC (probably upstream), possibly with mini-MIND-like structures for broad muon analysis acceptance

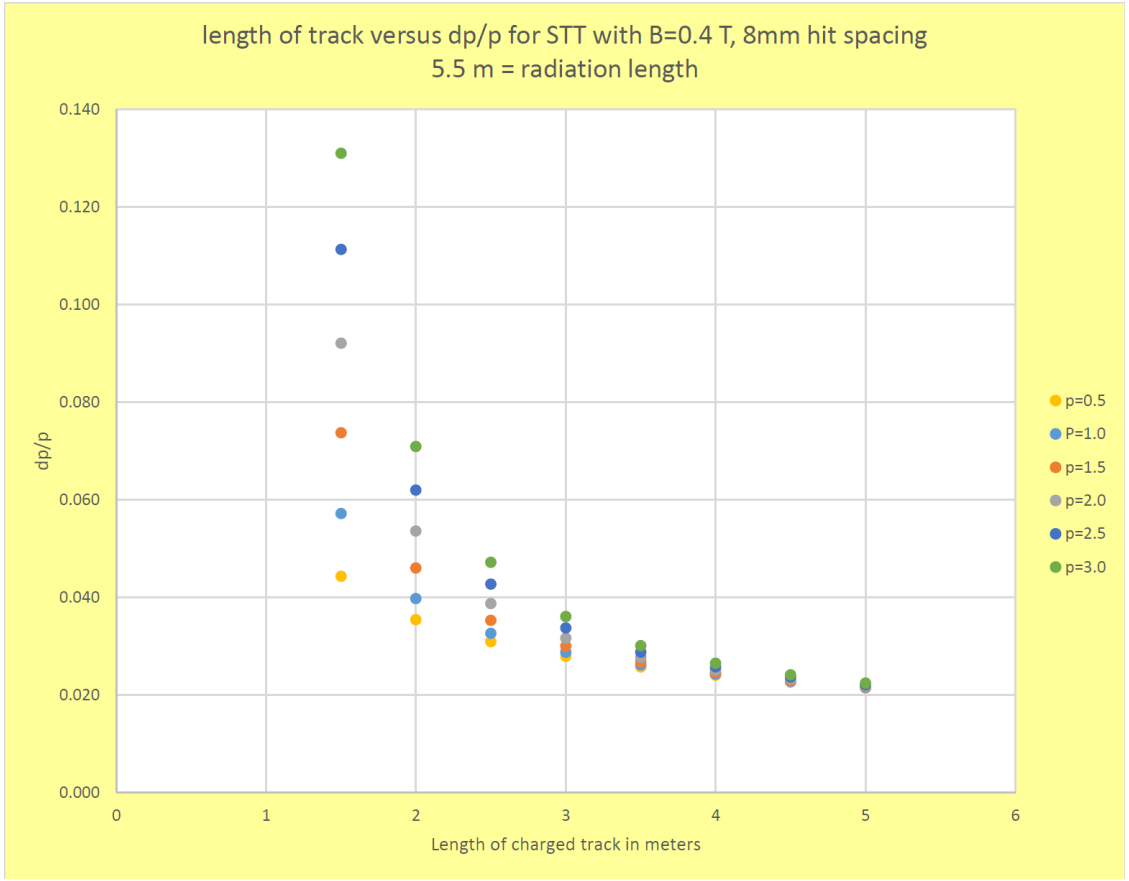
T2K downstream ECAL:

34 layers of 1.75 mm Pb and 1 cm scintillator
0.33 radiation lengths/layer
34 layers
11 radiation lengths total

Option	X_o	θ_{rms} @ 1 GeV/c	$\Delta p/p$ for B=0.4 T
Minerva-like	40 cm	~6 mrad	~10%
Scint. with smaller strips	40 cm	~4 mrad	~10%
LArTPC	14 cm	~4 mrad	~6%
STT	5.5 m	~2 mrad	~3%
GasArTPC	12.6 m	~0.4 mrad	~2%

So, for strawperson design, choose:
ECAL to be 34 layers x 1.2 cm/layer = 40.8 cm
Add a little and call it 50 cm thickness for real estate considerations



