

KLM Status

R. de Sangro
per il gruppo KLM - Frascati & Roma Tre
Belle II Referee Meeting
8 Settembre, 2021

Outline

- KLM Operations in runs 2021a,b
- Neutron backgrounds
- Summer work
 - DAQ upgrade
 - Digitization Look-back window study
 - New SCROD firmware for EC/Barrel Scintillators
- Attività italiane in corso
- KLM Upgrade

KLM 2020c-2021ab DAQ Operations

- KLM DAQ notably more robust
- KLM errors were significantly reduced

Full summary of KLM DAQ errors in run 2021a and 2021b

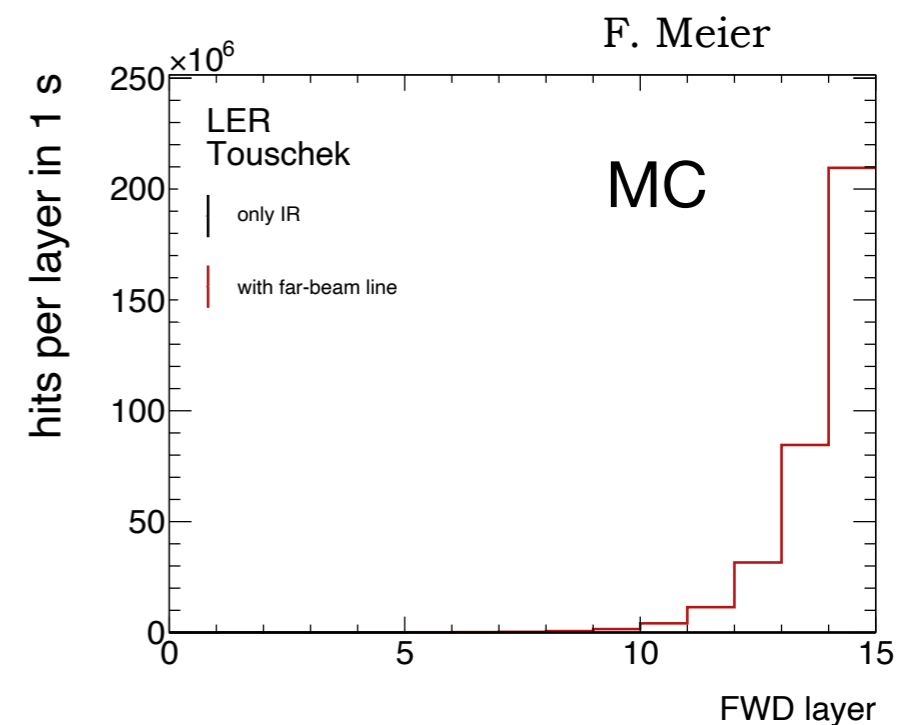
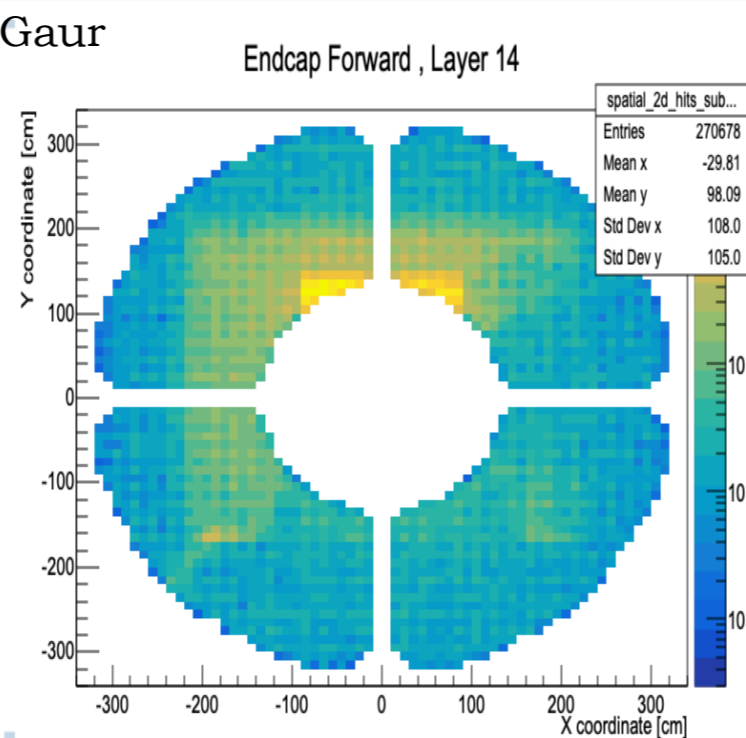
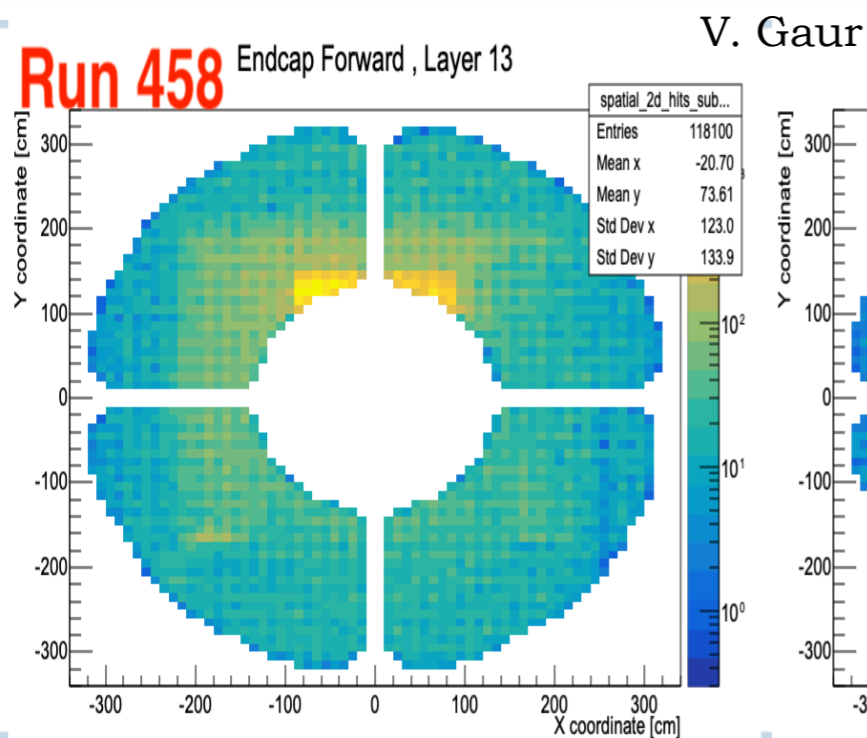
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June 13	ttlost	FTSW 170
June 15	ttlost	FTSW 170

