KLM overview and μ identification algorithm

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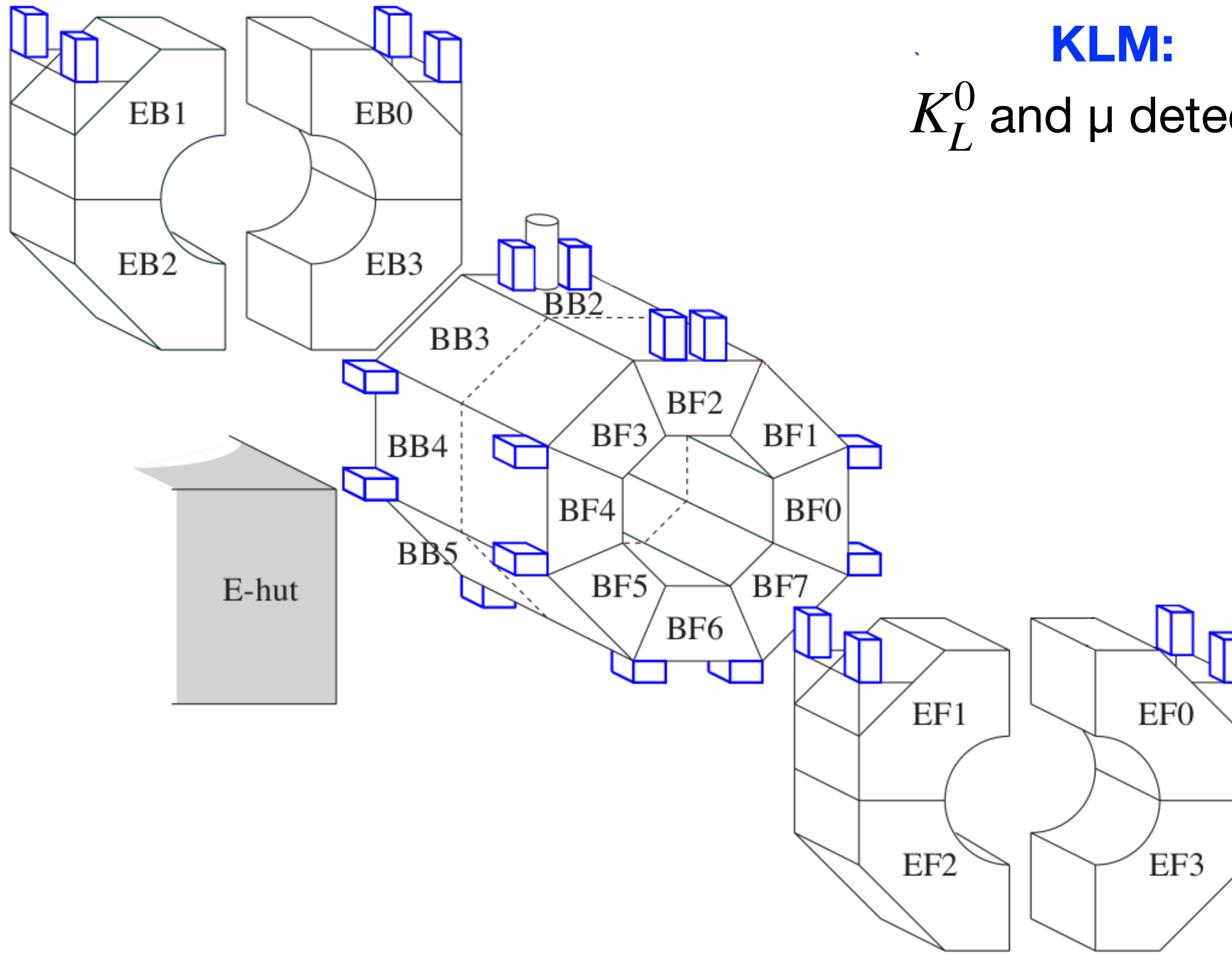
University & INFN Roma Tre

5th Starter Kit, 30 January 2020, PID session - *μ*ID

KLM general view



KLM:

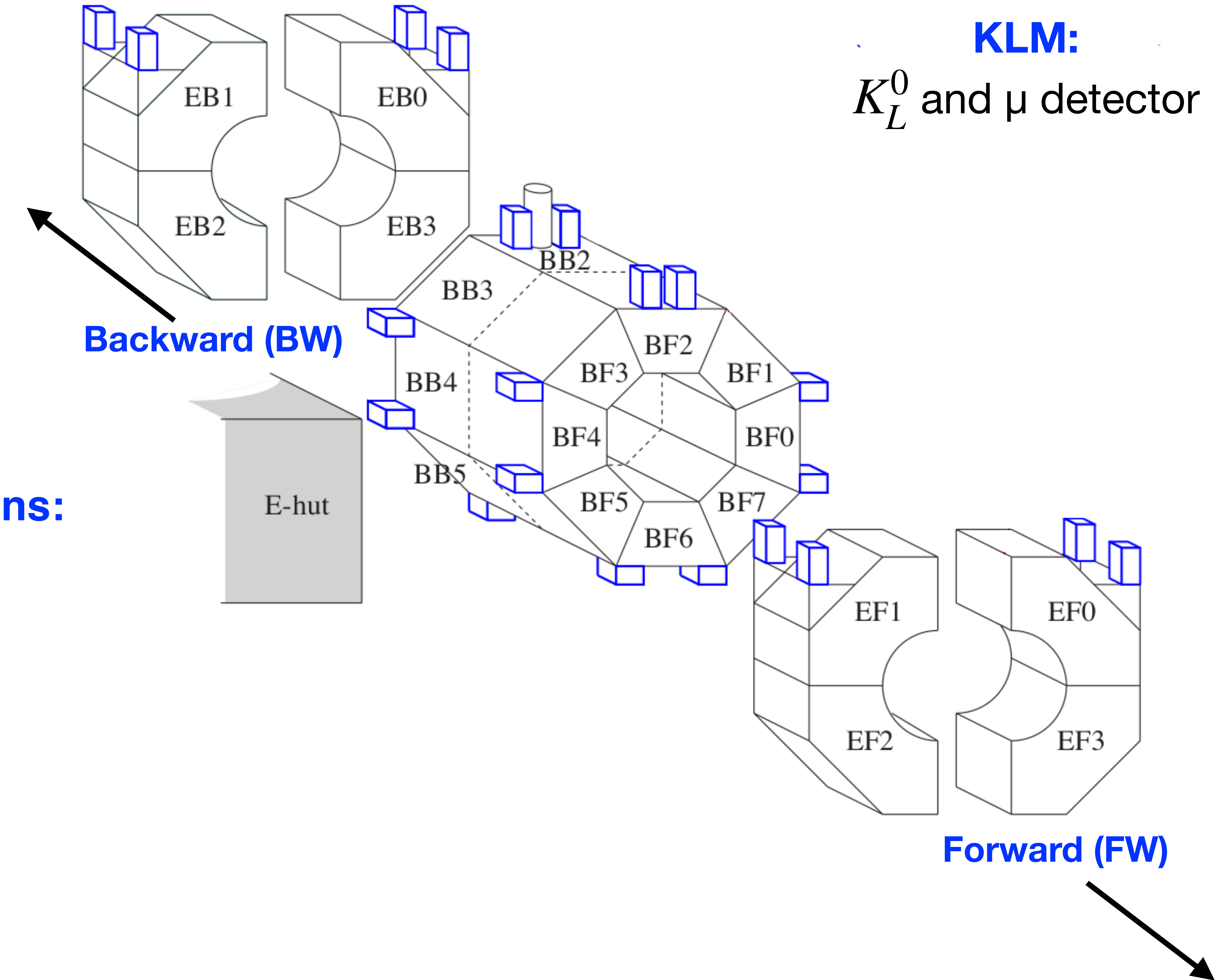
K_L^0 and μ detector

KLM general view

KLM is made of:

Barrel KLM: **BKLM**
Endcap KLM: **EKLM**

KLM:
K_L^0 and μ detector



Important informations:

- BKLM has 16 sectors;
- EKLM has 8 sectors;

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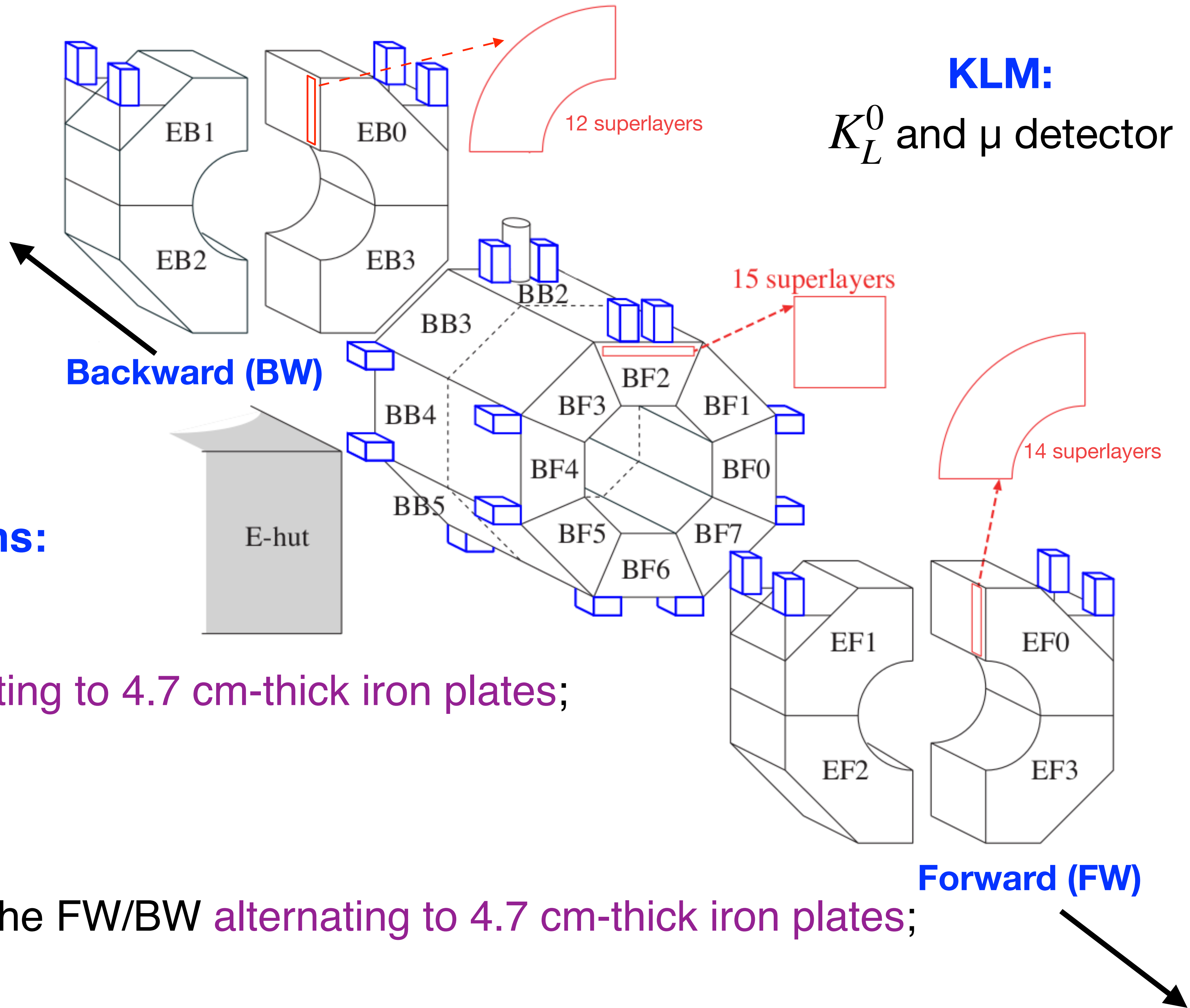

Important informations:

◉ BKLM has 16 sectors;
- BKLM has 15 layers alternating to 4.7 cm-thick iron plates;

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- EKLM has 14/12 layers for the FW/BW alternating to 4.7 cm-thick iron plates;

