Comments on "KLM" Implementation w/ Updated CORE (Symmetric) Solenoid

CORE Meeting
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"KLM" Interleaved Readout in Return Steel Considerations - I

- Idea here is **not** a chopped off sampling HCAL (e.g., a STAR type FCS w/ 20mm Fe/3mm scint sandwich) … we need to measure position & response in individual layers

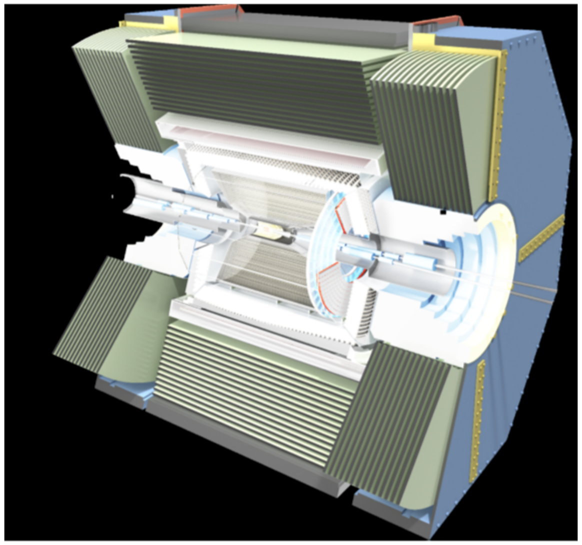
- **Scintillator strips are a reliable/inexpensive and widely used** readout method for such large area hodoscope/sampling detectors => use here vs. other possible options

- We'll want ultimately to be able to access the active readout planes w/o dismantling solenoid magnet structure => some practical limits on mechanical slot/shelve configuration, size, etc.

- The long (several meter) strip lengths require use of embedded (WLS) fibers in order to get sufficient light out and obtain enough p.e.'s (even with use of SiPM technology)

- Hence we arrive at a solution similar to the Belle II KLM scintillator upgrade,

Belle Detector



Octagonal Iron structures:

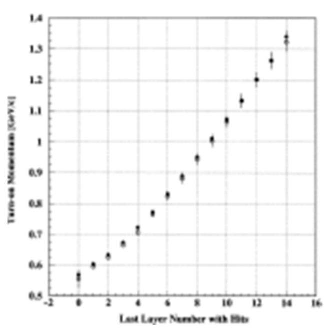
- 14 layers of ~ 47 mm thick steel plates
- ~ 40 mm thick air slots => 15 barrel, 14 Forward , 12 Back instrumented yoke

	X_0 (cm)	λ_I (cm)
return steel	~ 37.5	~3.9
scintillator	~ 1.4	~0.7

"KLM" Interleaved Readout in Return Steel Considerations - II

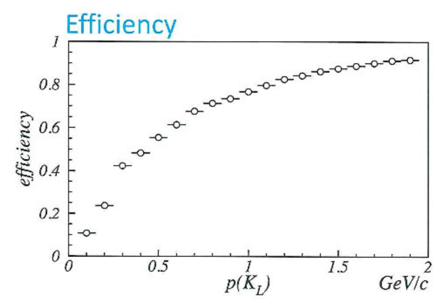
Muon Performance Issues

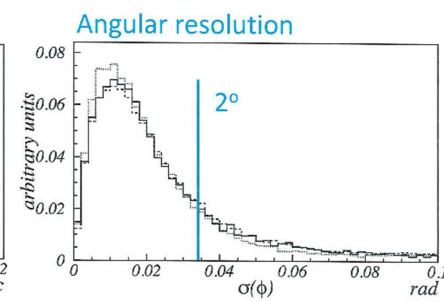
- Material burden before first readout layer determines effective threshold for "KLM" muons
- Subsequent layers then turn on at higher momentum and help w/ ID; fake rate decreases with layer up to 7
- Muon multiple scattering determines needed spatial resolution (was ~ 10mr at Belle); momentum determined most precisely from tracking detectors