February 11	COPPER 7001	<ul style="list-style-type: none"> • New SLC script had a glitch • Used older one ~/bin/bootslc_ropc_cpr_klm.sh
March 11	COPPER 7001	<ul style="list-style-type: none"> • CPU daughter card replaced
March 14	COPPER 8004	<ul style="list-style-type: none"> • cprcontrol process crashed due to an out-of-memory error • Due to memory leak during NSM data allocation • Fixed on maintenance day
April 15	COPPER 7001	Data corruption
April 15	COPPER 7002	Data corruption
April 18	COPPER 7002	Data corruption
May 10	COPPER 7002	Data corruption
May 23	COPPER 7004	Data corruption
May 25	COPPER 7002	Data corruption
June 2	COPPER 7004	Data corruption
June 4	COPPER 7002	Data corruption

- Need to fix FTSW 170 during summer
- Copper 7002 may need daughterboard replacement

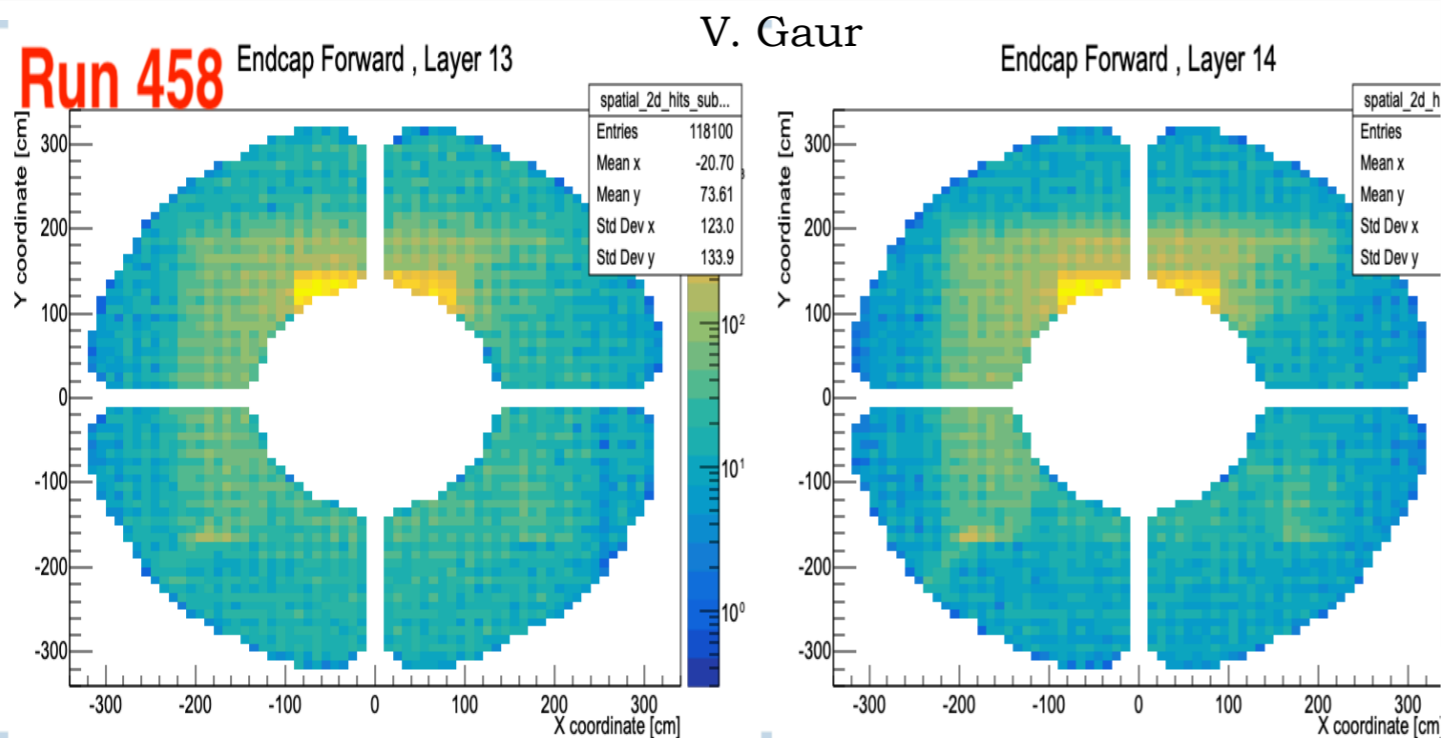
Neutron Backgrounds

- Observed high rate in the last two layers of scintillators in the FWD EndCaps
- According to MC this is due to neutrons related to (mostly) Touschek background in the LER



Neutron Back

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PE wall in KEKB tunnel



Figure 10.11: Polyethylene shield.



Figure 10.12: Tapered shield.

PE at QCS

- Study possible shielding to be installed during LS1 (2022)

KLM Summer 2021 Work

KLM: 2021 summer-shutdown work plan

- ✓ PCIe40 testing (TOP+KLM) by DAQ group during most of summer shutdown

indico.belle2.org/event/4490/contributions/23352/

- ✓ Slow-control GUI finalization to prepare for PCIe40 DAQ in 2021c

indico.belle2.org/event/4490/contributions/23353/

- ✓ Measure signal quality on the TTD line for recently problematic FTSW 170 → replace the cable or the unit

indico.belle2.org/event/4490/contributions/23351/

- ✓ Opportunistic testing (*coordinated with DAQ group*) of scint-readout firmware updates for feature extraction (better time resolution + pulse-height measurement) and of KLM-trigger firmware updates (cross-sector, back-to-back definition, ...)

indico.belle2.org/event/4490/contributions/23349/

KLM TTD tree:

FTSW191(master-KLM)

- ↳ FTSW229(BKLM-ehut) → FTSW162-165
- ↳ FTSW230(BKLM-ehut) → FTSW166-169
- ↳ FTSW204(EKLM-ehut)
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FTSW170 was fine