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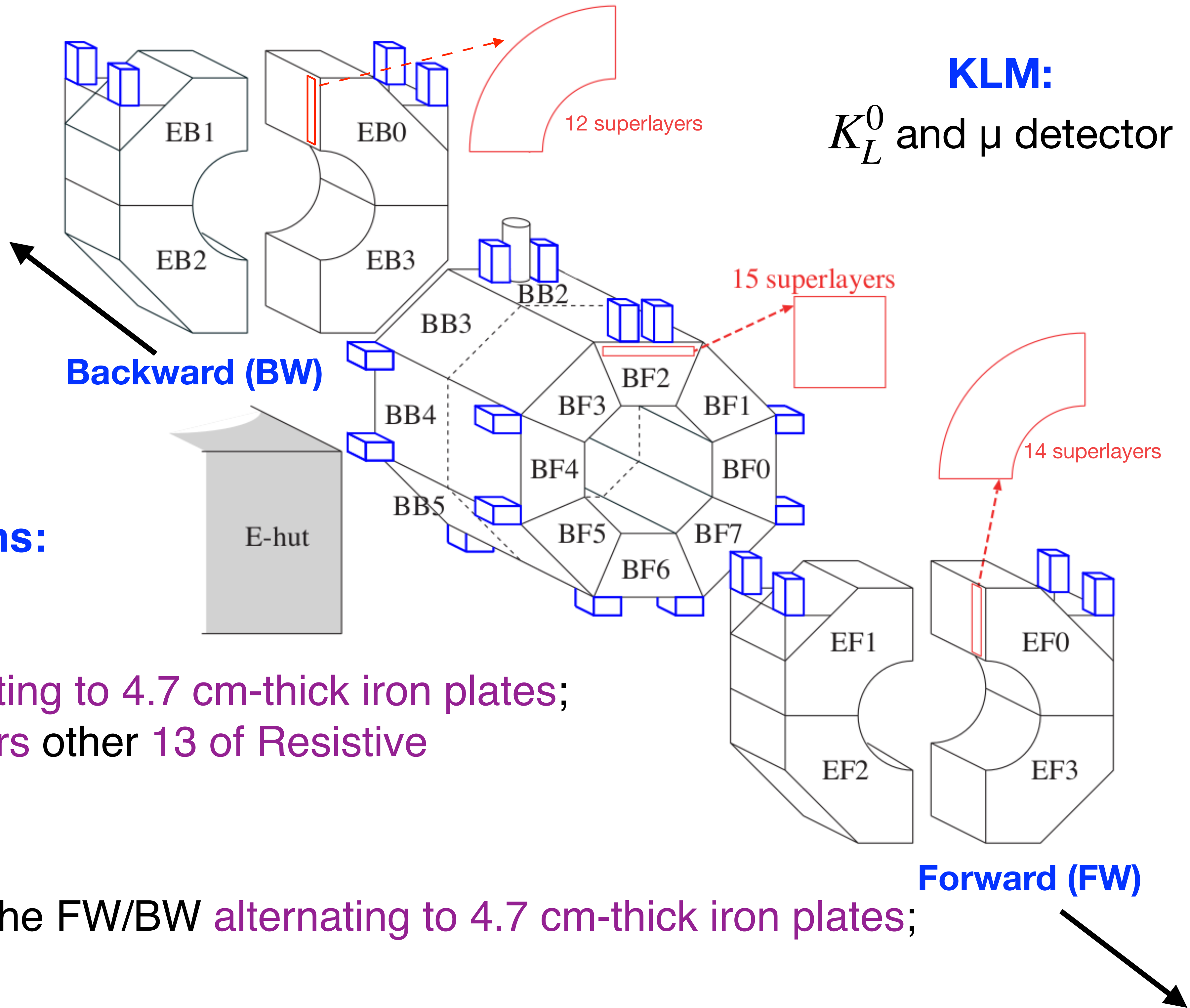

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  - ✦ First 2 layers of scintillators other 13 of Resistive Plate Chambers (RPC);

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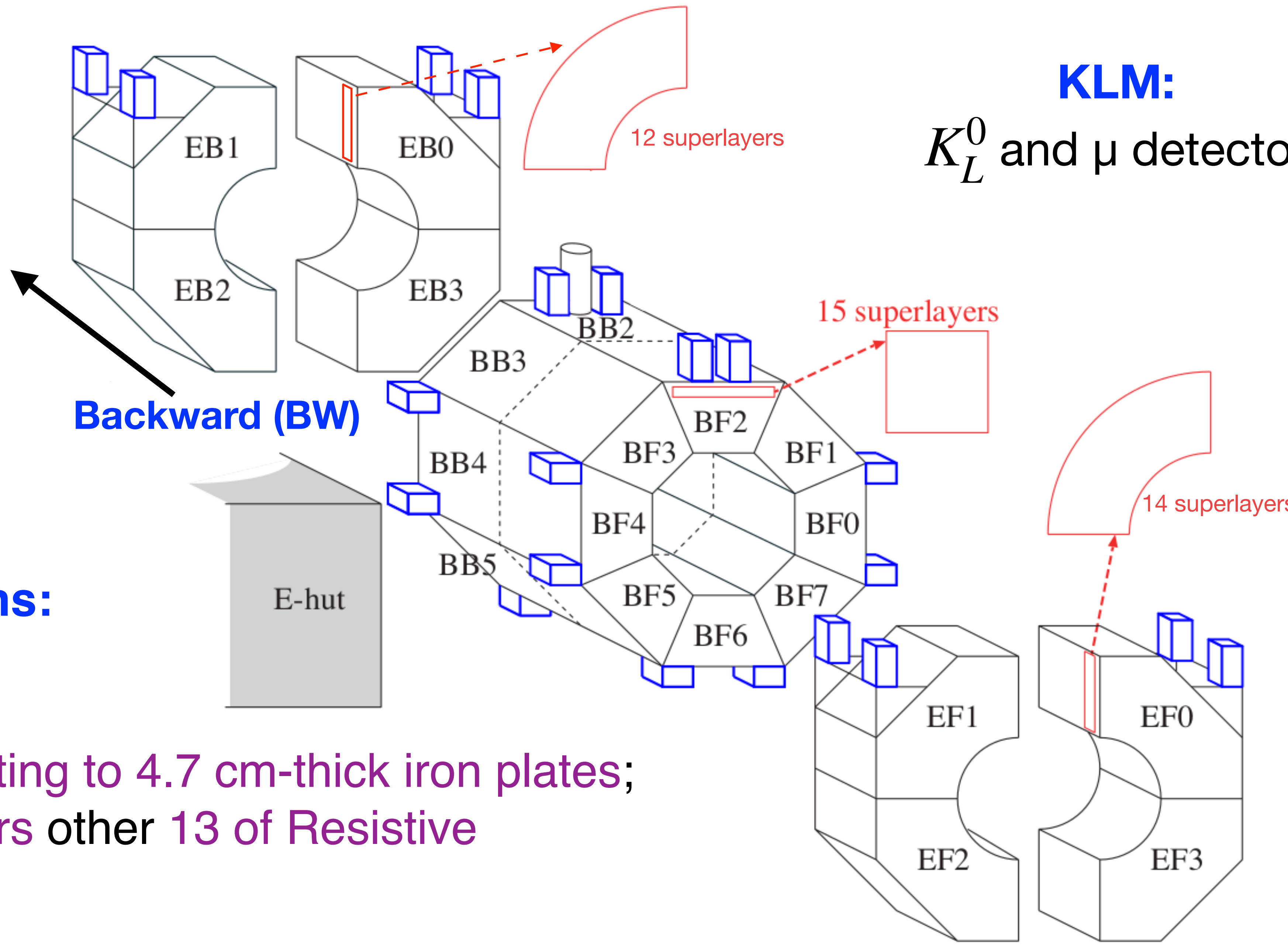

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◉ EKLM has 8 sectors;
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  - ✦ Only scintillators;

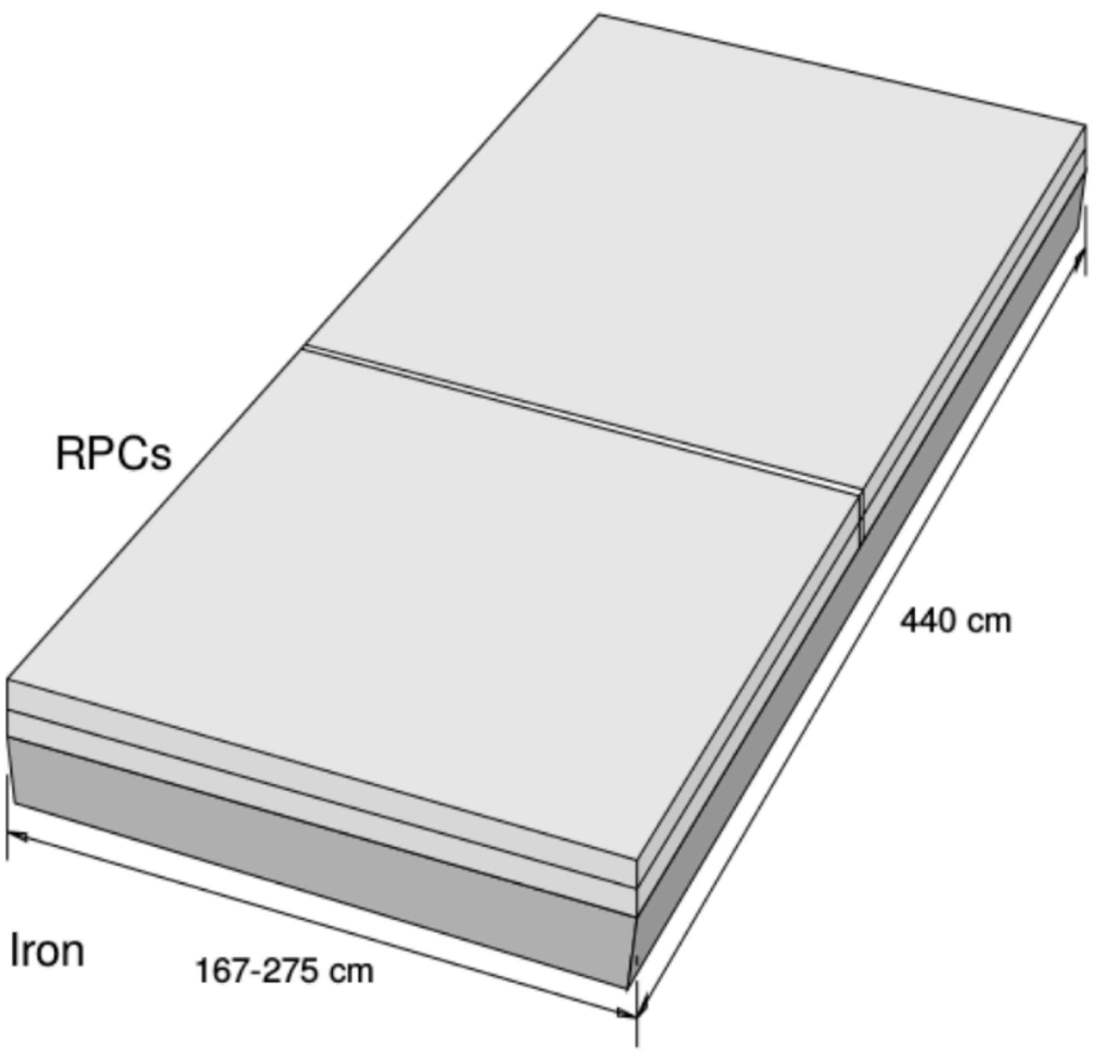
serve as the magnetic flux return for the solenoid

KLM layers: RPC and scintillators

RPC= Resistive Plate Chamber

Gas detector supplied with 4.7kV

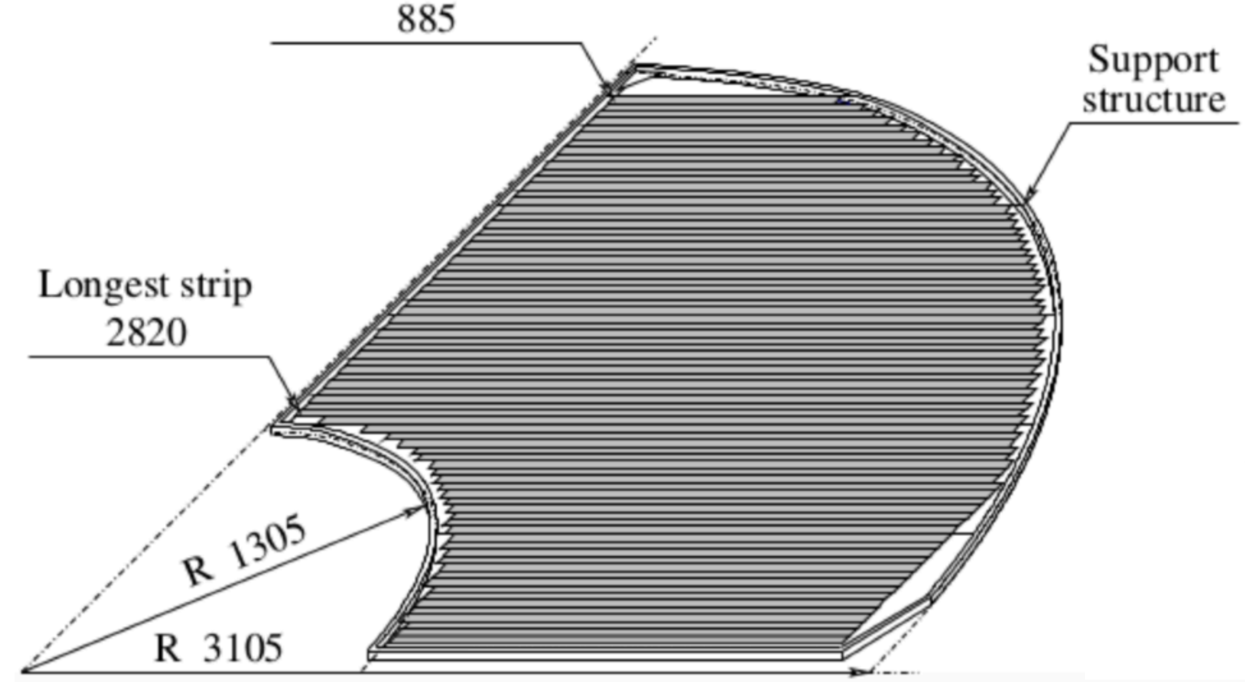
2.4 mm thick float glass (73% SiO_2, 14% Na_2O, 9% CaO, and 4%)