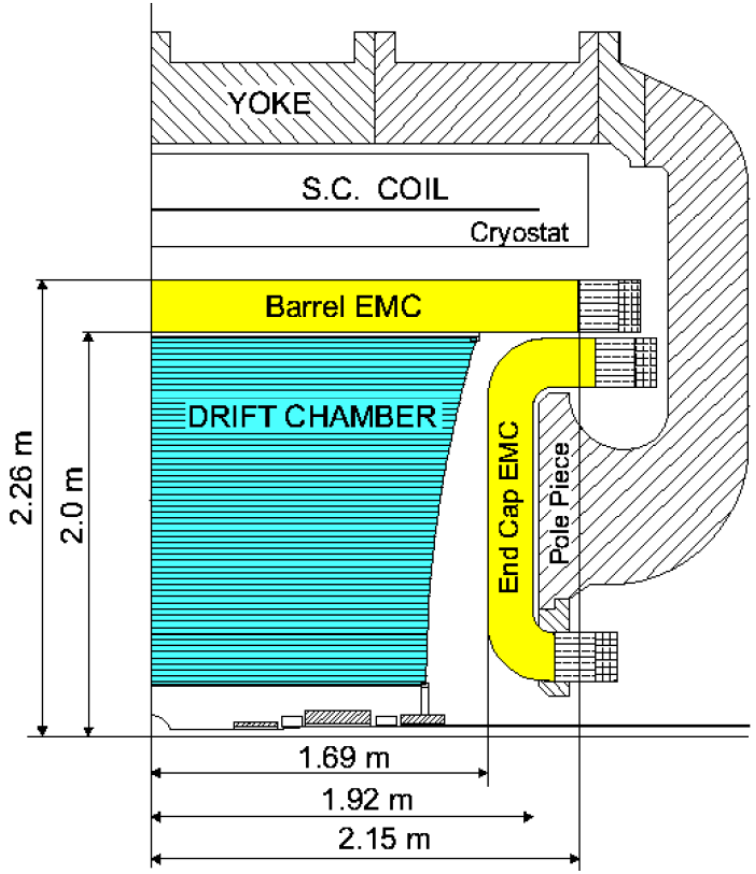


So, for strawperson design, choose:
GArTPC to be 3 m x 3 m transverse x 3 m length
Assume takes up 3.5x3.5x3.5 m^3 with container

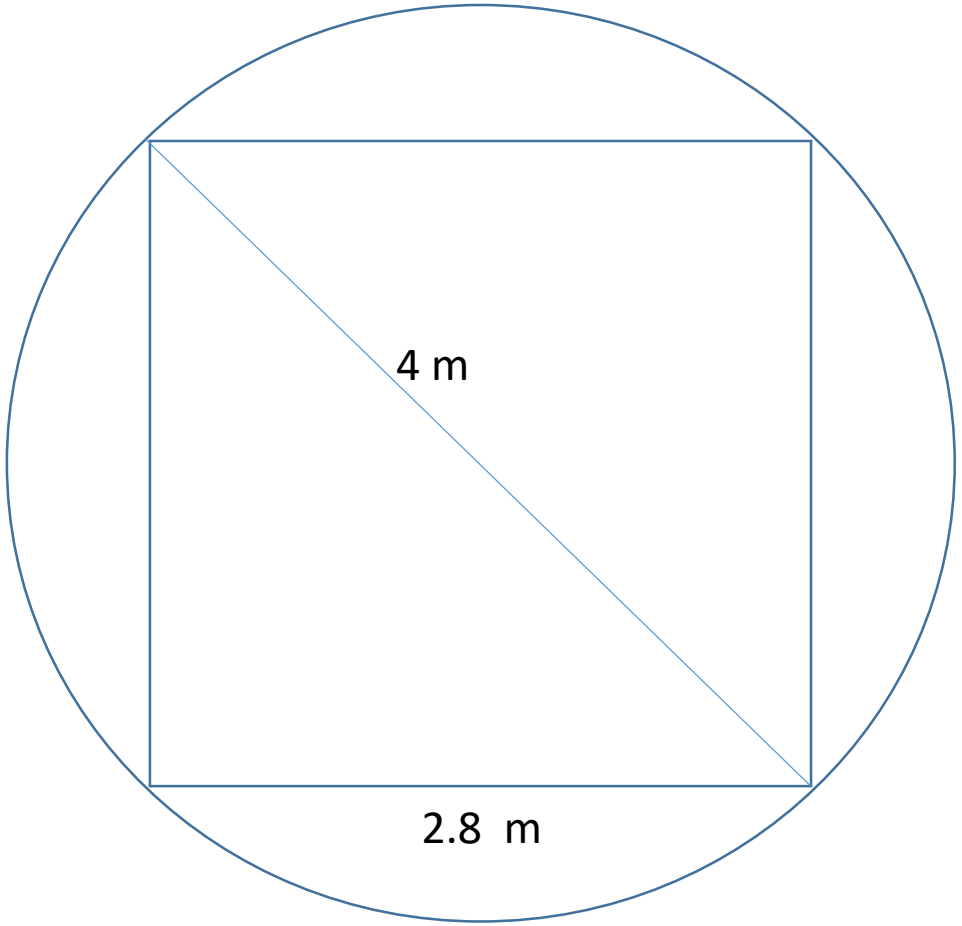
So, for strawperson design, choose:
STT to be 3.5 m x 3.5 m transverse x 5 m length