⇒ replace TTRX cards on Copper and CAT cables

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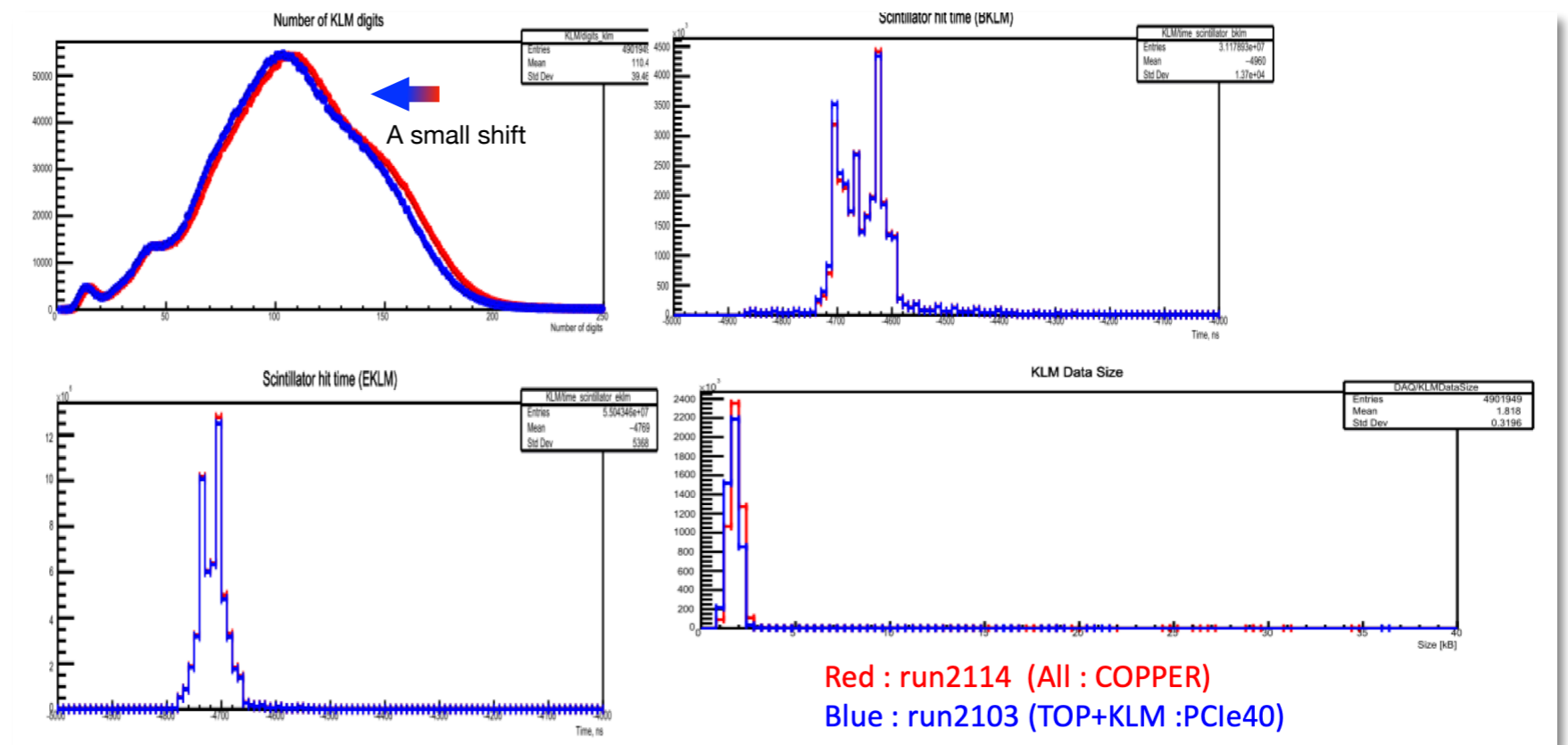
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Ongoing

KLM DAQ Upgrade to PCIe40

- Preliminary tests were performed during run 2021ab
- Will migrate to the new DAQ for run 2021c, if all tests OK



Present status:

- Commissioning of full KLM+TOP in August is ongoing
 - Long (~19hrs) run times achieved at 30 kHz DAQ rate
 - Still some (quite rare) problems (persistent BUSY) to be understood
- BKLM fully operational while connected to PCIe40

KLM DAQ Upgrade to PCIe40

New PCIe40 based KLM GUI basically finished, under extensive test

The screenshot displays the KLM DAQ GUI with several key sections:

- RC tested:**
 - KLM FEE not configured by GUI
- Mask/unmask scheme:**
 - Check / uncheck
 - Load (active mask/unmask)
- TTD clock status** and **TTD link status** (indicated by arrows pointing to the TTD status area).
- DMA RUNNING**, **DMA FIFO**, and **DMA transmit data size** (indicated by arrows pointing to the DMA status area).
- RC_RKLM** section: Run # 1627, READY status, buttons for START, ABORT, BOOT, and a Disconnect button.
- FTSW #191** section: ERROR status, resettt and stattd buttons, Trigger type (AUX), Run start at 2021-05-26 16:30:51, Trigger limit (-1), Run time (32[sec]), Dummy rate (3000 [Hz]), Trigger In (0.0 [Hz]), Max time (44999[us]), Trigger out (0.0 [Hz]), Max trig (1), Input count (0), Output count (0).
- STORE_KLM** section: NOTREADY status, Run type (kim), eb2rx input, Event rate (kHz) (0), Event size (kB) (0), Event counter (0), Flow rate (MB/s) (0), File size (MB) (0), # of files (0).
- Hostname** table:

Hostname	READY	Label	TTD	DMA	DMA [kBytes]	Size [Bytes]	Rate [MB/s]
rk1m1	READY				0	0	0.00
1-4					0	0	0
5-8					0	0	0
9-12					0	0	0
13-16					0	0	0
17-20					0	0	0
21-24					0	0	0
25-28					0	0	0
29-32					0	0	0
- RKLM** section: Run # 1627, READY status, buttons for START, ABORT, BOOT.
- Dummy Boxes not Currently used** section: OK button, Configuration (dropdown), SCINT Threshold (input field).

Annotations and additional notes:

- RC_HLT_KLM is also added for local KLM operations
- Additionally if possible, perhaps having a button on the local RC GUI to re-program SCRODs and DCs could also be nice

Present status:

- KLM local run GUI was tested with 50% of KLM FEEs.
 - 18 hours run at 10kHz, with no troubles.
- Global run GUI also tested with KLM only
 - 9 hours at 30kHz input rate and it was also fine.