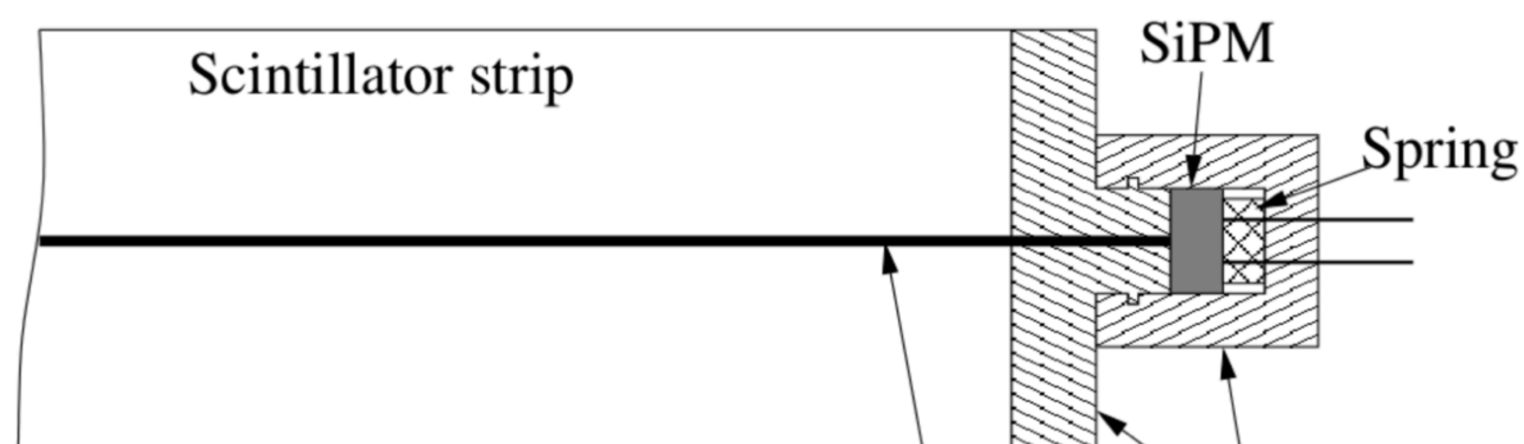


Scintillator strips:

Supplied with ~73V

Wavelength shifting (WLS) fibers coupling and photons read out by silicon photomultiplier (SiPMs)





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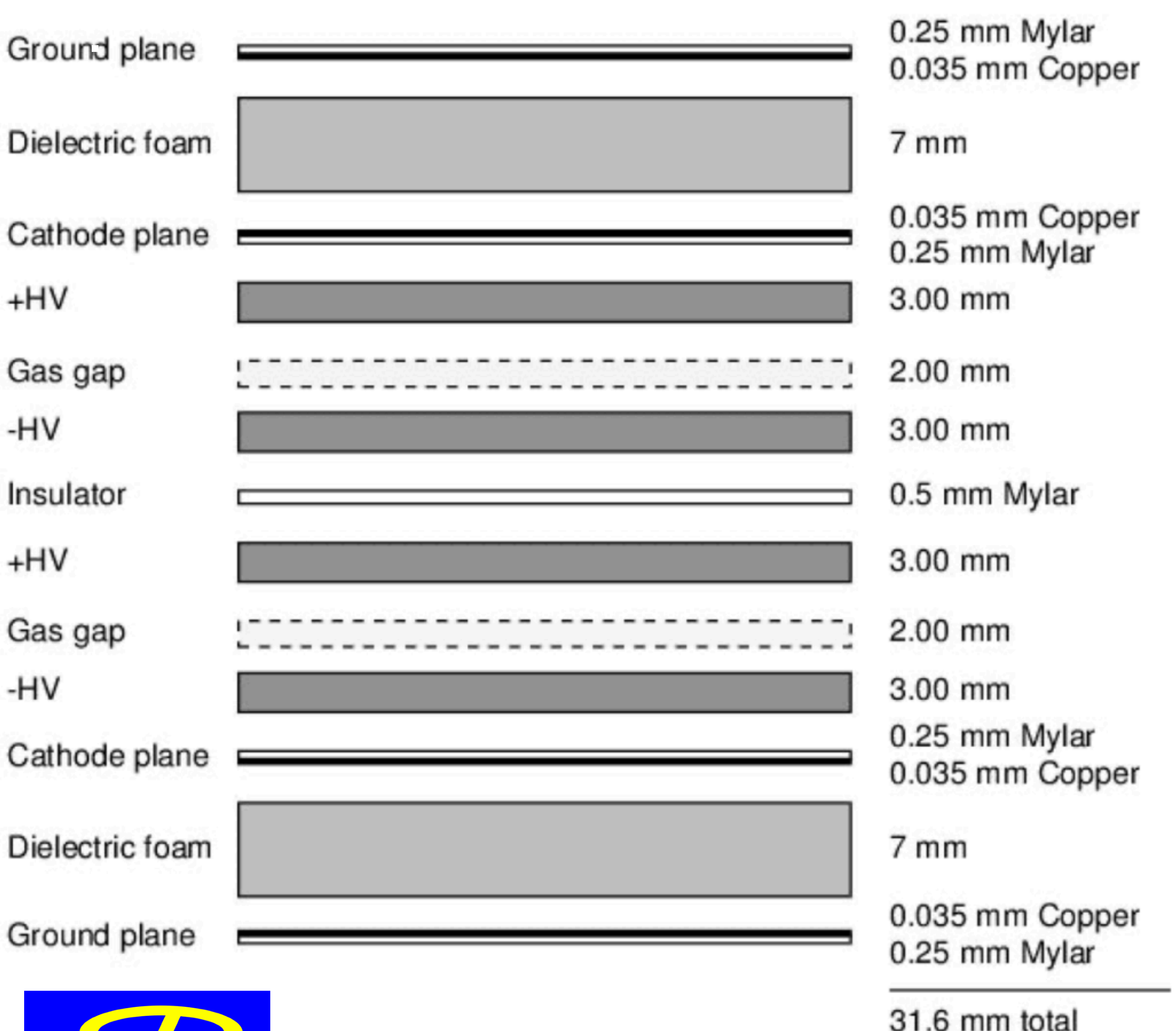

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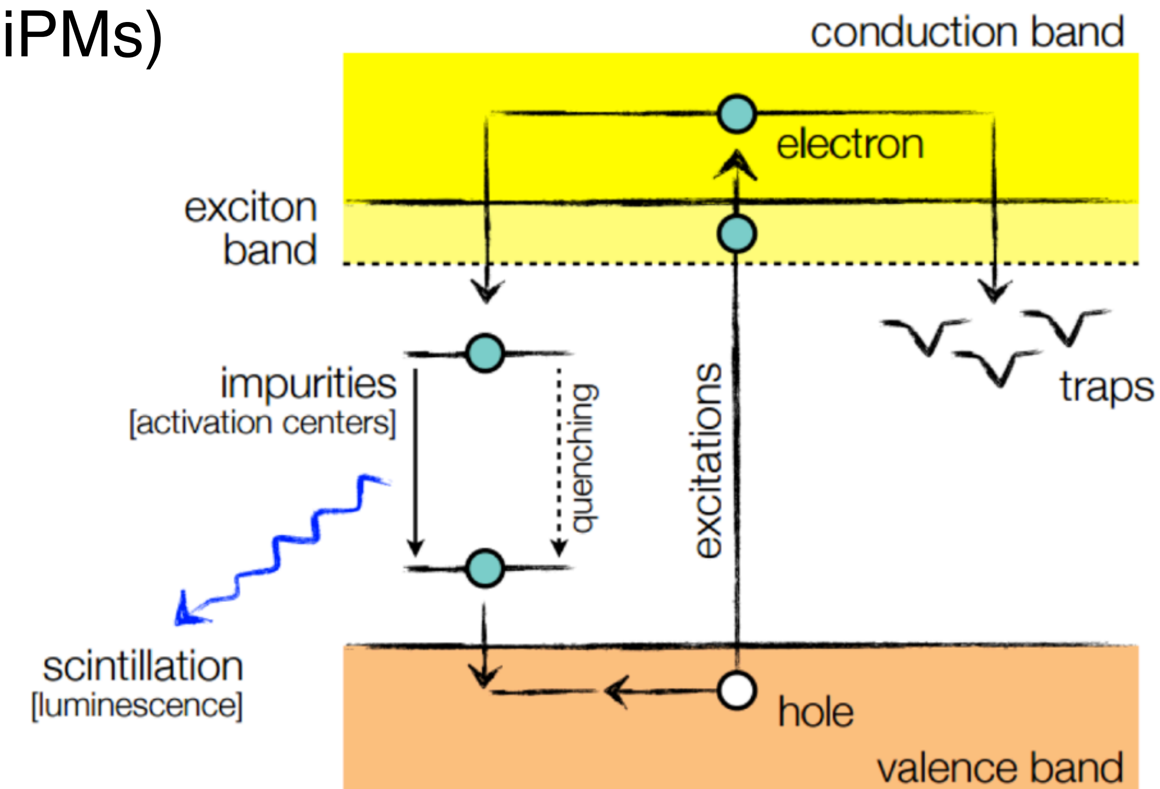
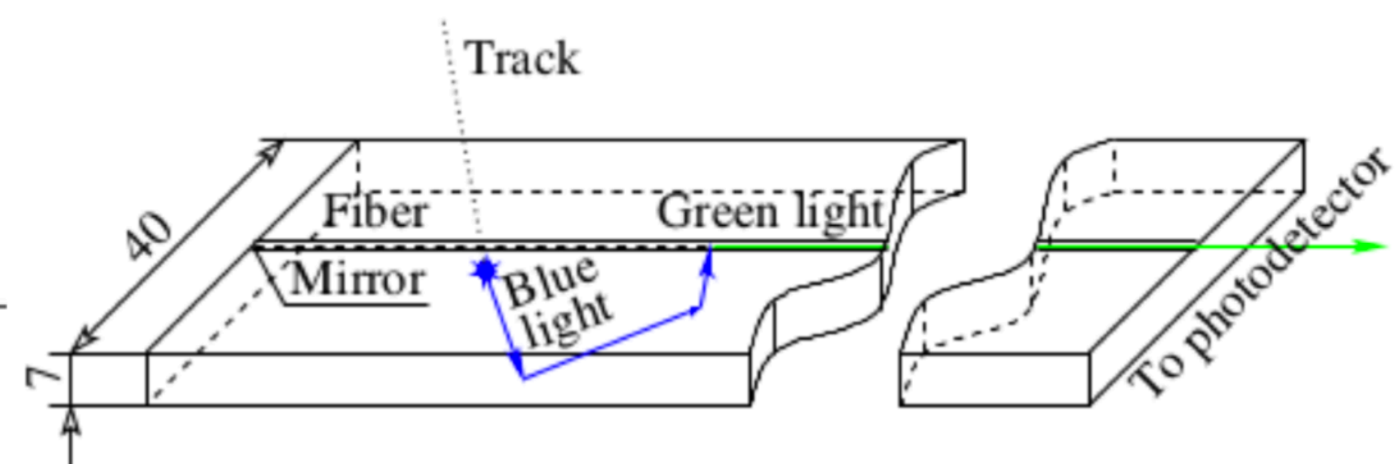
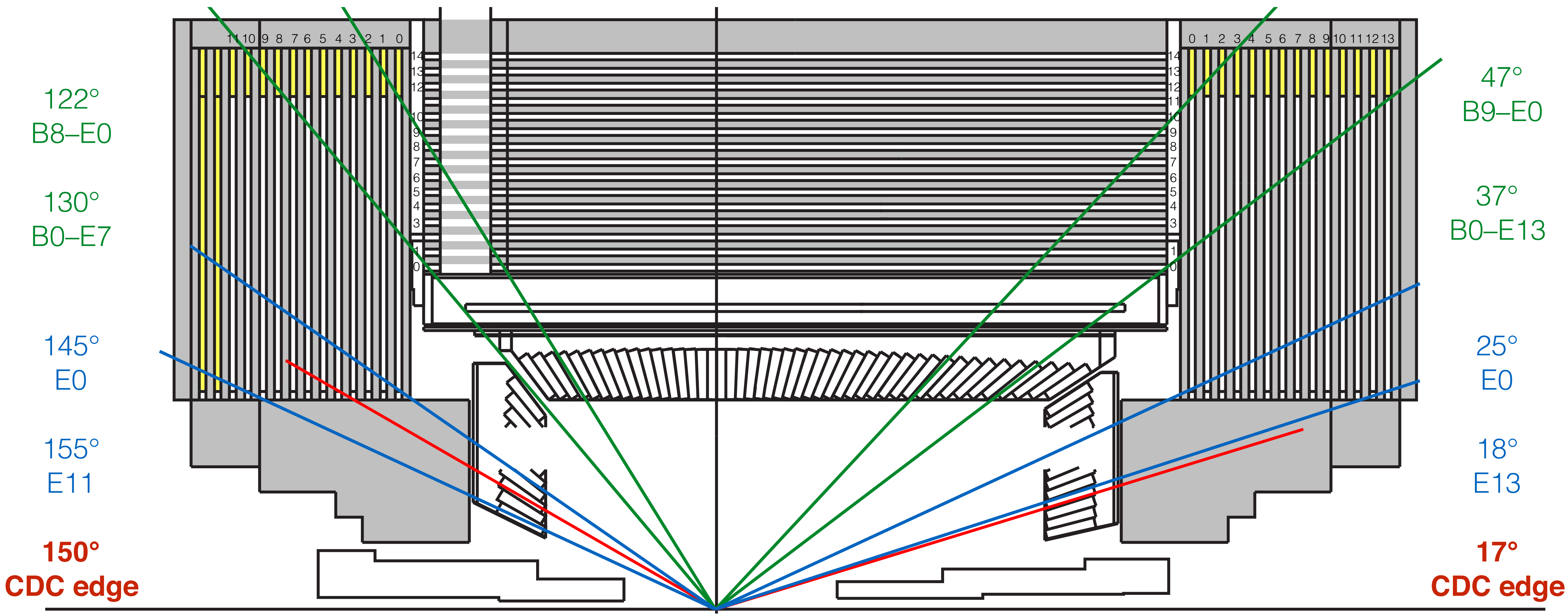