Thoughts on FGT designs using the KLOE magnet plus ECAL

KLOE measurements

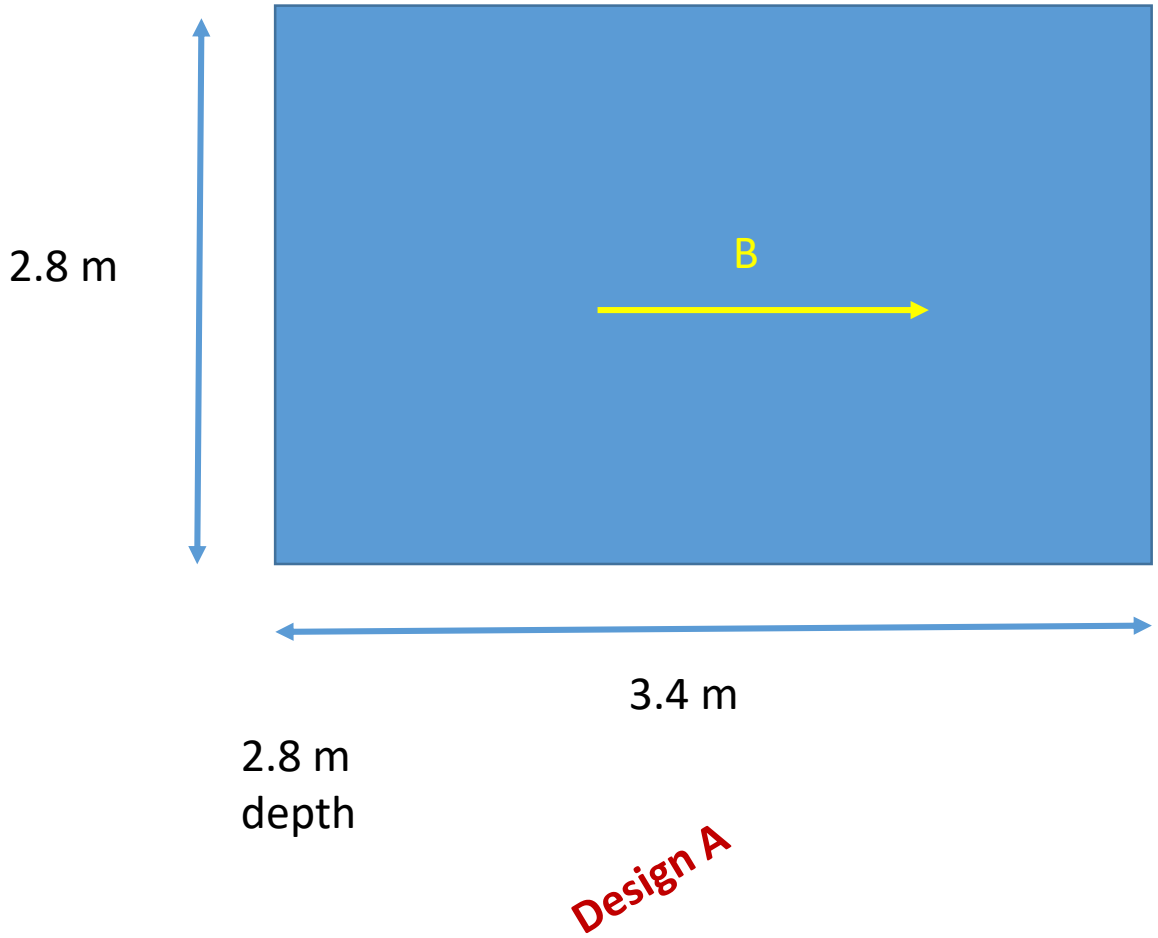


View along B

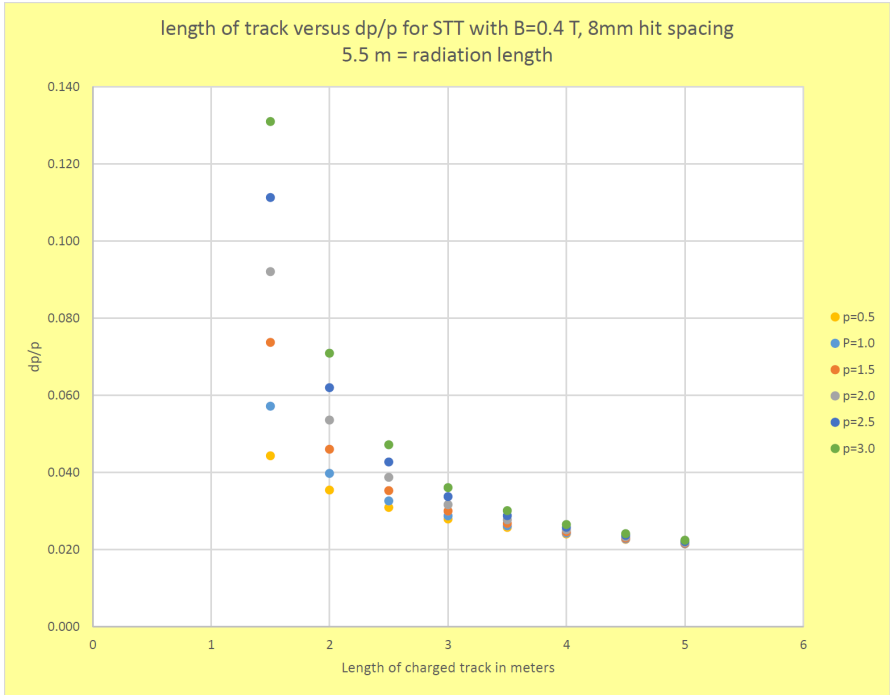


3.4 m long

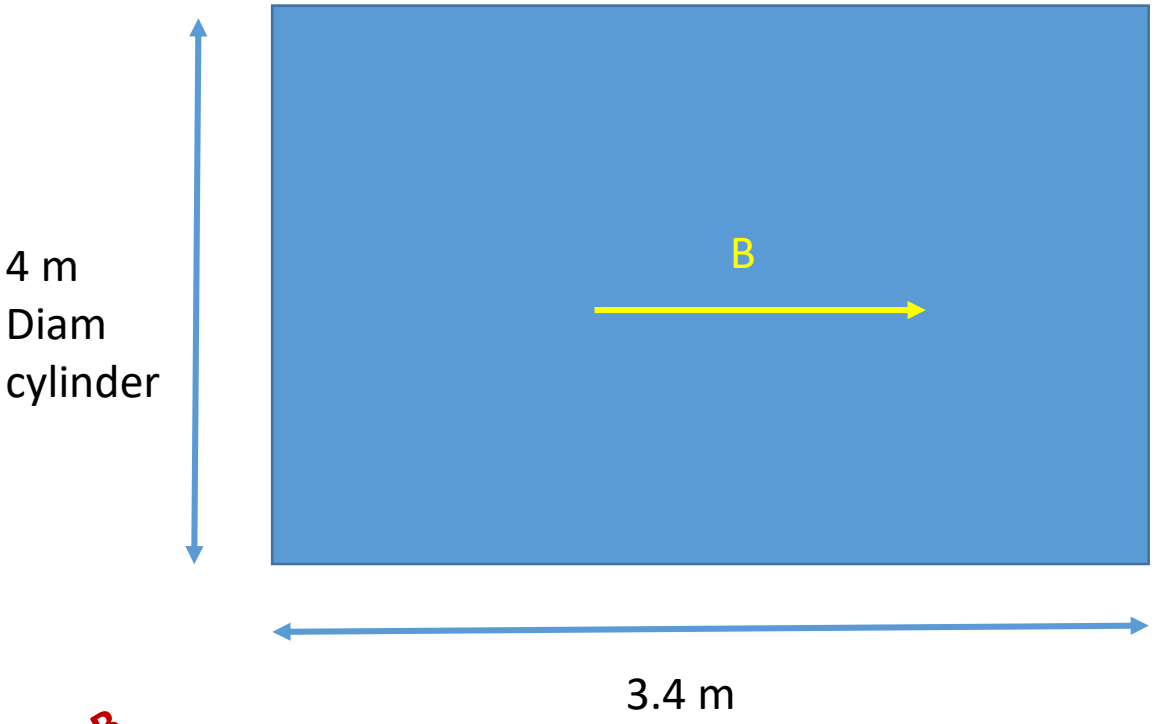
STT in KLOE magnet + ECAL
Neutrino view, solenoid turned transverse to beam



- Volume is 0.34 that of reference STT
- Mass is 2.7 tonnes
- Transverse length short in one direction
- Depth short