K long Performance Issues

- Efficiency increases with total interaction length of detector (instrumented steel in the flux return)
- Sampling frequency (thickness of steel layers) also likely impacts detection efficiency of neutral hit products (don't have a simulation to optimize)
- Spatial criteria commensurate with muons





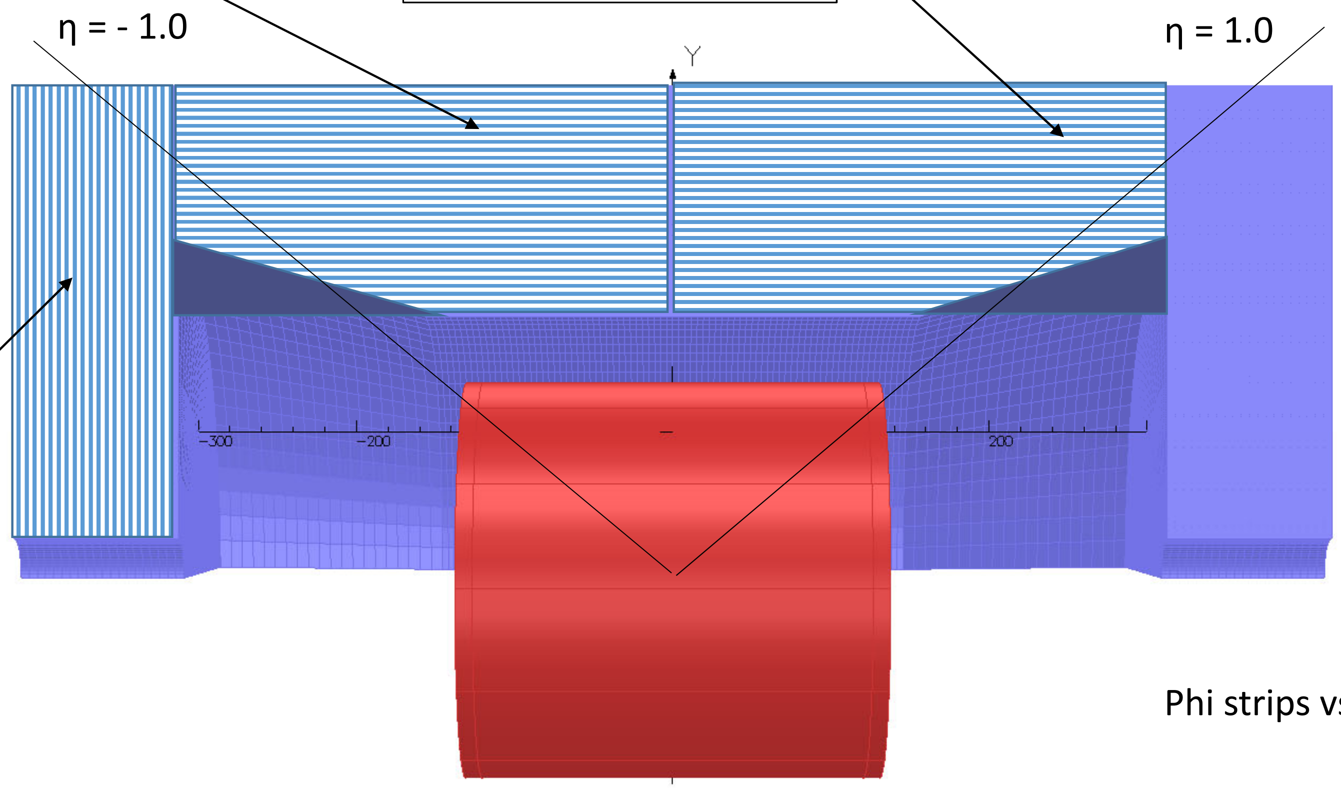
Muon & K long Composite

Shoot for: equal sampling spacing & maximal total interaction length lacking any other directive