KLM and μID acceptance



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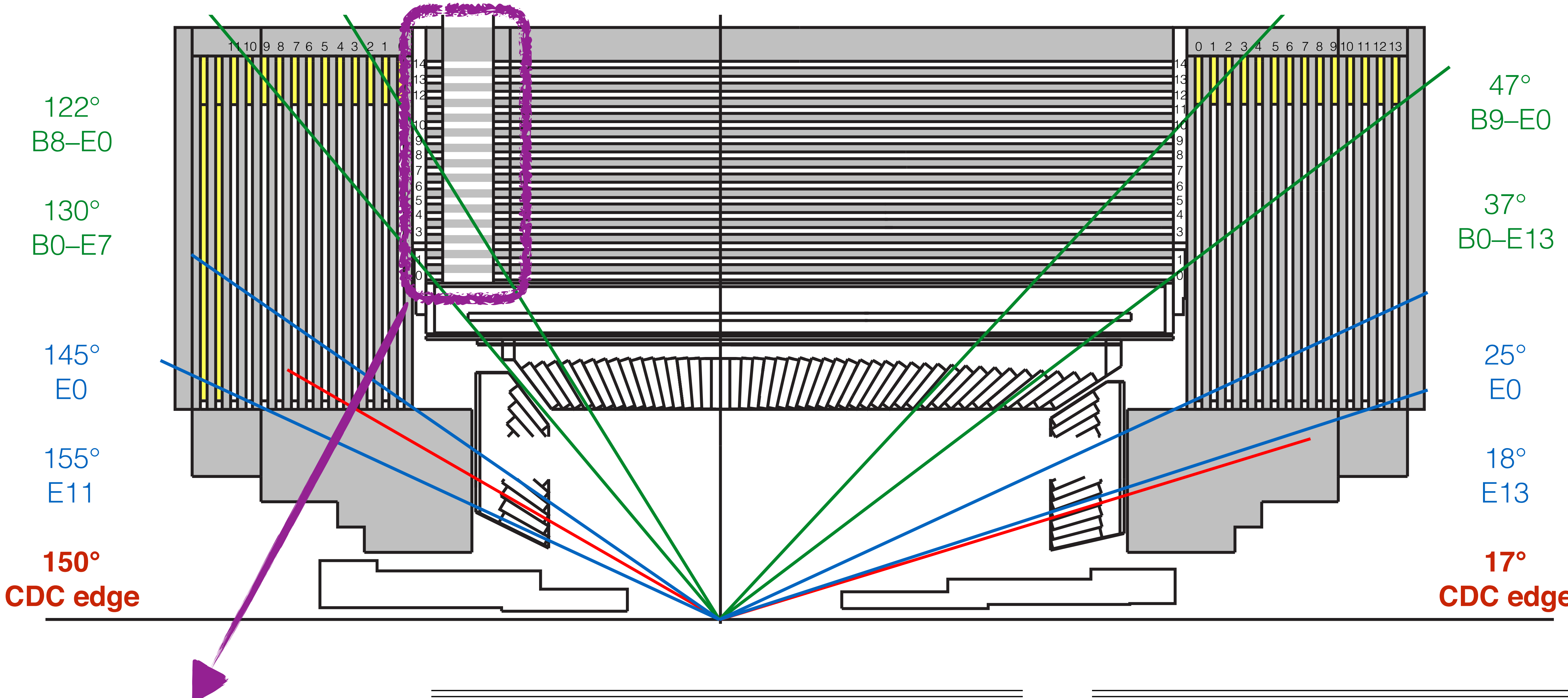

Solenoid chimney

↓

not instrumented area

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Belle II

μ and K_L difference (I)

KLM provides 3.9 hadronic interaction lengths of material, beyond the 0.8 interaction lengths of the calorimeter

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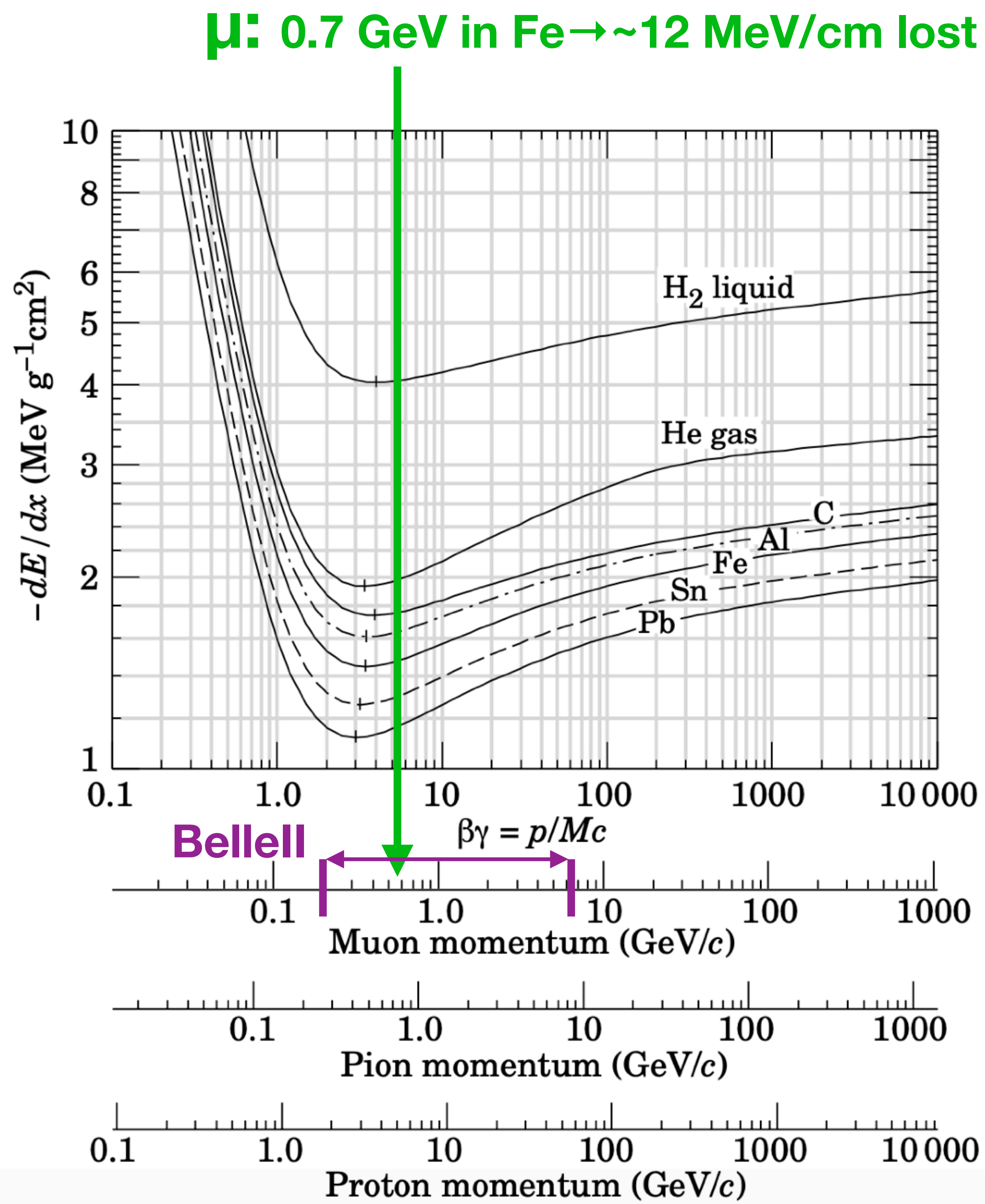
Muons characteristics:

Muons have a high penetration power (no hadronic interactions) → crossing lot of matter before being stopped.
Muons can reach the outermosts layers of KLM leaving a very contained interaction shower



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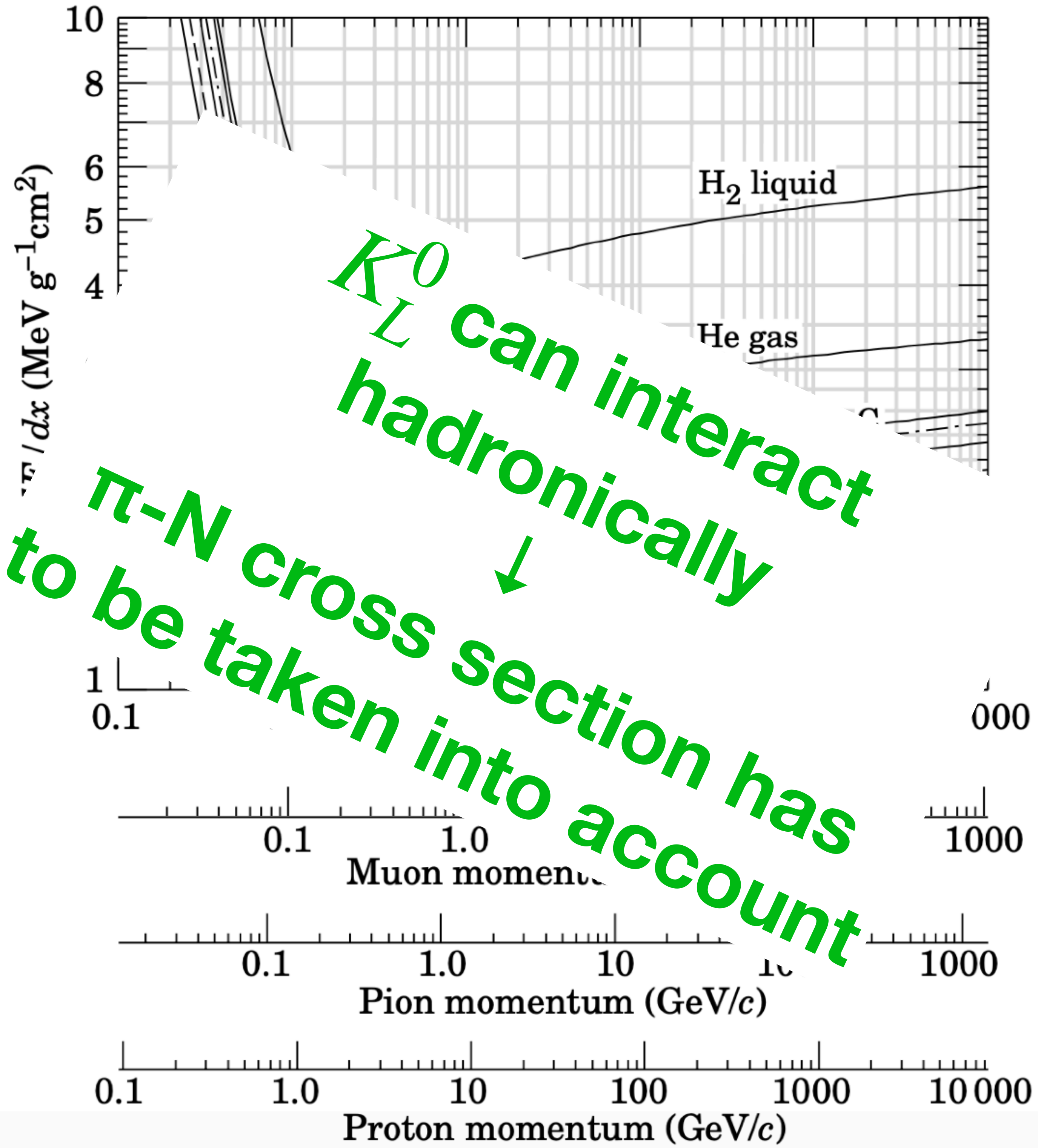
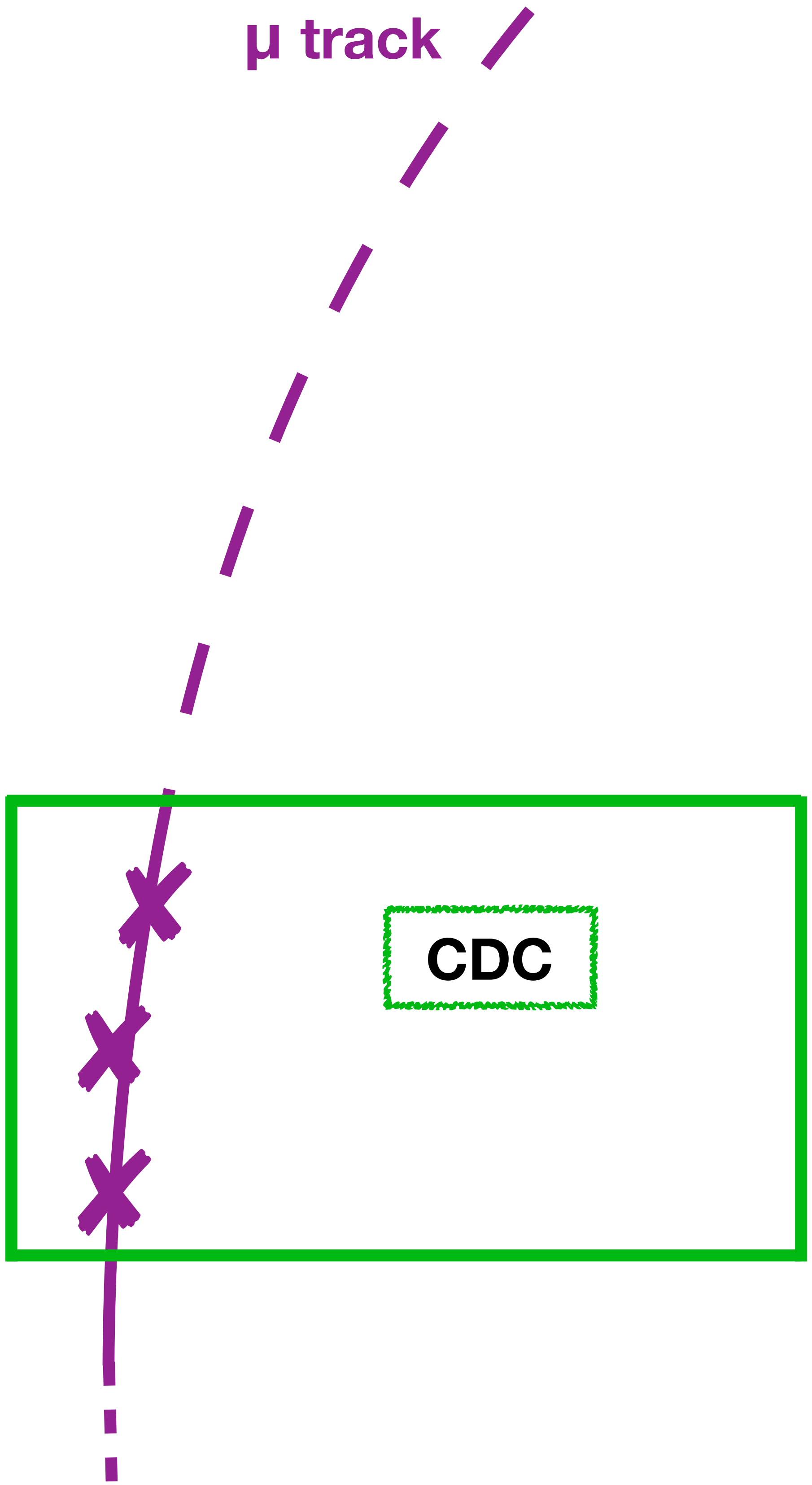
K_L^0 characteristics:

K_L^0 can hadronically interact in the KLM or the calorimeter → hadronic showers appear in the KLM → clear K_L^0 signature



K_L^0 can interact hadronically
↓
π-N cross section has to be taken into account

μ and K_L difference (II)



Muons

Geant4e is used to extrapolate tracks reconstructed from the inner detectors by the tracking software

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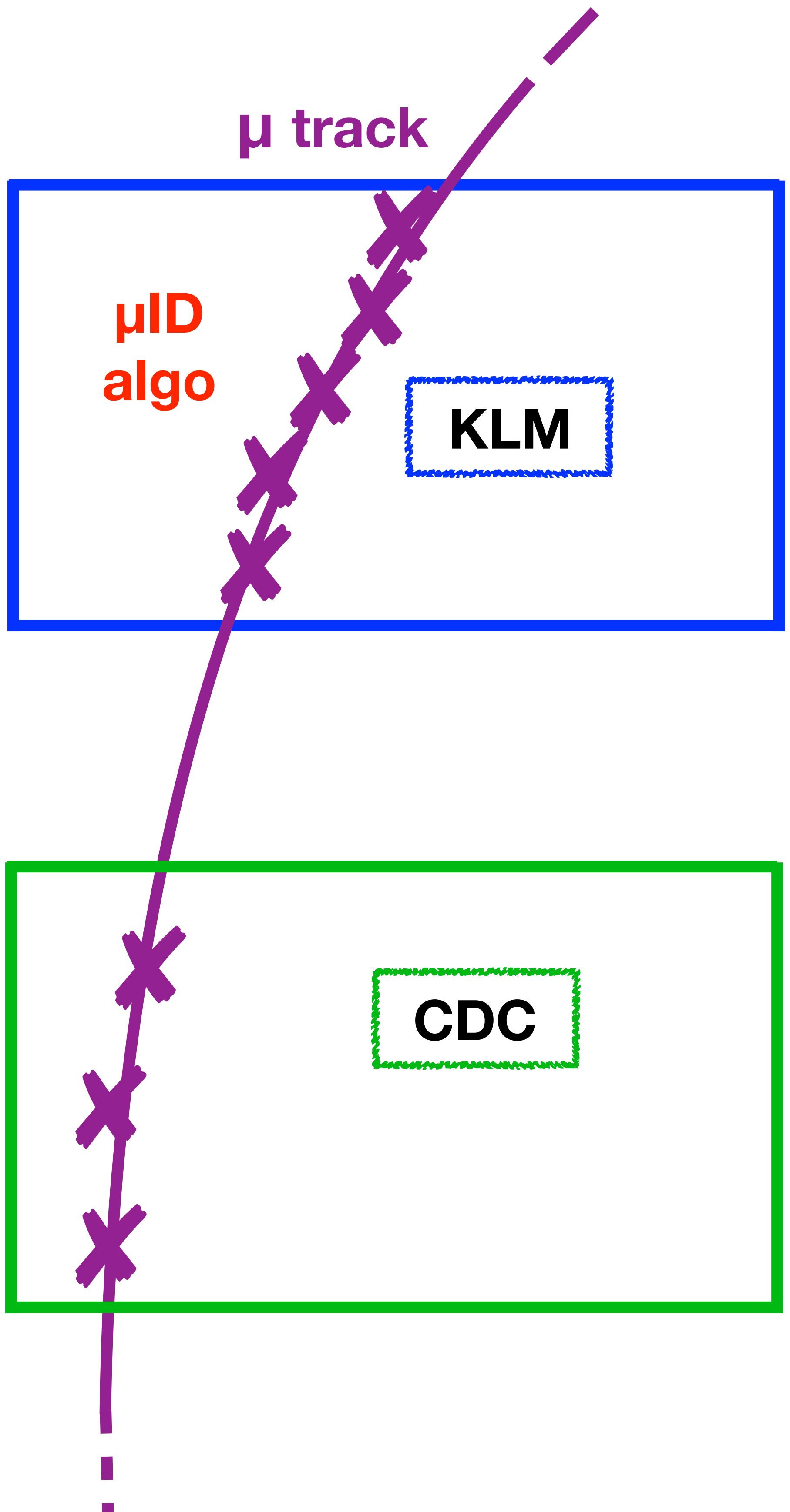

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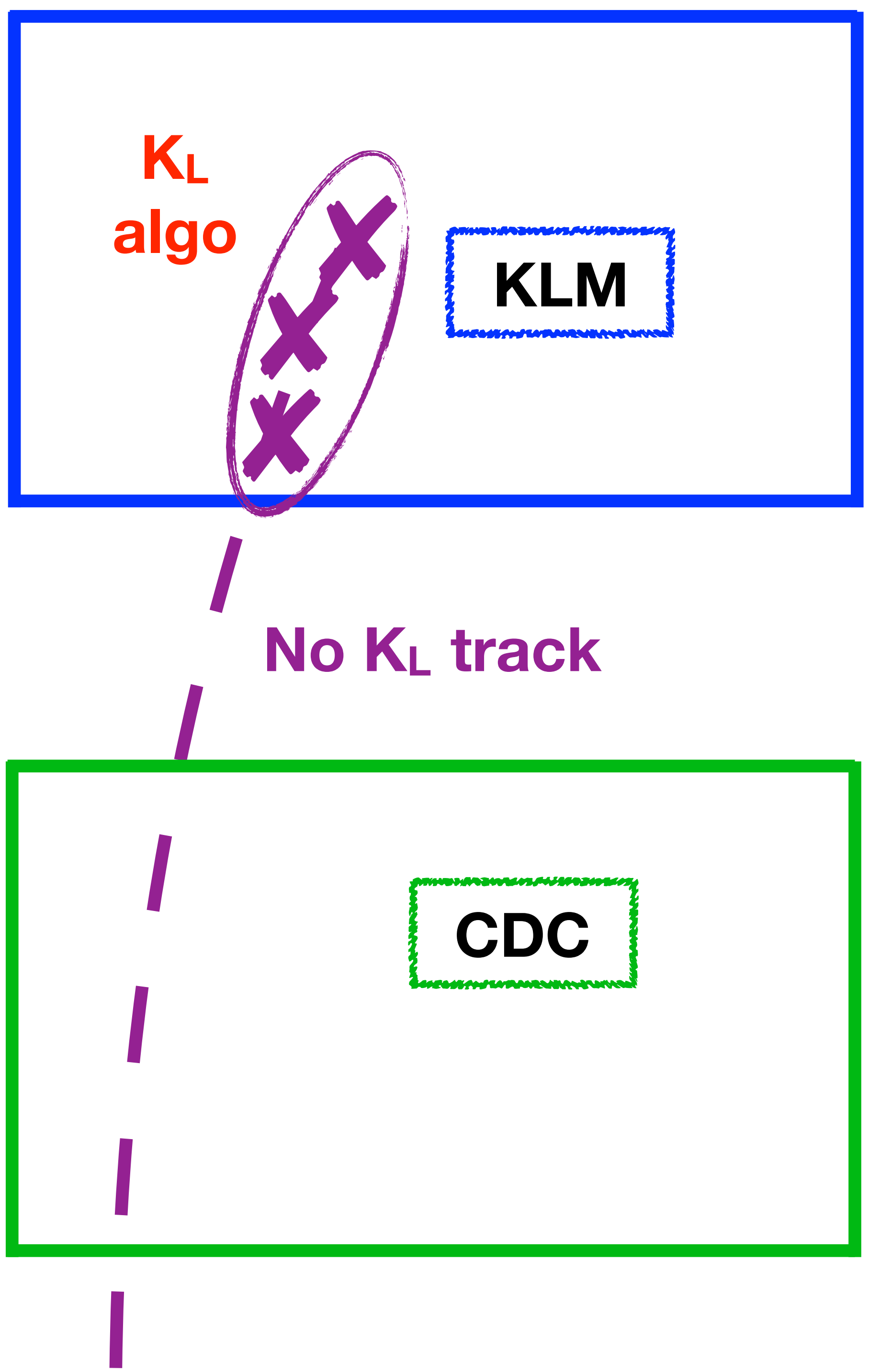

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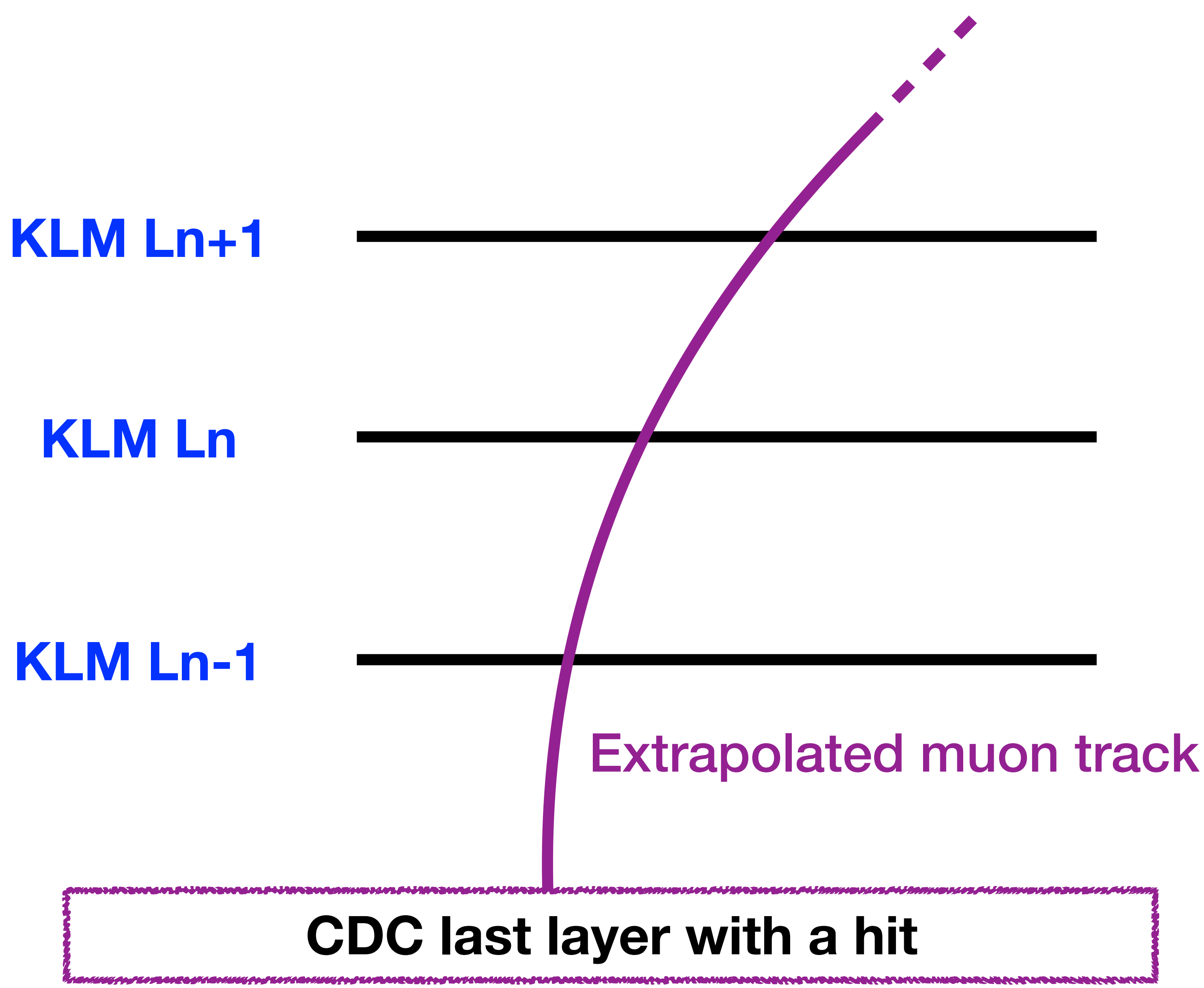
K_L

Reconstructed by looking at KLM signals only.
Usage of clusters (bunch of consequential layers)

μID algorithm: working principle

Algorithm steps:

- Track extrapolated from last CDC layer hit towards the KLM. **Always μ hypothesis**.