HPGArTPC in KLOE magnet + ECAL
Neutrino view, solenoid turned transverse to beam



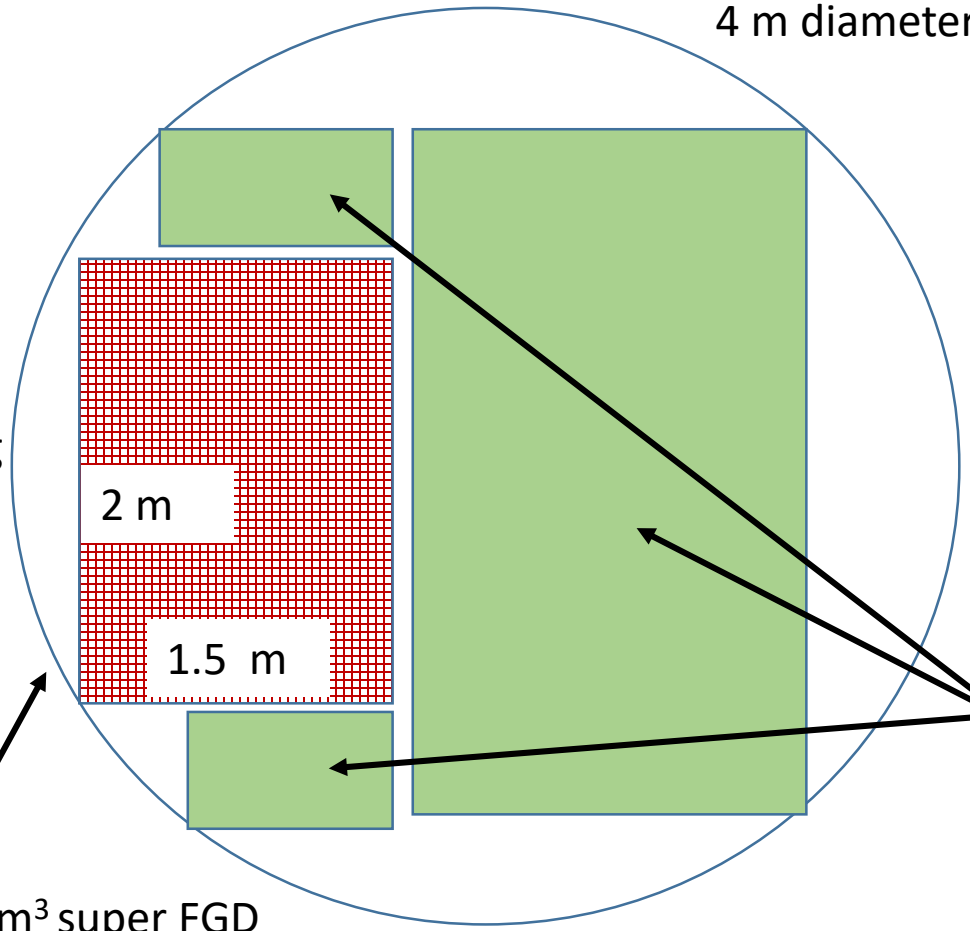
Design B

Take gas volume to be maximal here, not putting in room for the vessel for now

- Volume is 0.68 that of NDTF design
- But this assumes drift to side and not to endplate does not lose fiducial volume, probably not true
- Mass is 0.68 tonnes under this assumption

KLOE magnet plus ECAL
inner volume
4 m diameter, 3.4 m long

View along B



Gas TPC's for tracking

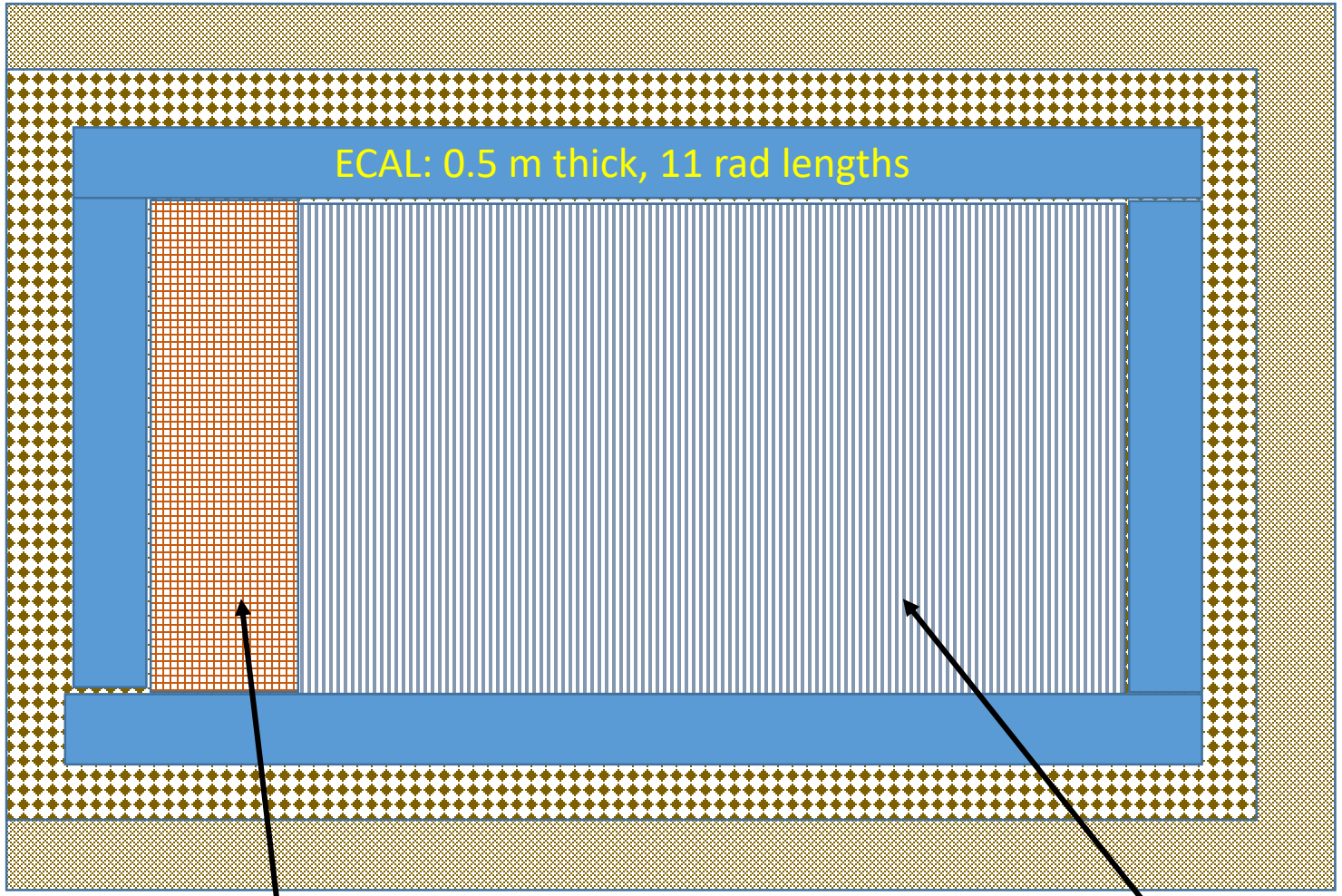
2x1.5x3.4 m^3 super FGD
3d scintillator module
as active target
4 m^3 = 10.8 tonnes

Design C

Thoughts on FGT designs using new magnet (some similarity to UA1 magnet, dimensions may differ a bit)

Return yoke with RPCs on 5 sides, 6 sides if not using FGT as muon spectrometer for LArTPC