CORE "KLM" Implementation with Symmetric Solenoid Model

Barrel e-side:
octant structure
w/ rectangular RO
inserts

Barrel e-side:
octant structure



Endcap e-side:
quadrant RO
layers; endcap
vertically split in
halves for access

Phi strips vs z

N.B.: maximum scintillator readout strip length < ~ 3m in all layers

All Endcap layers upgraded to scintillator at start of Belle II

Nominal air gap stackup – initial strawman
(thinner than Belle which filled existing RPC slot)

. a) clearance 1.5-2 (big area dets w/ big area steel bars)
b) top cover/frame 1.5 (could also use w/ h) for any routing
e.g., associated with 2-ended readout, etc.?)
c) scint layer 10.5 (z readout)
d) epoxy
e) central substrate 2
f) epoxy
g) scint layer 10.5 (phi rreadout)
h) bottom cover 1.5 (room for external U/angle?)
i) clearance 1.5-2

<u>29-30mm (generous can trim to 26-27mm, etc.)</u>

Fitting stackup into return steel with
– 1m radial length example / scalable

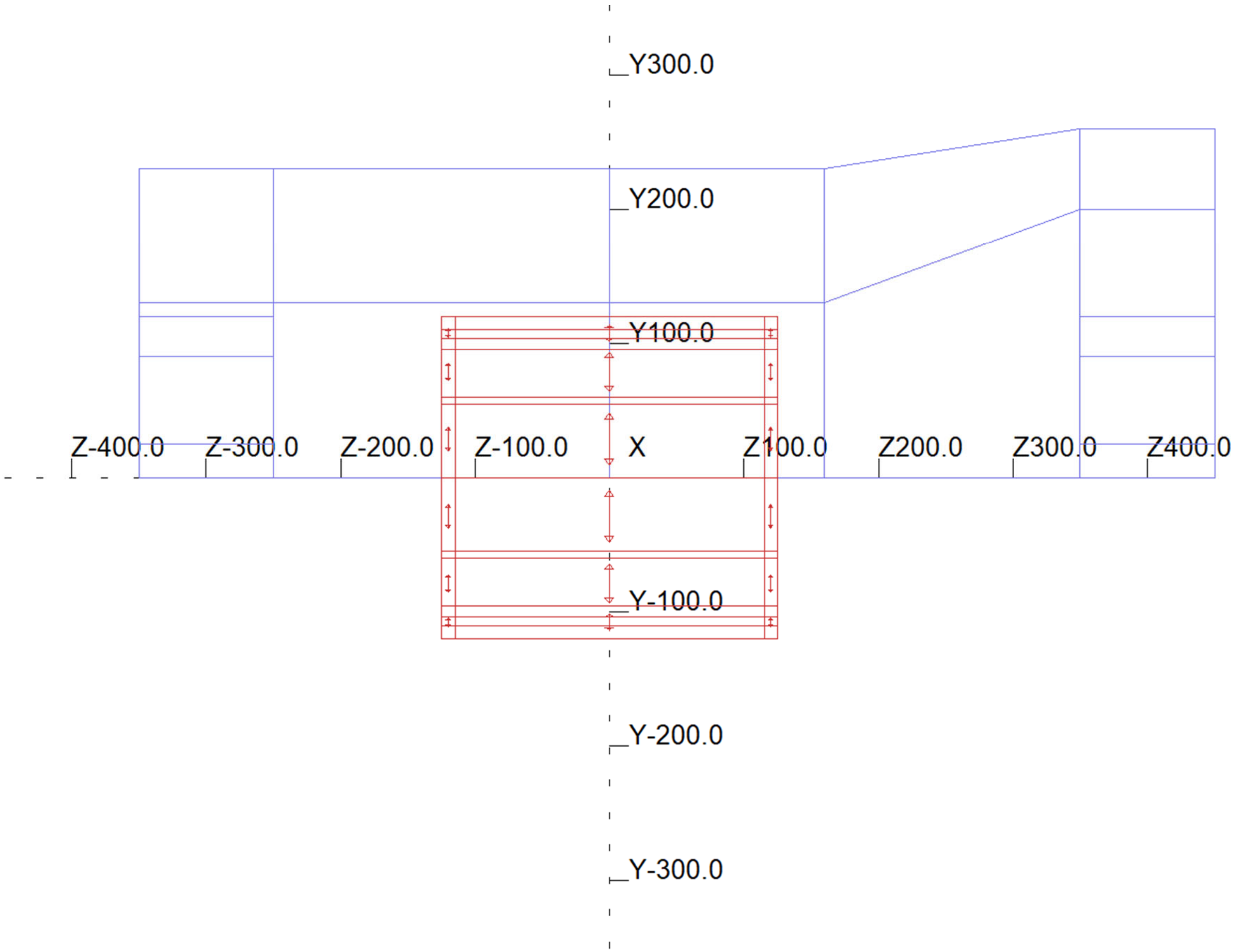
- if fit sensor/RO in **<u>27 mm air gap</u>**
  => (1000 - 13*27mm)/14 = 46.4mm steel bars,
  using ~ 65% steel density
  e.g., compared to Belle w/ 14*47mm bars and
  40mm gaps (~ 55% steel)
- w/ one sensor before steel starts, and one after
  all bars => 15 total readout layers
- so, for 1 m steel thickness, about same amount
  of interaction/steel length, sampling rate. etc.
  as in Belle (new CORE solenoid 1.4m thickness)