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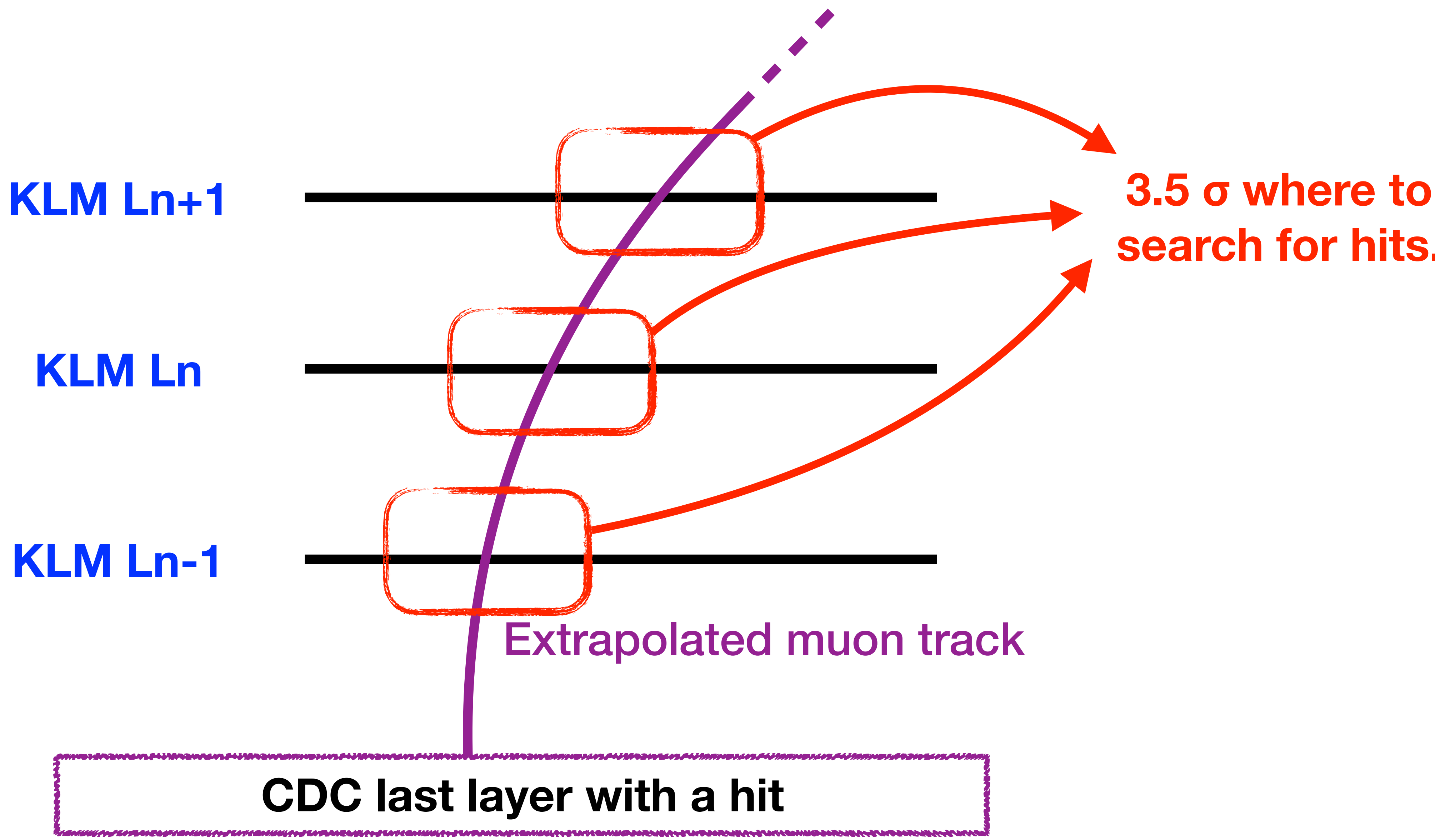

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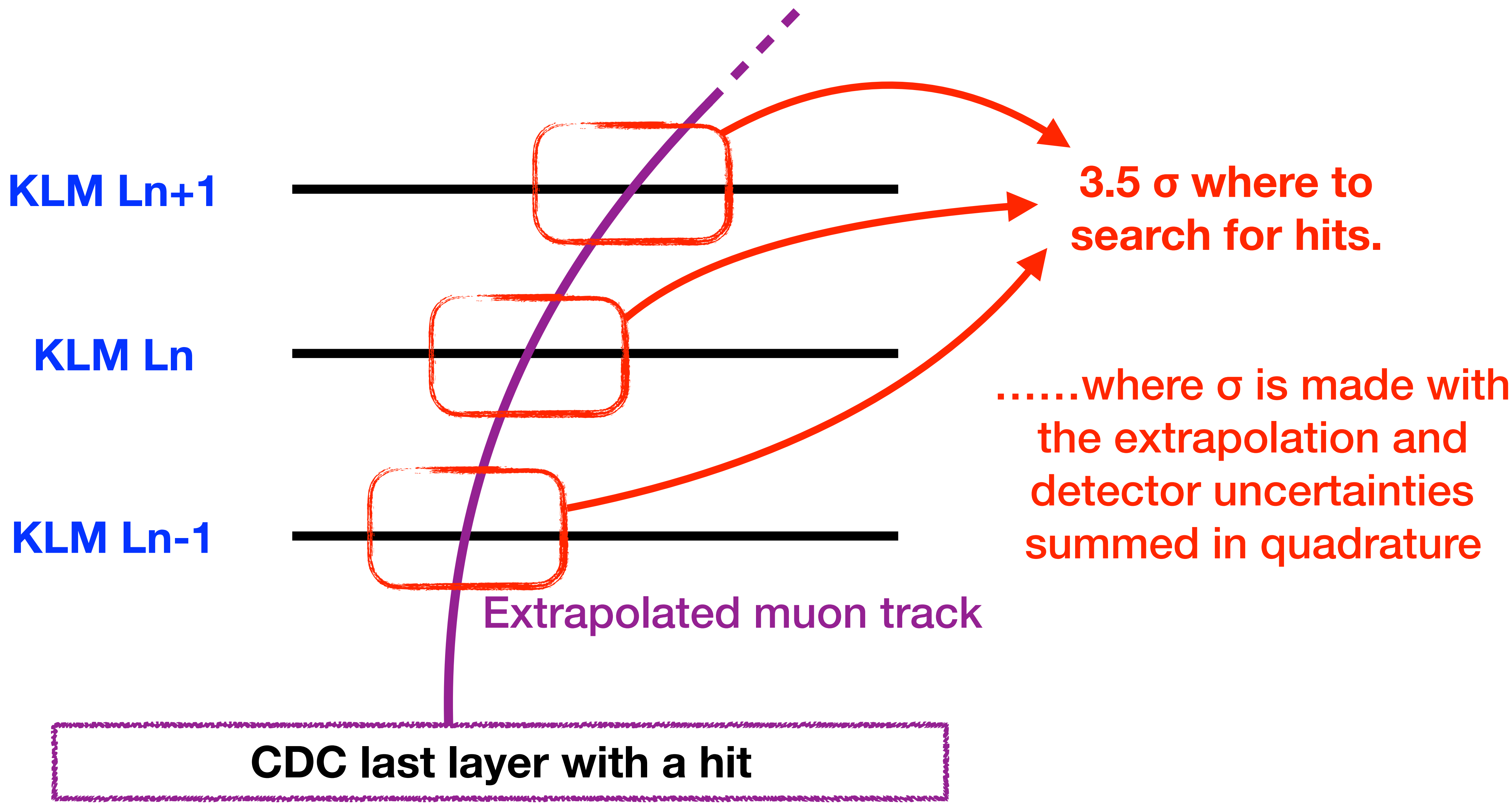
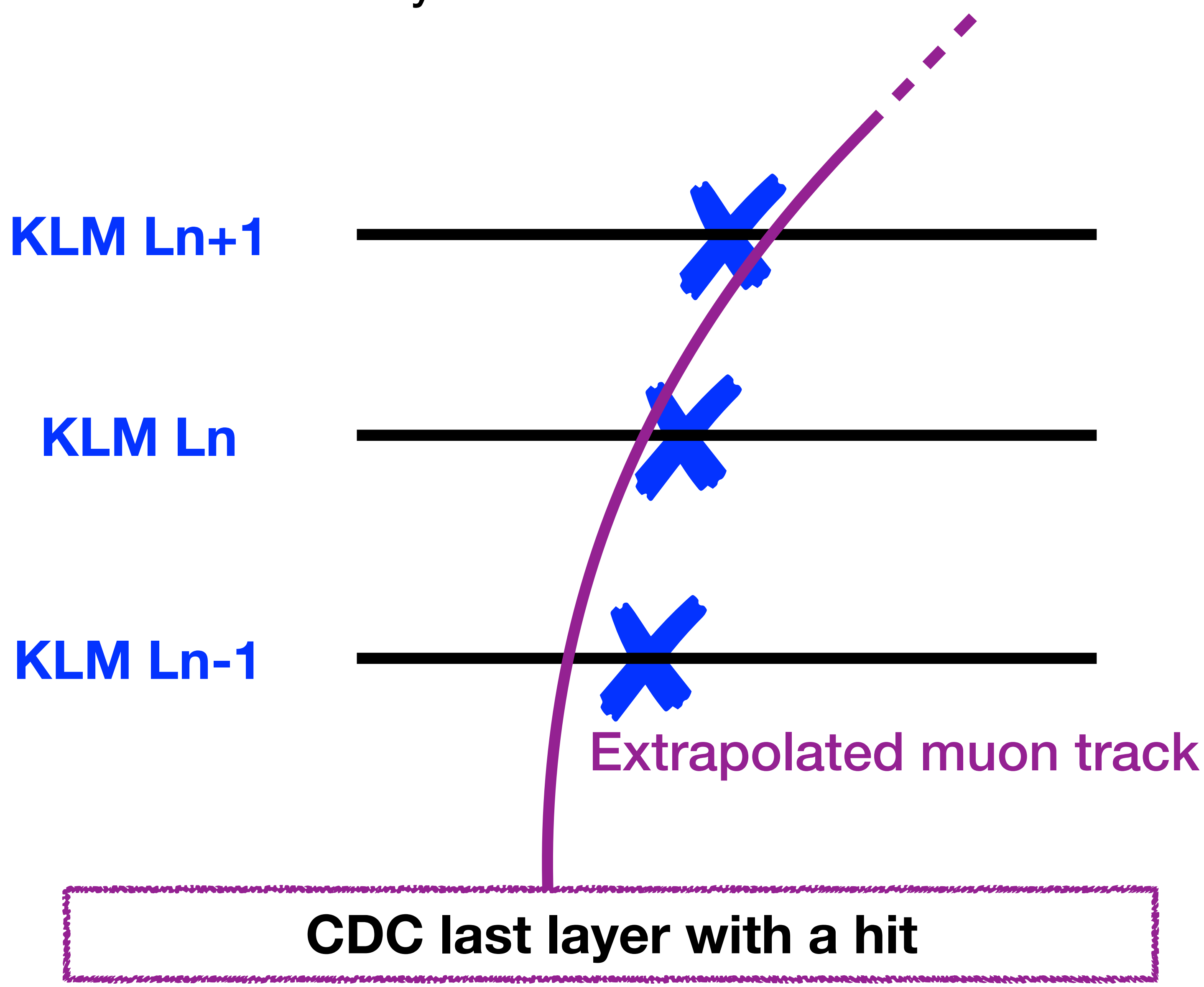


μID algorithm: working principle

Algorithm steps:

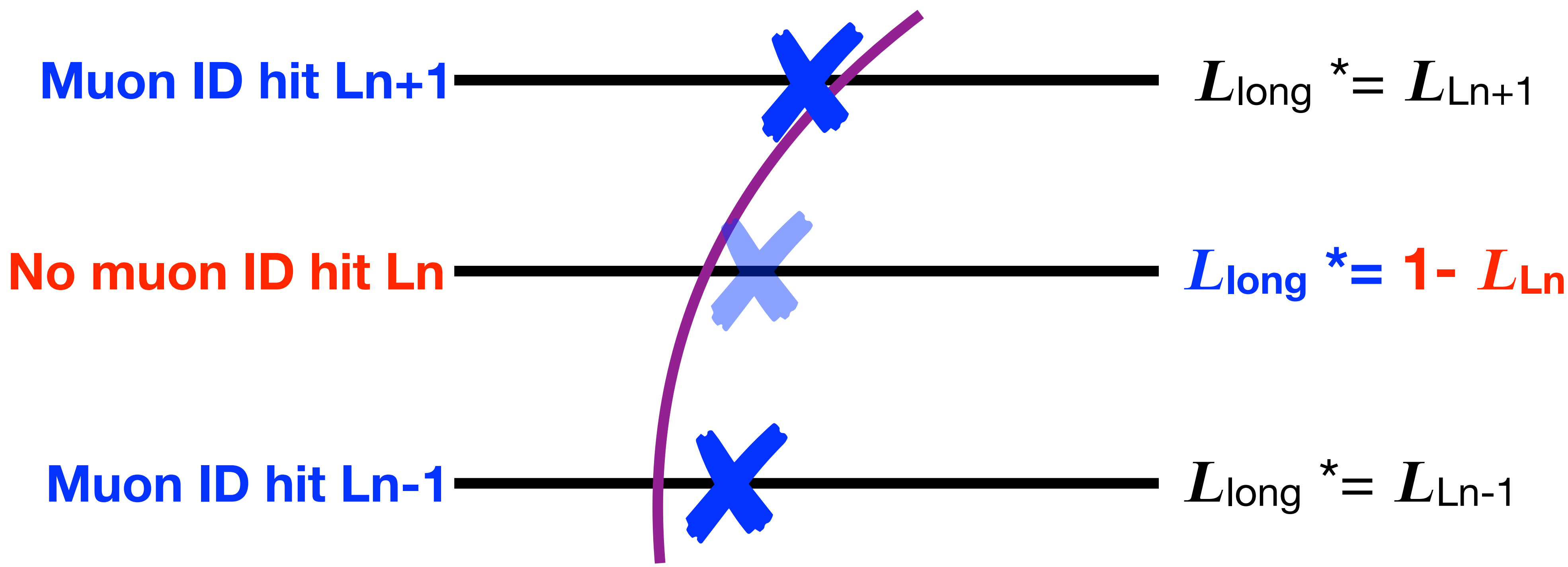
- Track extrapolated from last CDC layer hit towards the KLM. **Always *μ* hypothesis**.
- Check the presence of hits in KLM layers within 3.5σ from the extrapolated position.
- If there are hits in the KLM layers → the track is considered most likely as a muon.