KLM Summer 2021 Work

KLM: 2021 summer-shutdown work plan, cont'd

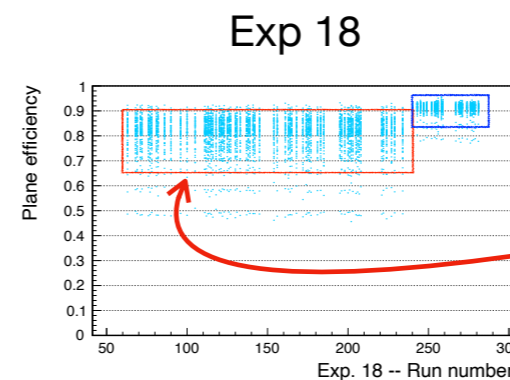
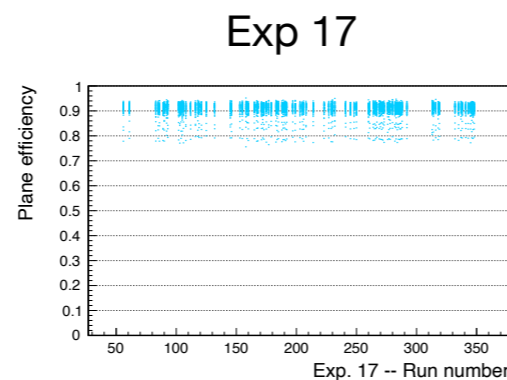
✓ Updates of DQM to

- provide real-time efficiency measurements

indico.belle2.org/event/4490/contributions/23352/ slide 13

Ongoing

Barrel
Scints



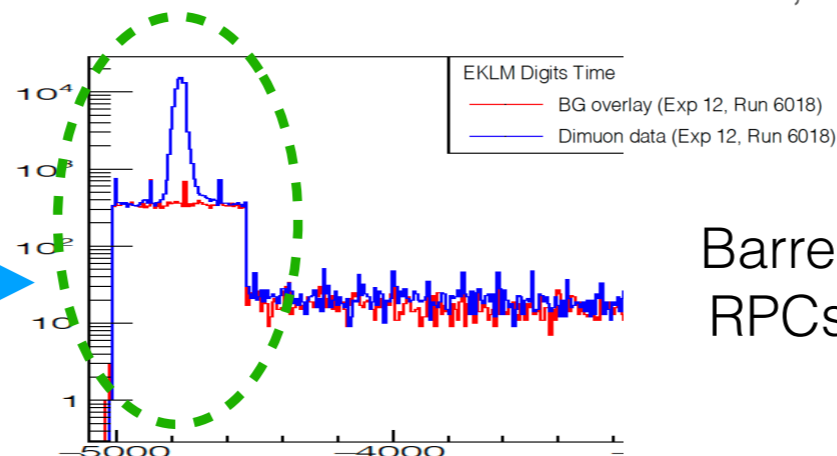
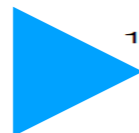
~one-week shift due to unintended
(and unnoticed!) misconfiguration
of scint-readout parameters

- monitor location of in-time peak relative to digitization window

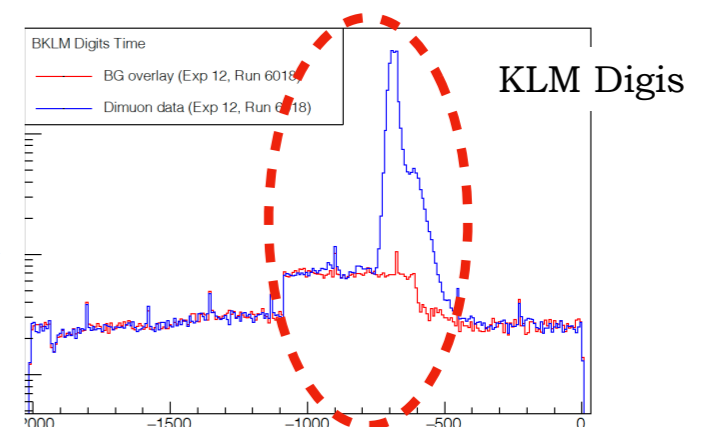
indico.belle2.org/event/4490/contributions/23356/ slides 11, 14

Done!

Endcap
Scints



Barrel
RPCs



- implement best practices of other groups (especially ECL) for more user-friendly presentation and programmatic alerts

indico.belle2.org/event/4490/contributions/21569/

KLM Summer 2021 Work

KLM: 2021 summer-shutdown work plan, cont'd

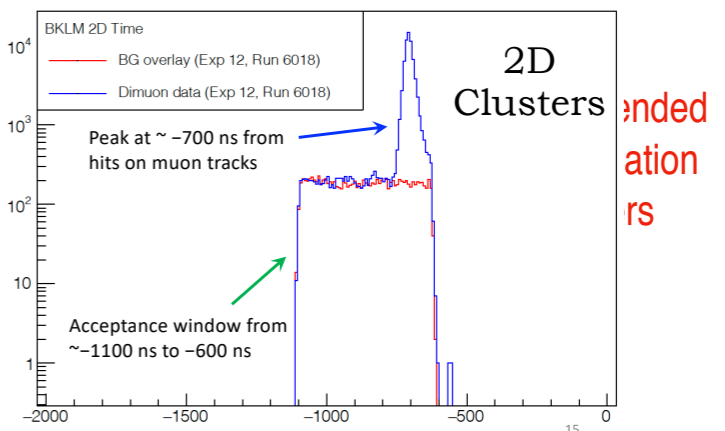
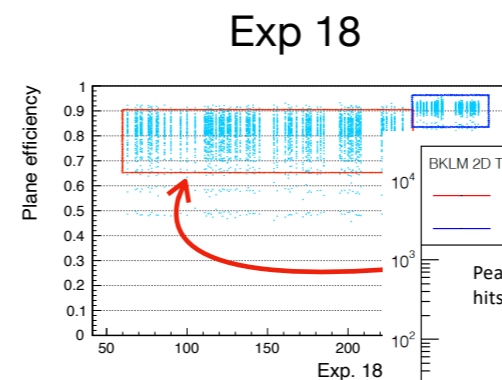
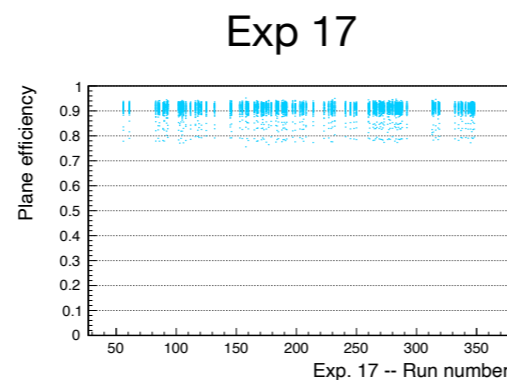
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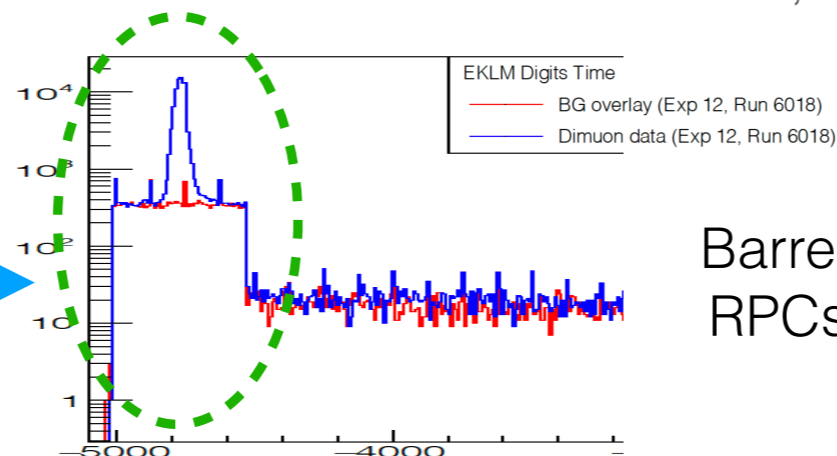
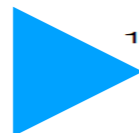