Note: on board elec. RO form factor to
be reduced => expected to be quite ok

At present Solenoid design has ~ 1.4 m steel @ 60% density at the mid-rapidity location => we can instrument more layers, improving neutrals detection efficiency

Note: physical strip width/# channels driven by IP to first layer distance for given pitch:

BACKUP SLIDES



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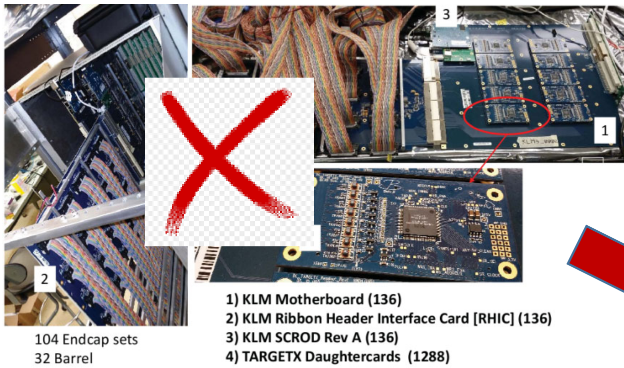
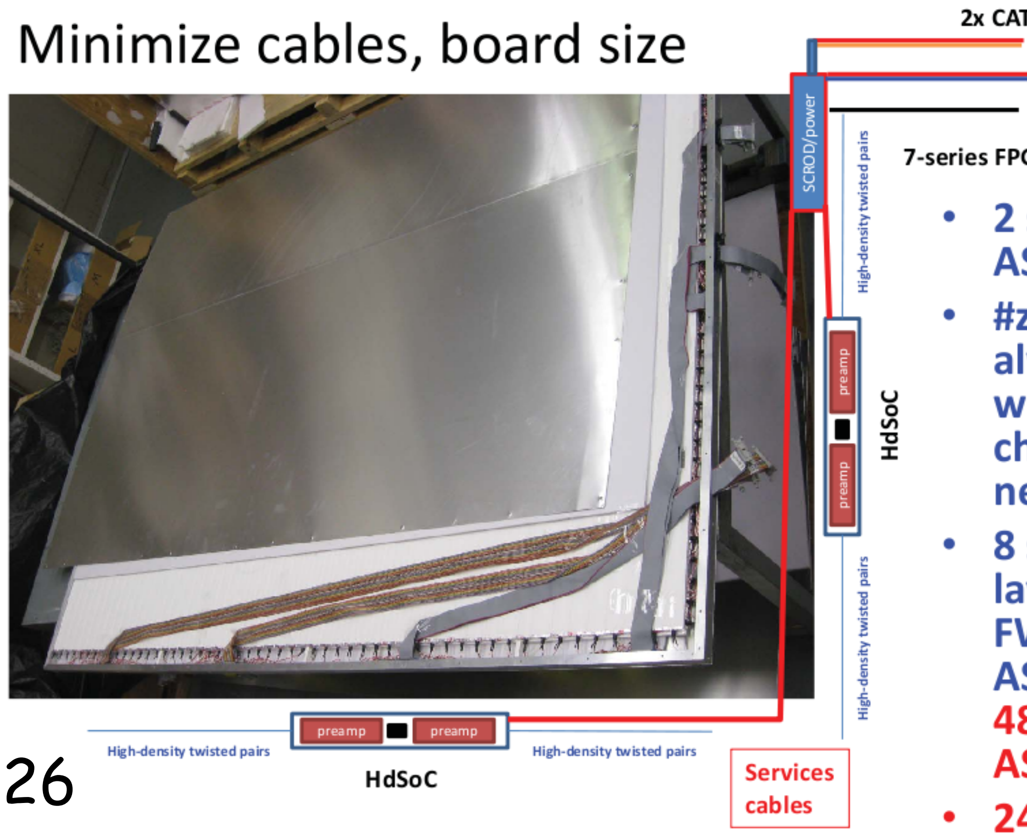
Pre Processor