µID probability calculation (I)

L_{Ln}= probability of having a hit in the Ln layer, for a particle hypothesis (MC pre-calculation)

$L_{long} = \prod_{n=1}^{n_{OuterExt}} L_{Ln}$ is the longitudinal probability of a track to be the hypothesised particle.



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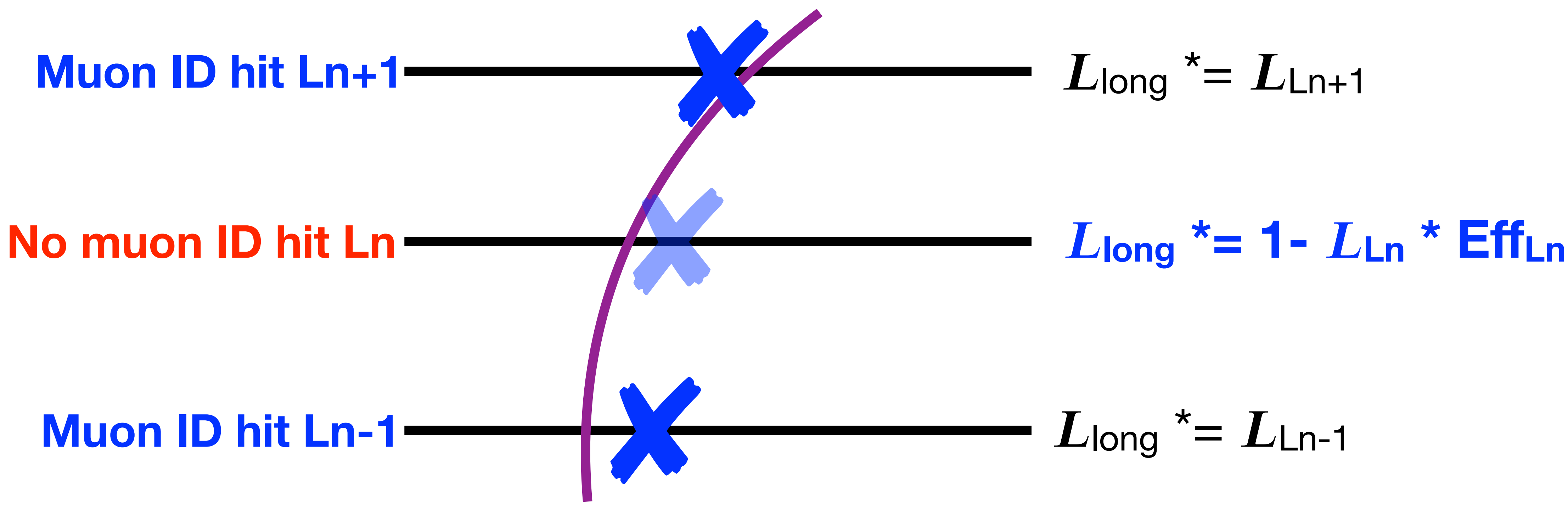
In order to correctly treat inefficient layers, if there are no hits in the layer → take into account efficiencies and store: $1 - L_{Ln} * Eff_{Ln}$



Algorithm is corrected for _both_ BKLM and EKLM since release 4

μID probability calculation (II)

Following the same layer per layer logic the $L_{\chi 2}$ **probability** is also defined and it **depends** on **how much broad the hit pattern** made by the tracks is (due to **transverse shower effects**)

The μ hypothesis follows the reduced χ2 distribution.

$$L_{tot} = L_{long} \cdot L_{\chi 2}$$

$L_{\chi 2}$ has significantly less discrimination power of L defined in the previous slide

μID problems

The most relevant issues with the algorithm are:

- Very similar behaviour from other particles (mostly pions). μ-π discrimination can be done almost completely by the KLM.

The interaction length λ_I for a pion of p∼few GeV is:

$$\lambda_I = \frac{A}{\sigma N_A \rho} \simeq \textbf{17 cm in iron}$$

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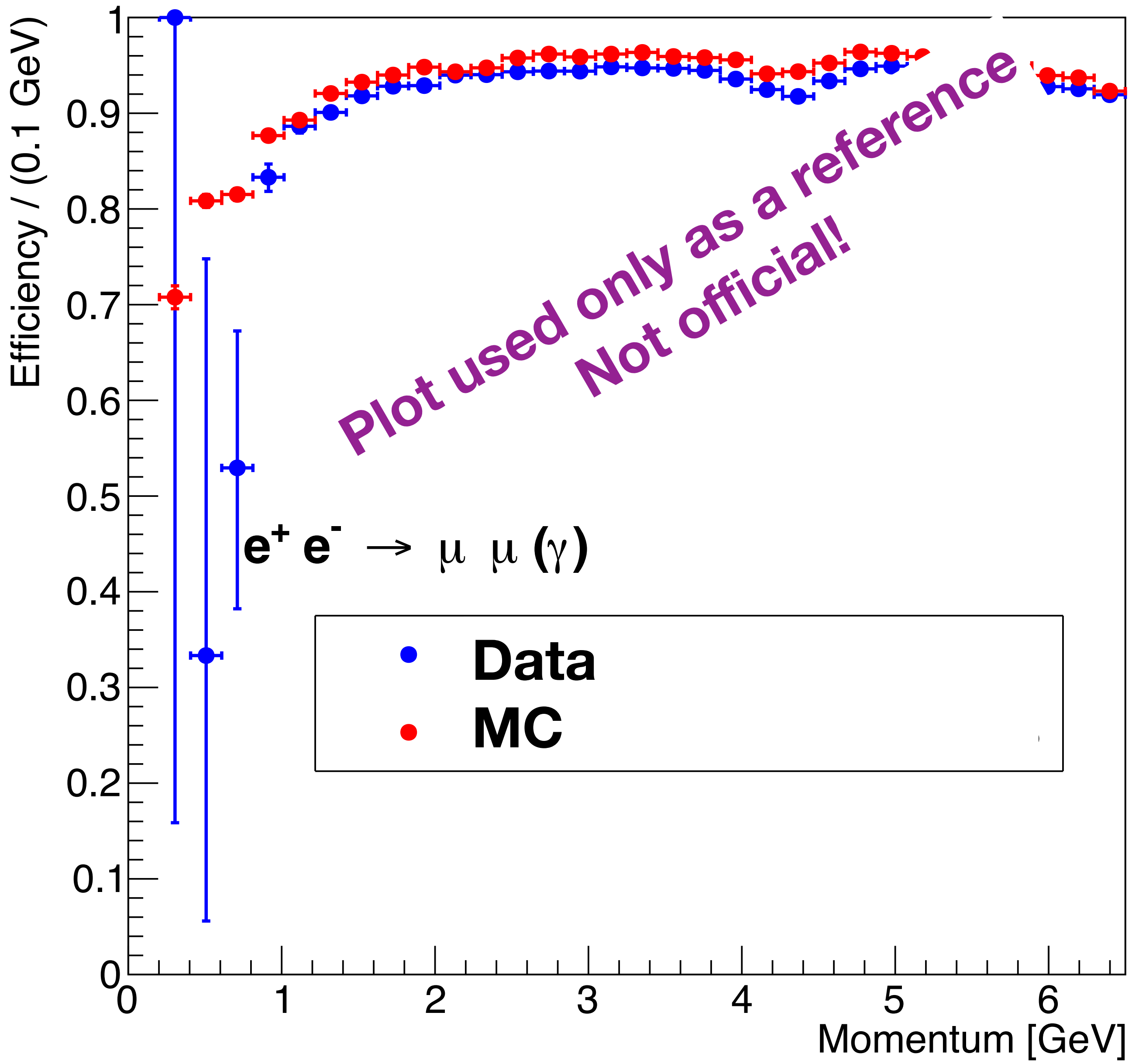
Recoverable issues:

- Not instrumented regions;
- KLM inefficiencies;

Direct implication on pion fake rate → not having some hits allows the algorithm to identify tracks more likely as hadrons

μID performances

μ ID eff VS μ momentum



μID performances depend a lot on the momentum of the tracks:

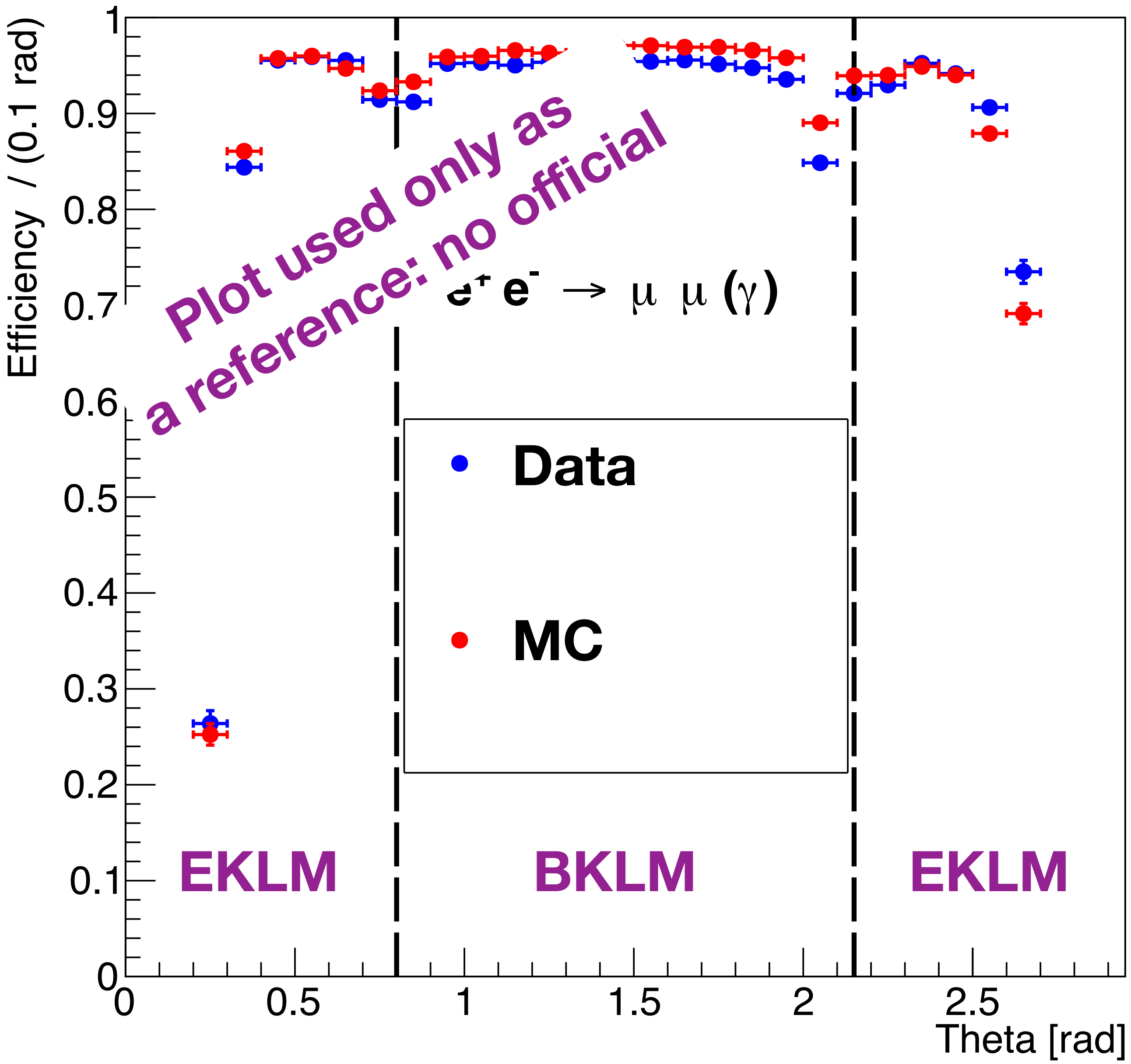
Once μ reaches KLM performances are good