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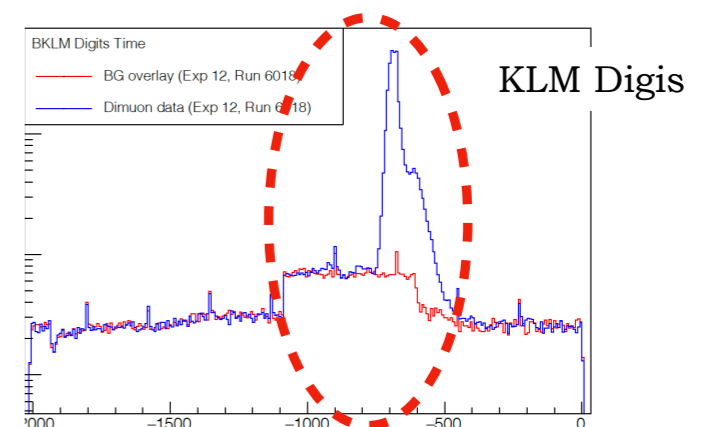
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Barrel
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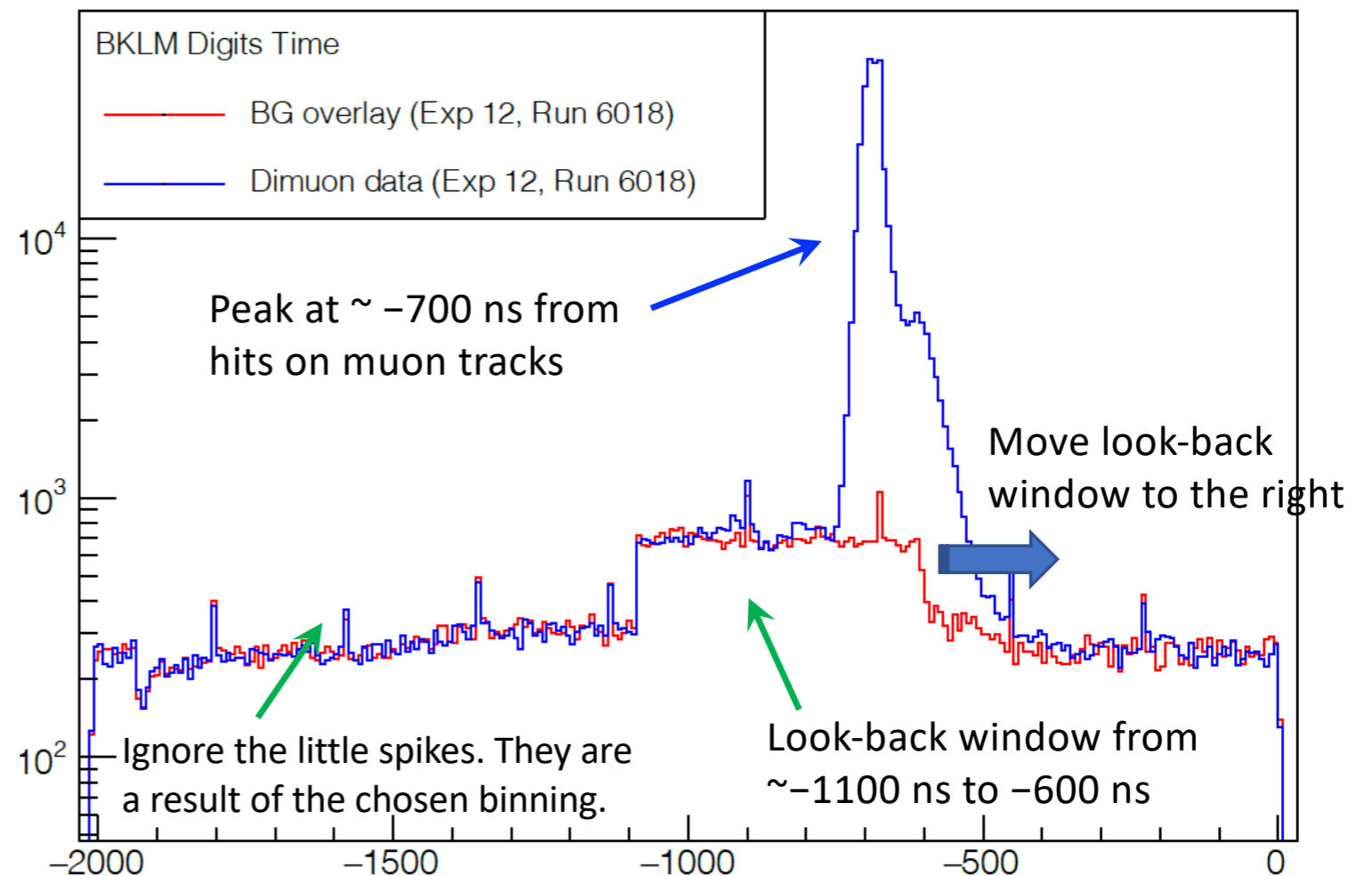
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Digitization Look-Back Window