Plans (EOI to Belle II): replace 13 remaining Barrel RPC layers



- Fabricate the new scintillator layers
- Redesign scintillator readout for all 15 layers

Minimize cables, board size



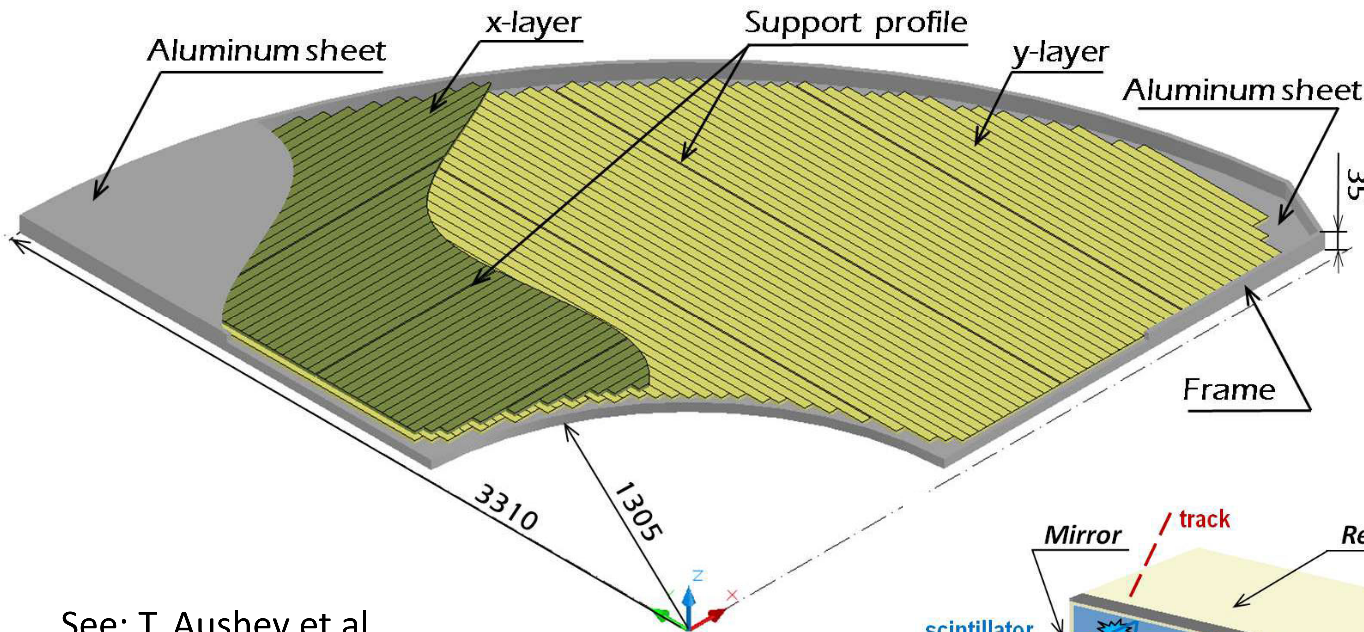
- 2 separate ASIC cards
- #z channels always same; wrap phi channels as needed
- 8 sectors * 15 layers * 2 FW/BW * 2 ASICs = 480 ASICs, ASIC cards
- 240 SCROD