Design D



Coil: 20 cm thick Al

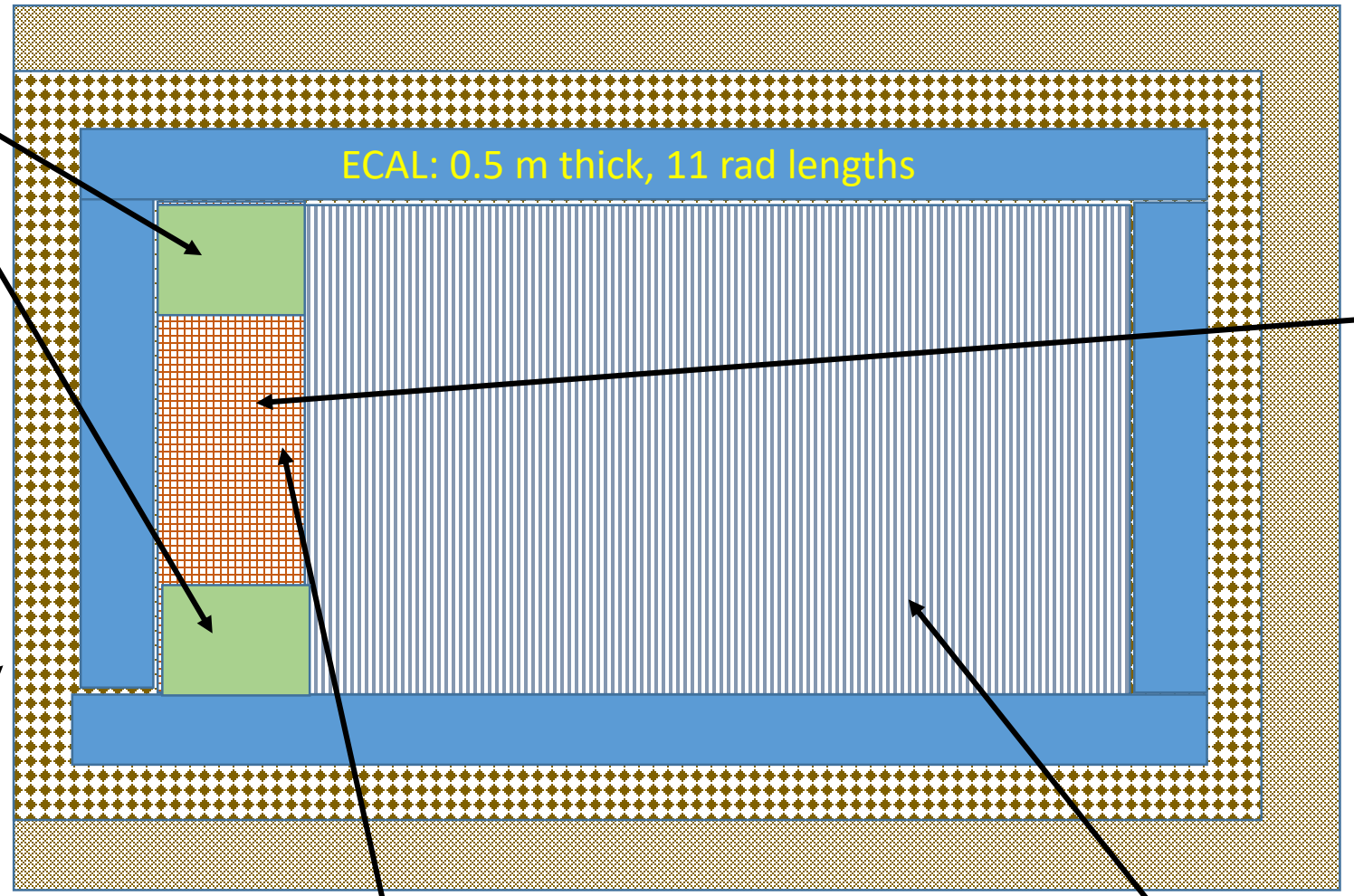
Inner dimensions of the coil volume:
4.5x4.5x8 m^3

3.5x3.5x1 m^3 super FGD
3d scintillator module
12.25 m^3 = 13 tonnes

3.5x3.5x6 m^3 STT
Can insert nuclear target layers as needed. 0.92 NDTF design volume. 7.4 tonnes

Return yoke with RPCs on 5 sides, 6 sides if not using FGT as muon spectrometer for LArTPC

0.75x3.5x1 m^3 gasTPC (top-bottom)



Design E

0.75x2x1 m^3 gasTPC (on sides)

Reduce transverse size of 3dst. 2.5 radiation lengths thick.