Remember μ energy looses from the first slides…

0.7 GeV is the minimum momentum to reach KLM

μID performances

μ ID eff VS μ theta



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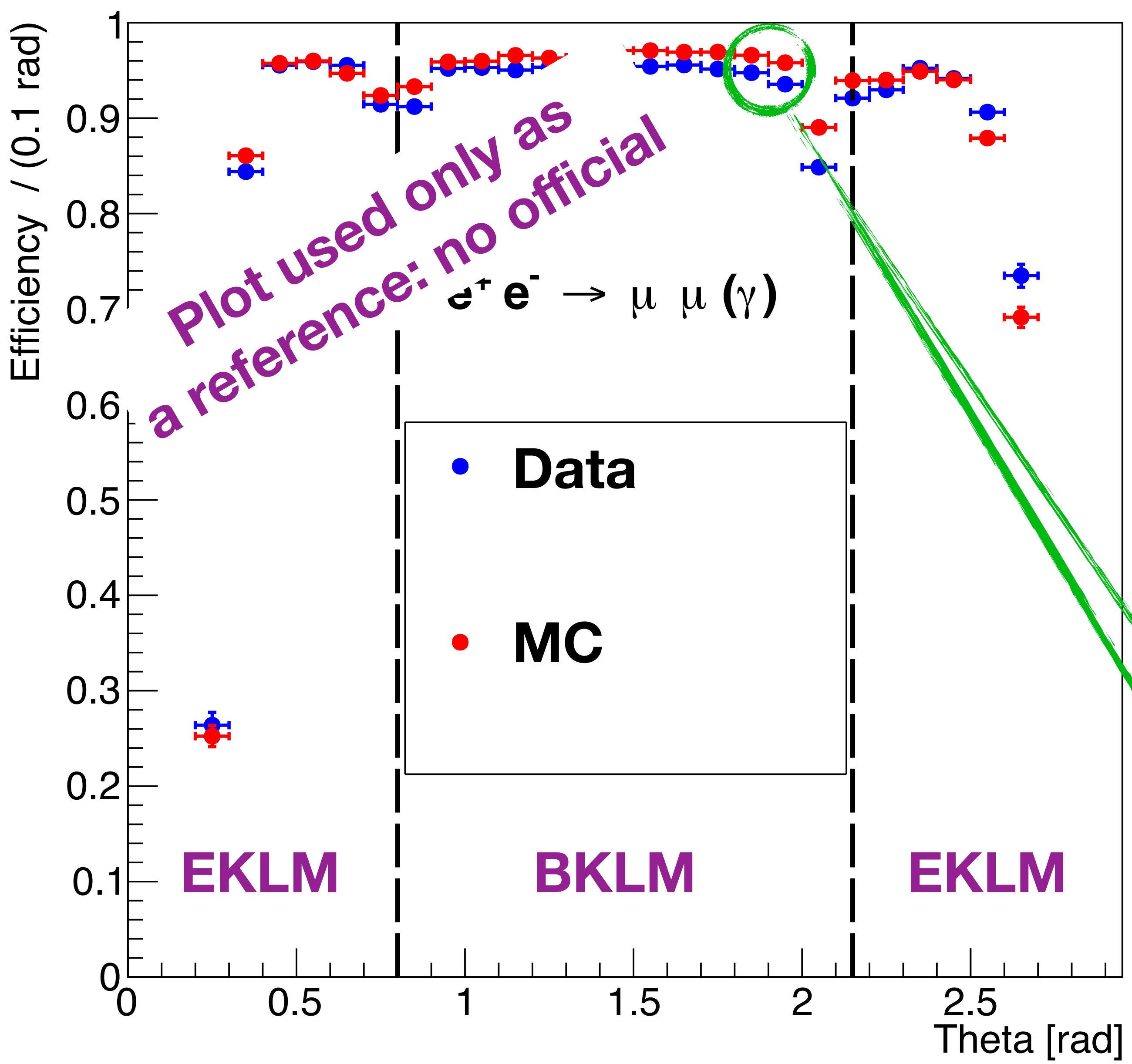
If μ pass through instrumented part of the detector → performances are good

Between BKLM and EKLM there is a small no instrumented area…

μID performances

μ ID eff VS μ theta



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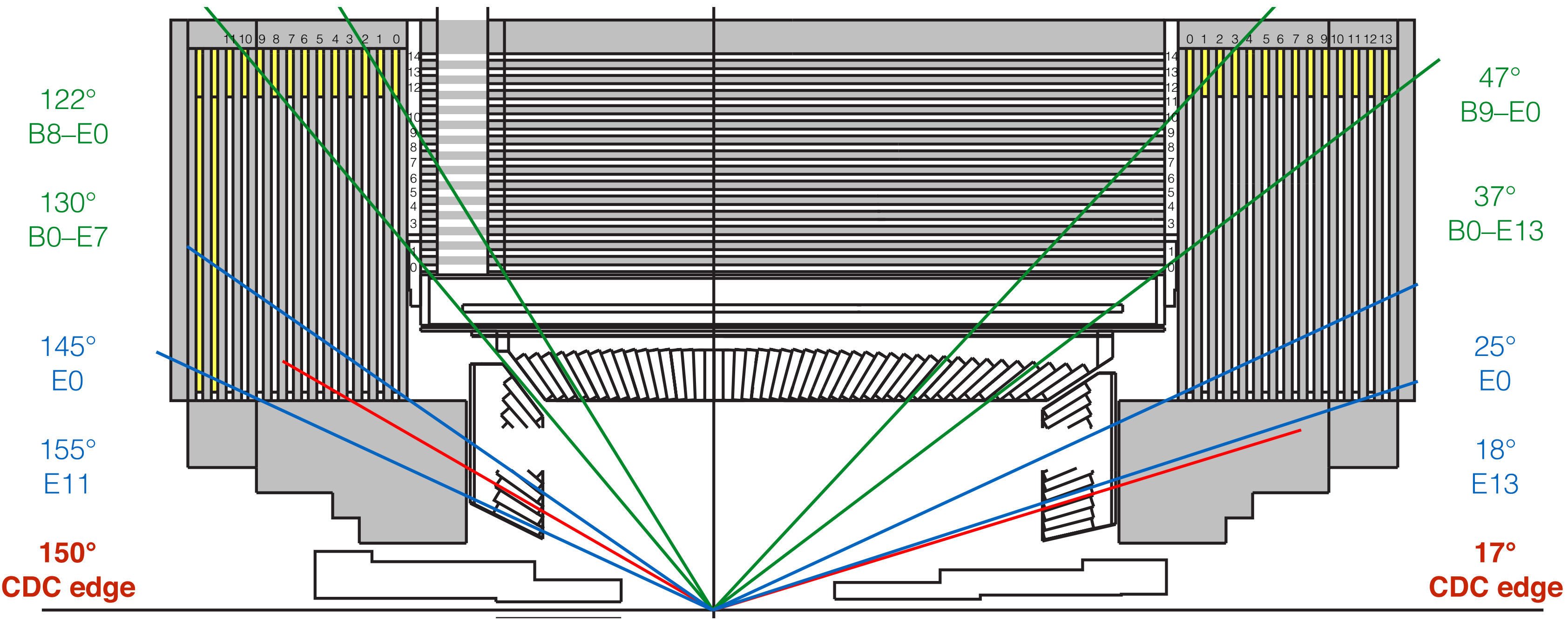
remember the chimney?

KLM and μID acceptance



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μID behaviour based on data performances:

μID momentum behaviour:

- P<0.7GeV μ do not reach KLM
- 0.7 GeV < P < 1 GeV μ reach KLM but no much info
- P > 1 GeV μ reach KLM and most of them exit it.

μID θ acceptance:

EKLM- backward: 131°-142°
BKLM: 40°-51° - 115°-131°
EKLM-forward: 24° - 40°

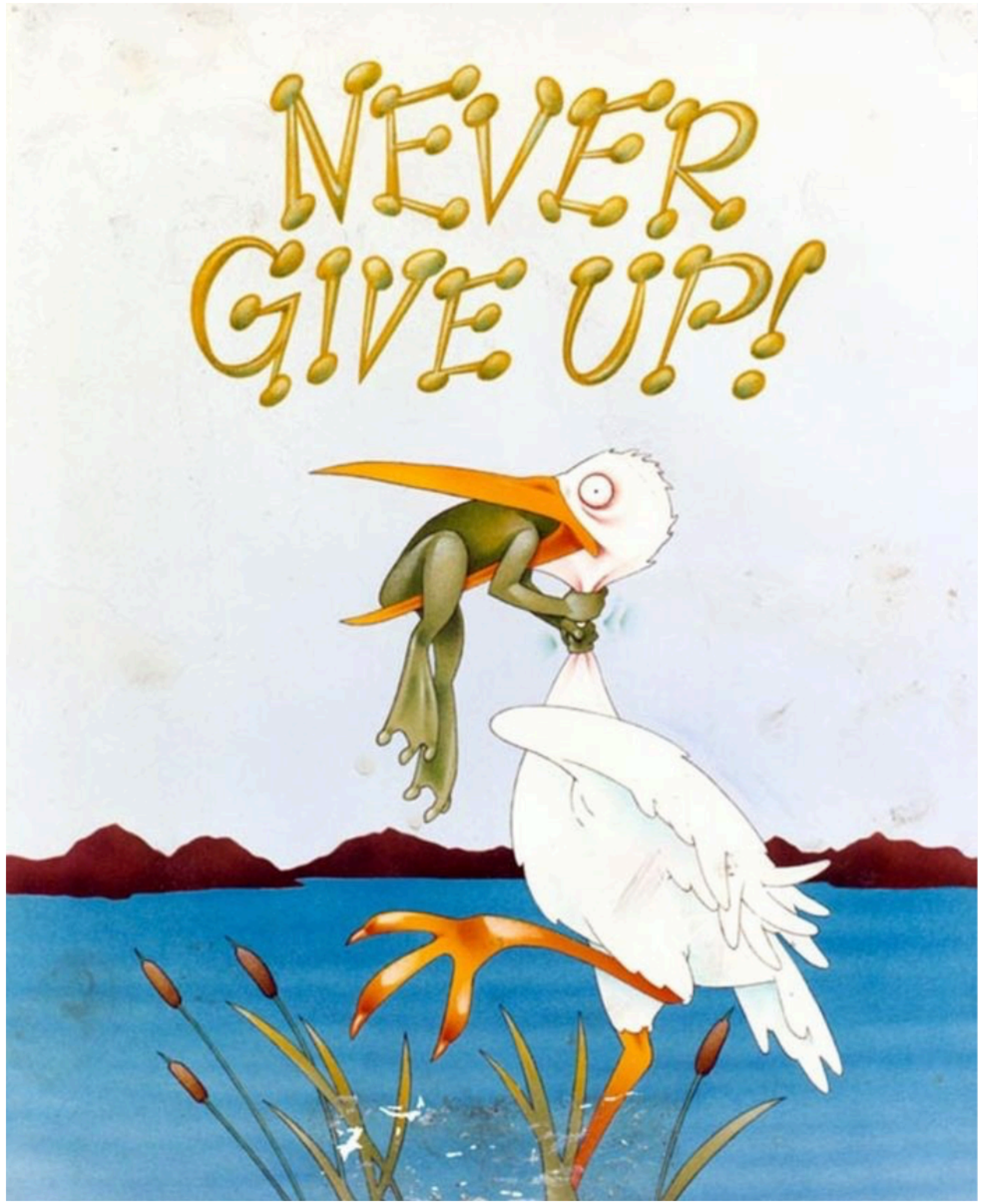
Summary and μID references

- **KLM subdetector is made of layer of Resistive Place Chambers, scintillators (active volumes) and iron (absorber) → Aim: identify long lived particles: K_L^0 and *μ***

- ***μ* identification algorithm working principle is based on the penetration power of muons in the material and *now* it takes into account KLM efficiencies.**
- **K_L^0 identification algorithm is not yet in a good shape: work is ongoing**

- ***μ* identification performances are giving good results and additional work is going on:**
  - Fine tuning of the algorithm and debug (if necessary) [**A. Martini**]
  - Performances in different channels: J/Ψ decay, μμ(**γ**) and 4l events and more to come [**all interested people**, so far: **Yo Sato, A. Martini, M. Milesi**]
  - Performance comparison with different approaches, like MVA [**M. Milesi, Jo Yamanouchi**]
  - π fake-rate study using different channels: J/Ψ K_S [**D. Ferlewicz, M. Milesi, A. Martini**], τ → 3π (**P. Feichtinger, N. Molina, A. Martini**), D* → D π (**all interested people**, so far **S. Sandilya, J. Strube**)
  - Data analysis results/official plots on J/Ψ [**G. De Pietro, D. Farlewicz, Yosuke Yusa, M. Milesi**], on 4l [**Yo Sato, Akimasa Ishikawa**]

Emergency slides!!



RPC strips detail

layer	phi strips	z strips
1	37	54 (*38)
2	42	54 (*38)
3	36	48 (*34)
4	36	48 (*34)
5	36	48 (*34)
6	36	48 (*34)
7	48	48 (*34)
8	48	48 (*34)
9	48	48 (*34)
10	48	48 (*34)
11	48	48 (*34)
12	48	48 (*34)
13	48	48 (*34)
14	48	48 (*34)
15	48	48 (*34)

* backward, sector#3, z strips are fewer, due to the chimney