- Move digitizing front end electronics into detector panel
- Developments: embedded ASIC; compact SCROD; 64-chn readout; several different preamp options
- K_L time-of-flight possible?

Expected installation ~ 2026

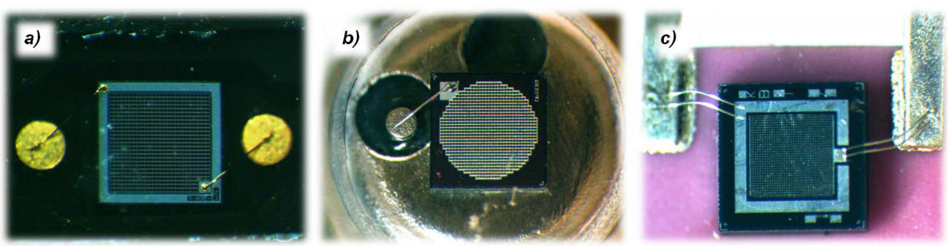
- ~ 25k channels: initial cost est. ~1.4-1.8M elec., ~4.8M det., w/ some reuse of crates, etc.

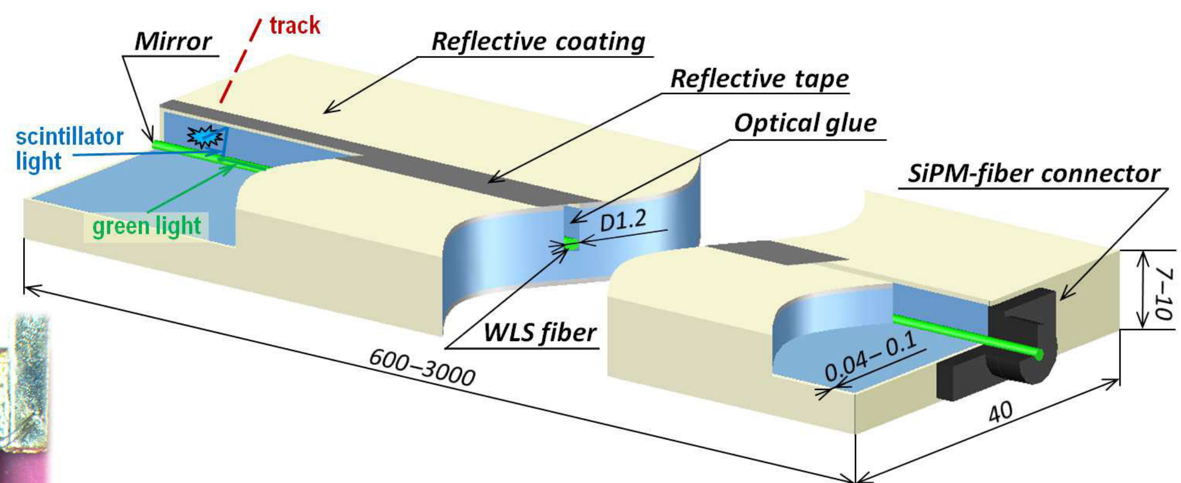
All Endcap layers upgraded to scintillator at start of Belle II