Coil: 20 cm thick Al

Inner dimensions of the coil volume: 4.5x4.5x8 m^3

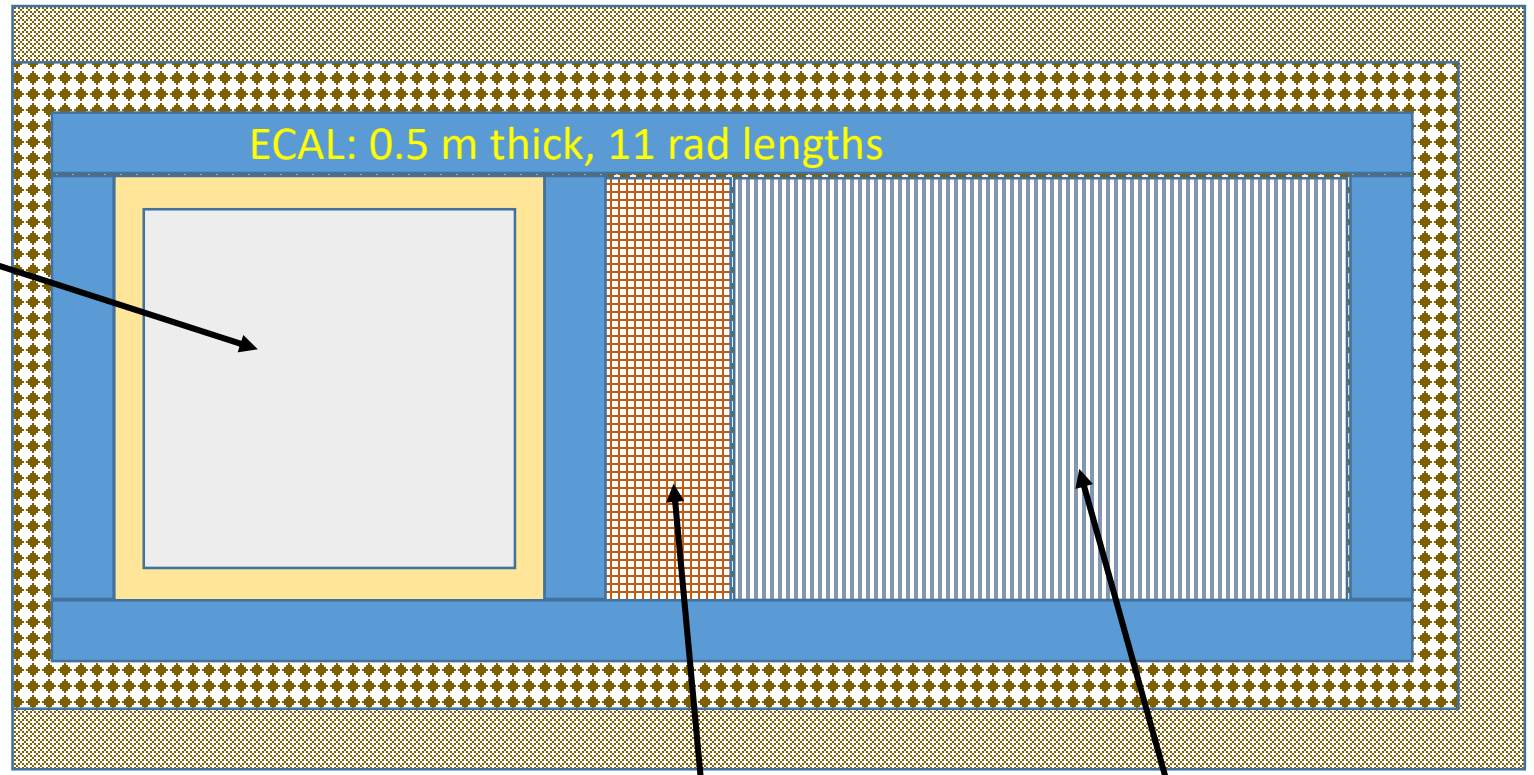
2x2x1 m^3 super FGD 3d scintillator module
4 m^3 = 4.2 tonnes

3.5x3.5x6 m^3 STT
Can insert nuclear target layers as needed. 0.92 NDTF design volume. 7.4 tonnes

Central ECAL provides photon containment for both upstream and downstream detectors.
Downstream detector provides good muon spectrometer for HPGTPC

Return yoke with RPCs on 5 sides, 6 sides if not using FGT as muon spectrometer for LArTPC

HPgasArTPC
3x3x3m^3 gas space
3.5x3.5x3.5 m^3 container space
Do cylinder with r=1.5 m and lenth = 3 m
0.34 x NDTF design
0.34 tonne Ar at 10 Atm