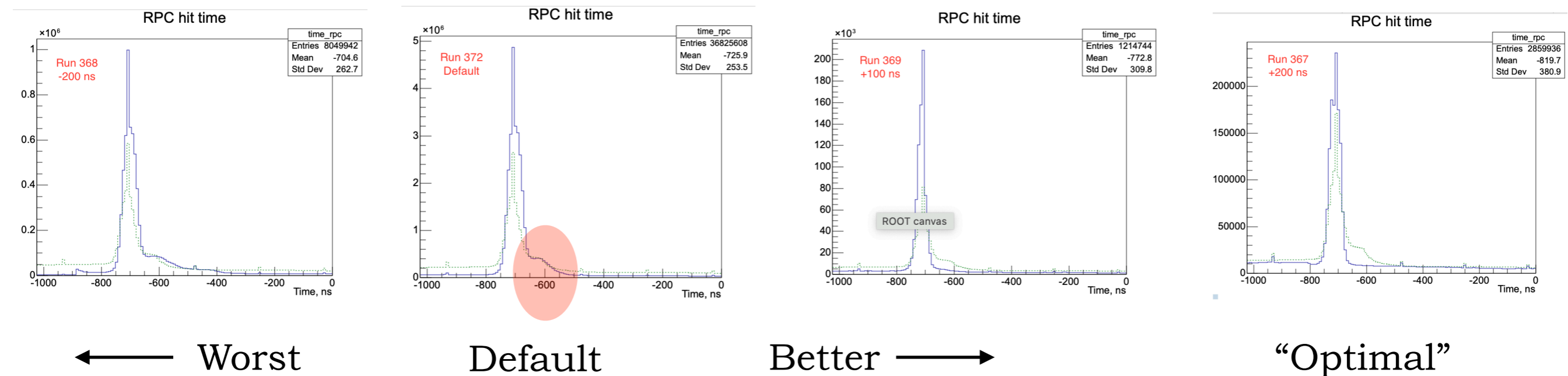
Reason for moving RPC look-back window: digit times

- Signal hits (muons) peak at -700 ns across the upper edge of look-back window from -1100 ns to -600 ns
- Background hits have a flat distribution in the window
- Separate issue: background hits also occur outside the window at a reduced rate
- Goal: move look-back window by about $+200$ ns



Digitization Look-back Window Scan

- Test scan of different digitization windows performed w/cosmic rays




- Adjust setting and study 2D digit efficiency to confirm choice of new value

New Scintillator FW

- Initial KEK testing of SCROD waveform readout firmware was carried out on August 7.
 - Version tested @ ttd11: /bdaq/group/b2klm/lastfw/klm_scint_vFE03.bit
 - Identified a few more things that need tuning
- More testing ongoing

Attività Italiane

- KLM Performances

- Muon ID (A. Martini)  Responsabilità vacante da quando Alberto ha lasciato Roma Tre
- RPC/Scint. Efficiency (G. De Pietro)
- KL ID
 - Responsabile Belle II KL-ID (G. Finocchiaro) ★
 - Sviluppo BDT (C. Martellini, A. Di Cicco, R.d.S.)
 - Analisi Eventi $\Phi\gamma$ (A. Di Cicco, G. Finocchiaro, A. Passeri, M. Piccolo)
- Trigger efficiency (E. Graziani, M. Campajola)

- KLM Software (G. De Pietro)

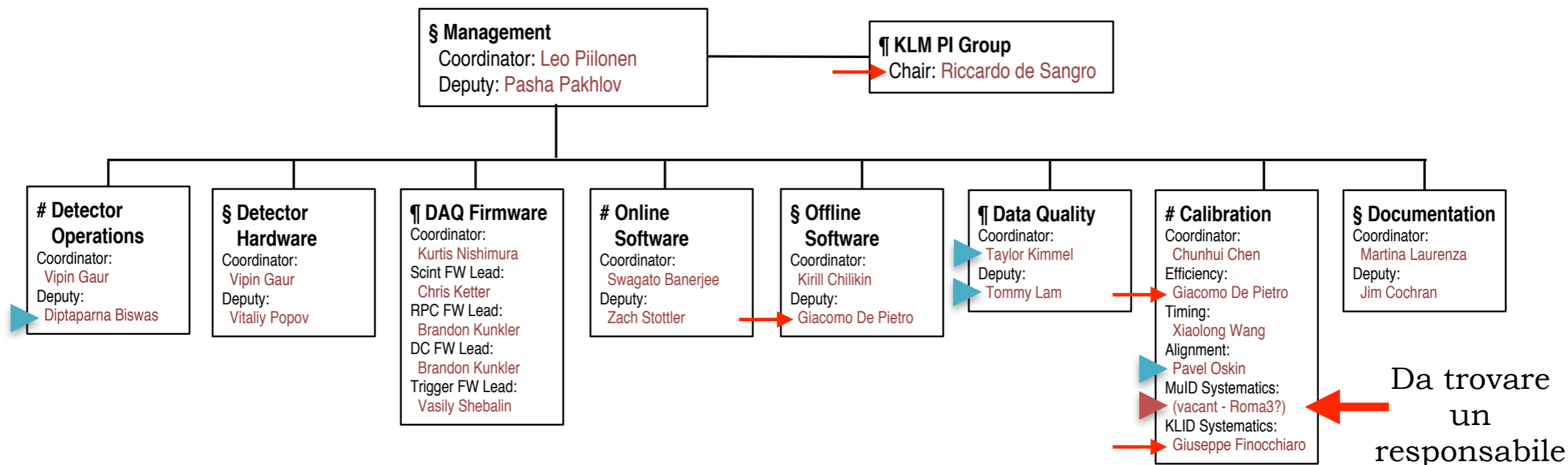
- Belle II Deputy Software Coordinator ★
- Belle II Minor Release Manager
- Deputy KLM software coordinator e KLM/Tracking Liaison & Calibration Expert

- KLM Documentation (M. Laurenza)

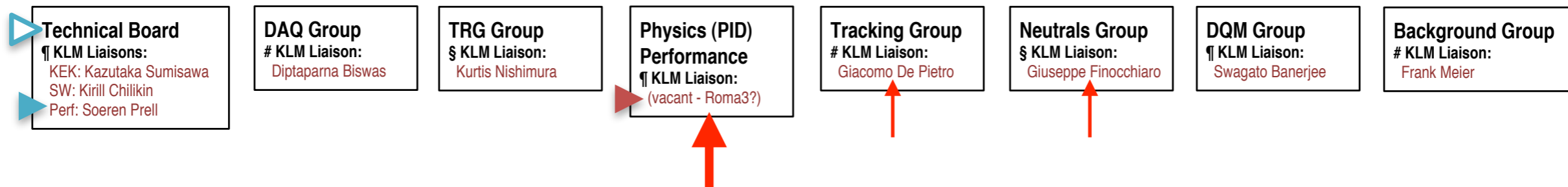
KLM Group Organization

Belle II KLM Organization

(June 2021)