- Similarly, scintillator strips ~ 0.7x4 cm^2 machined w/ cut)
- Single strip readout w/ SiPM
- FEE readout has pulse shape characterization capabilities … FW implementation (w/ barrel) under development

See: T. Aushev et al. arXiv:1406.3267v3 (2015) for details

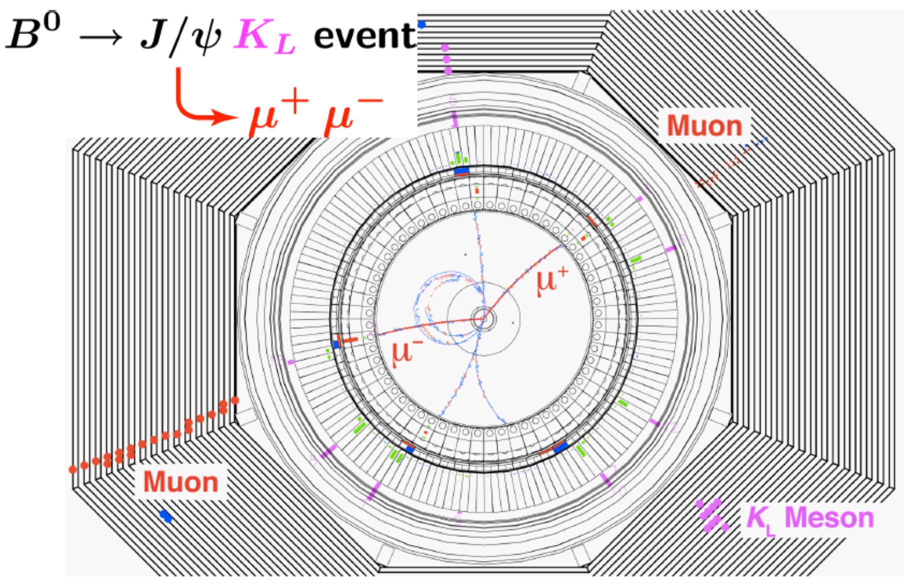




KLM @ Belle II: Useful Starting Point

Belle II and Prior Design Performance Requirements:

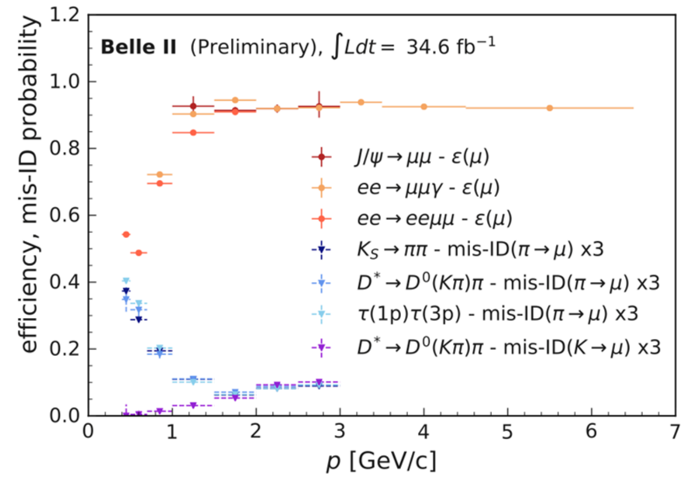
- Detect K_L mesons and muons
- Identify the muons and K_L mesons with high efficiency and purity
  - for muons above ~ 0.6 GeV momenta
  - good angular resolution (~ 2 deg) for the K_L's