Design F

Coil: 20 cm thick Al

Inner dimensions of the coil volume:
4.5x4.5x11 m^3

(UA1 magnet has inner dimensions of 3.5x3.6x7 m^3) this has 2.5xUA1 volume … ugh

3.5x3.5x1 m^3 super FGD
3d scintillator module
12.25 m^3 = 13 tonnes

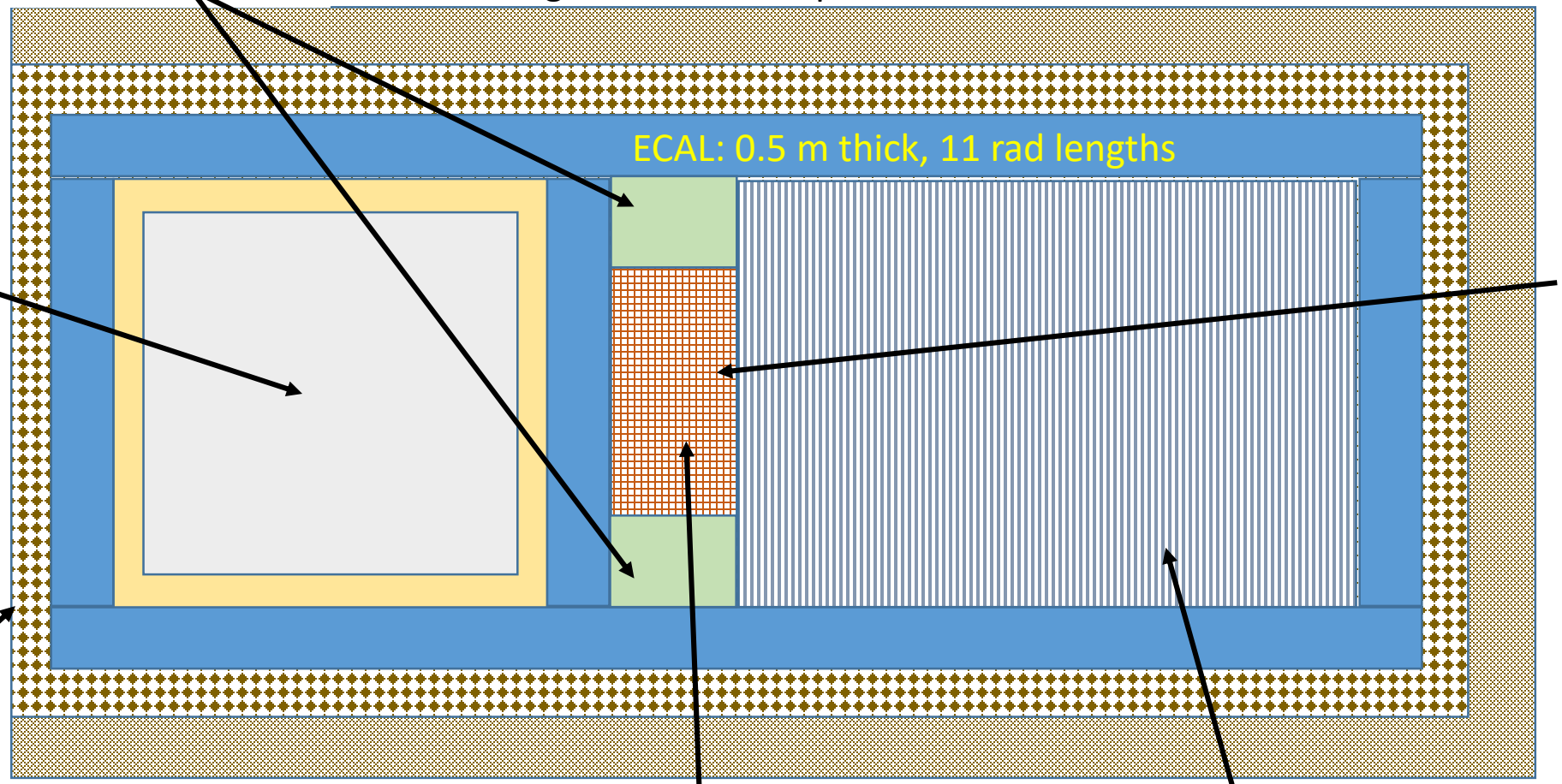
3.5x3.5x5 m^3 STT
Can insert nuclear target layers as needed. 0.77 NDTF design volume. 6.2 tonnes

0.75x3.5x1 m^3 gasTPC (top-bottom)

Return yoke with RPCs on 5 sides, 6 sides if not using FGT as muon spectrometer for LArTPC

Design G

HPgasArTPC
3x3x3m^3 gas space
3.5x3.5x3.5 m^3 container space
Do cylinder with r=1.5 m and length = 3 m
0.34 x NDTF design
0.34 tonne Ar at 10 Atm



0.75x2x1 m^3 gasTPC (on sides)

Coil: 20 cm thick Al

Inner dimensions of the coil volume:
4.5x4.5x11 m^3

2x2x1 m^3 super FGD 3d scintillator module
4 m^3 = 4.2 tonnes

3.5x3.5x5 m^3 STT
Can insert nuclear target layers as needed. 0.77 NDTF design volume. 6.2 tonnes

Design	Pros	Cons	SM comment
A (KLOE + STT)	Uses KLOE	Small for STT performance plus mass	☹
B (KLOE + HPGTPC)	Okay for performance, used KLOE	Mass on small side Only HPGTPC, not ideal for dune ND, already have LAr	☹ Bad for e-nu scattering, no/few photons convert in tracker making me worry about pizeros, relying on really understanding stuff in ecal. ☺ Nice xsec expt
C (KLOE + 3dST +TPC)	Good stats, uses KLOE	No low density target	☺ (esp. if someone does HPTPC expt separately) can work for DUNE ND
D (ref design with upstream 3dst)	Great stats, reference design advantages	No KLOE	☺☺ (reference design advantages with powerful active target for higher stats and enhanced upstream ecal)
E (ref design with smaller upstream 3dst)	same	same	☺☺ same as above with smaller 3dst to reduce cost
F (give me the works)	What's not to like!	Magnet volume 2.5xUA1 … yikes	☺☺☺
G (same with smaller 3dst)	same	same	☺☺☺