Liaisons to other Belle II groups:



All positions are term-limited (two years) and renewable

§ Term boundary is at February B2GM

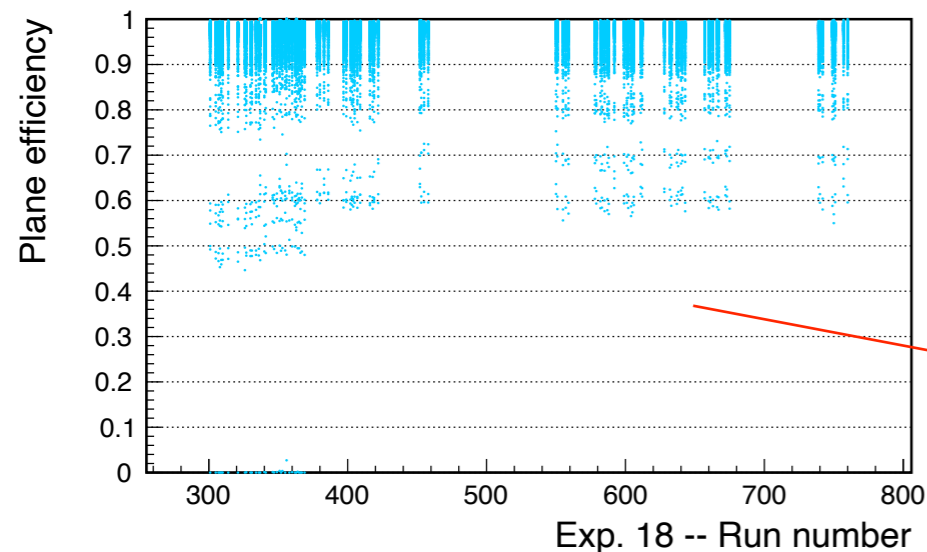
¶ Term boundary is at June B2GM

Term boundary is at October B2GM

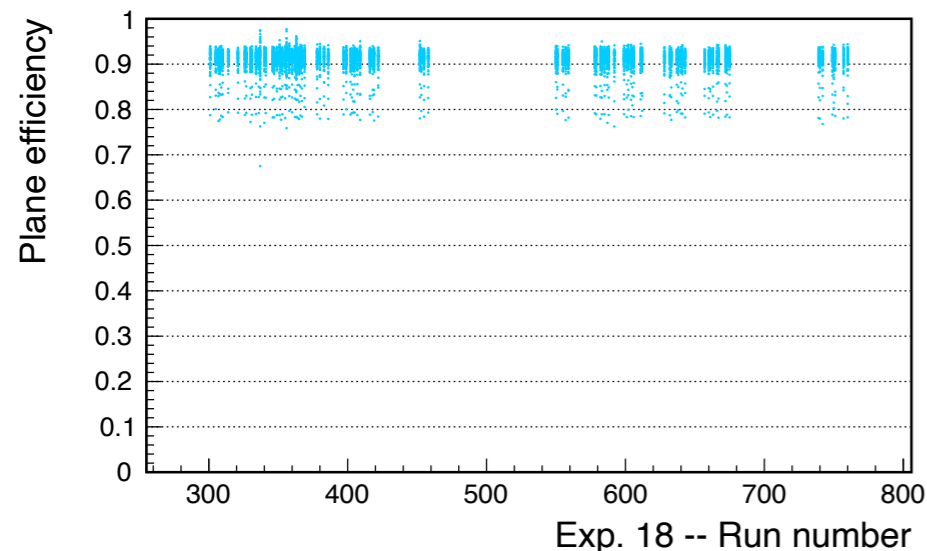
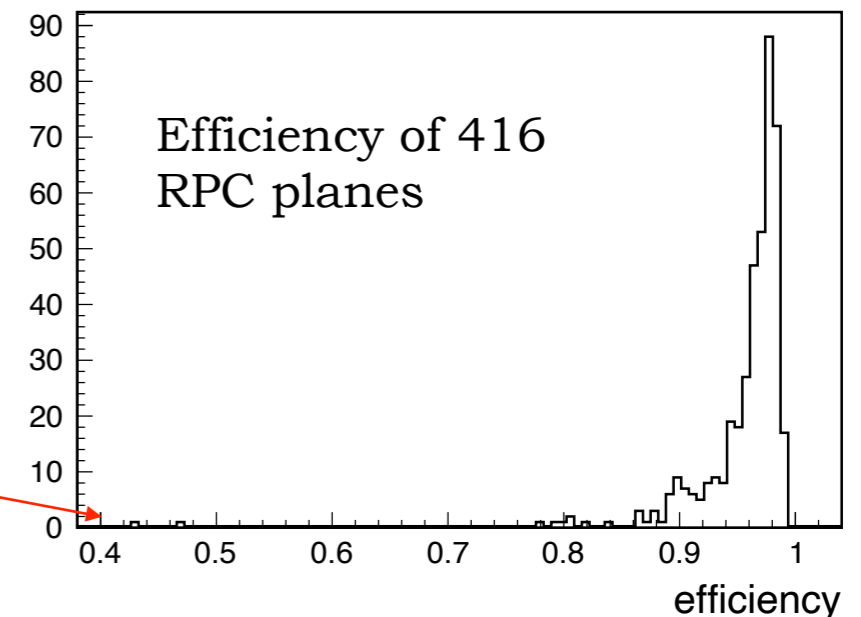
KLM RPC Efficiency