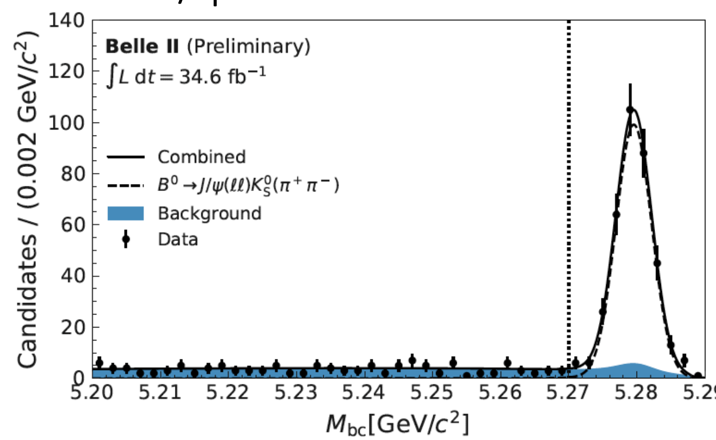
Also as a veto in missing energy modes like: B → τν

2020 muonID > 0.9 performance

(low p region under further study)



B → J/ψ Ks for ICHEP2020 CPV



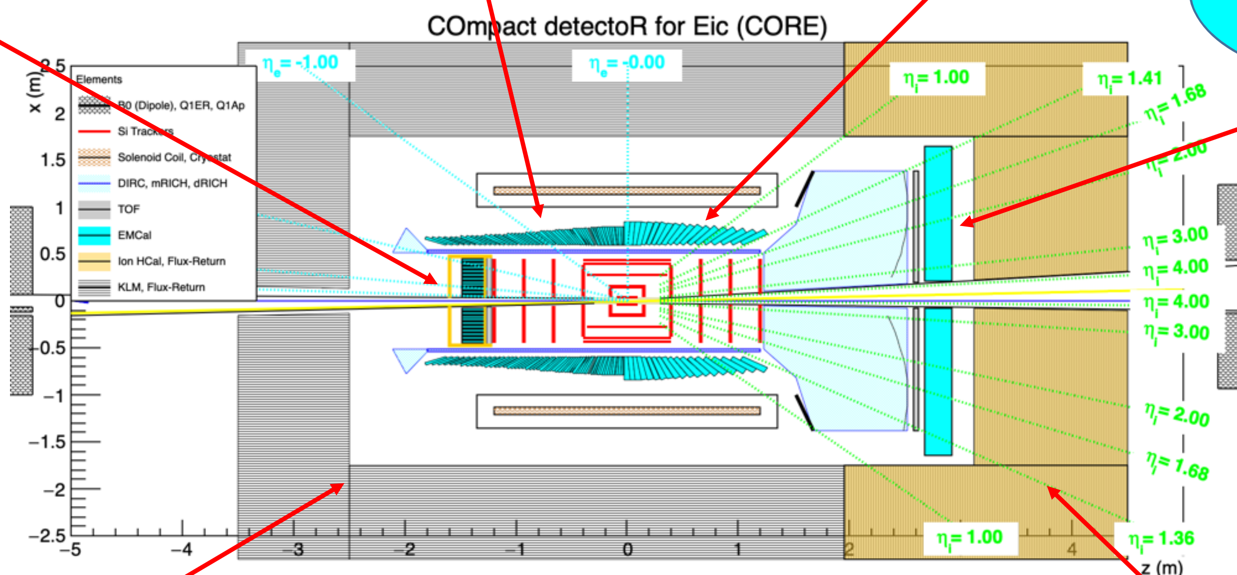
CORE Calorimetry EMCal, Hcal and "KLM" Components

Electron Endcap
$PbWO_4$ Crystals

Barrel: Electron Side
$PbWO_4$ Crystals

Barrel: Ion Side
W-Shashlik

Ion Endcap
W-Shashlik



Backward/Barrel: KLM style
"thin" Hcal w/ Fe/Scint strip

Forward HCal
Fe/Scintillator