G. De Pietro

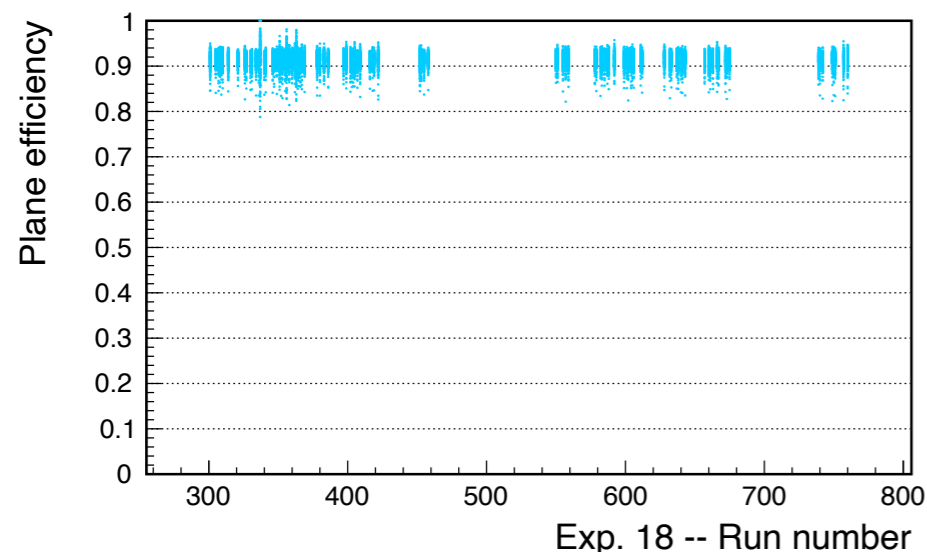
Exp 18



Barrel RPC



Barrel Scintillators



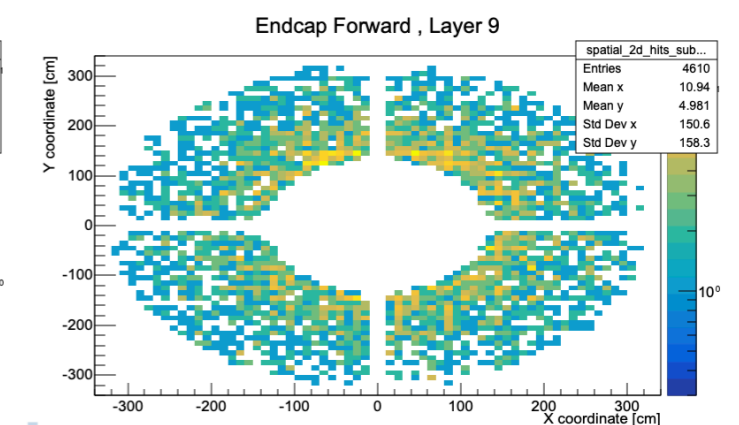
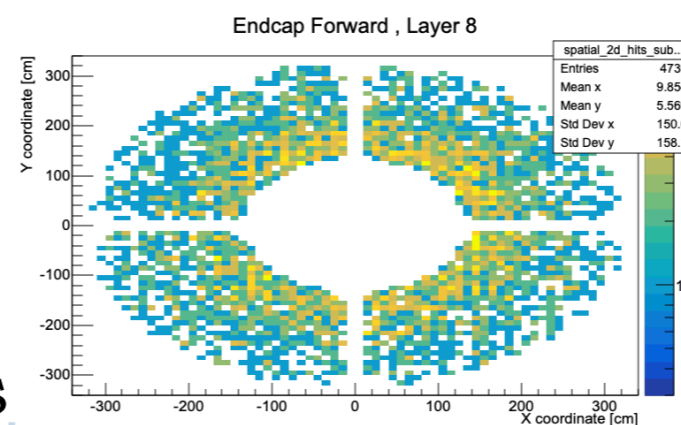
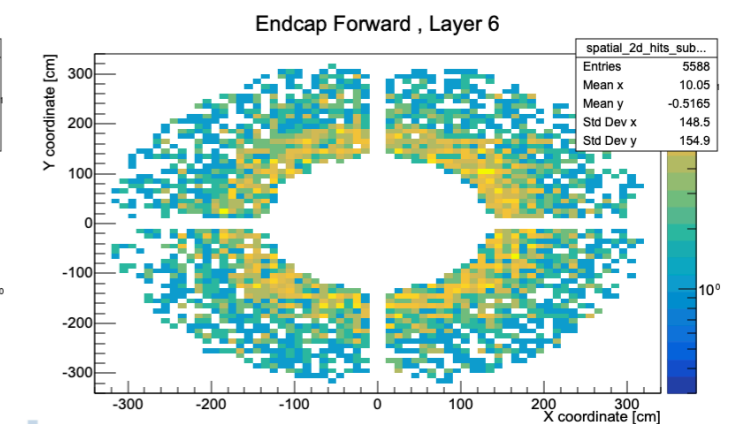
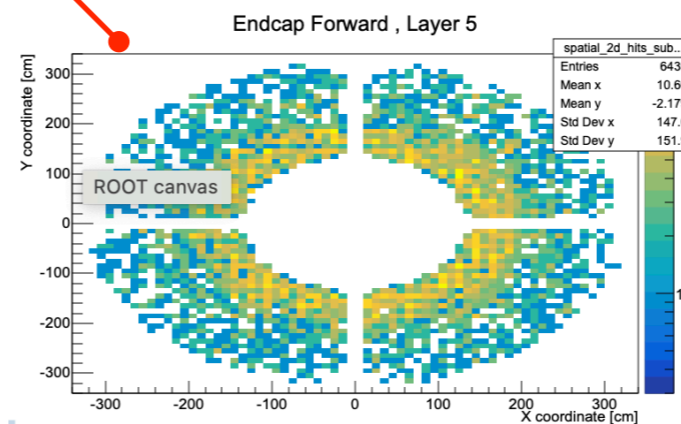
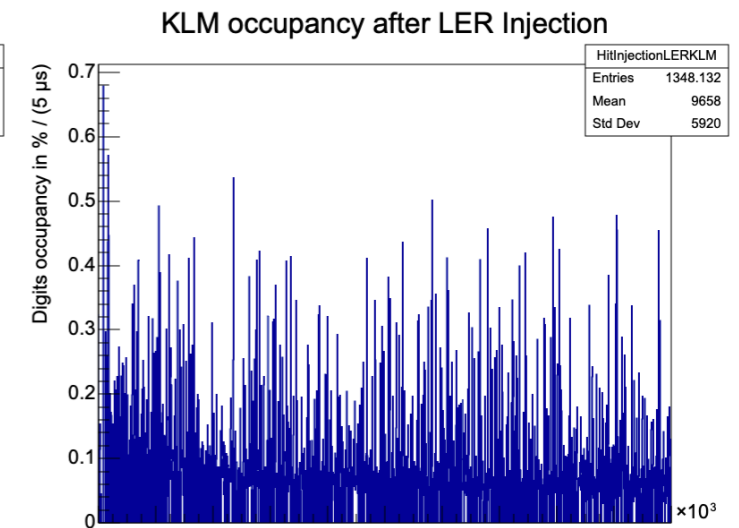
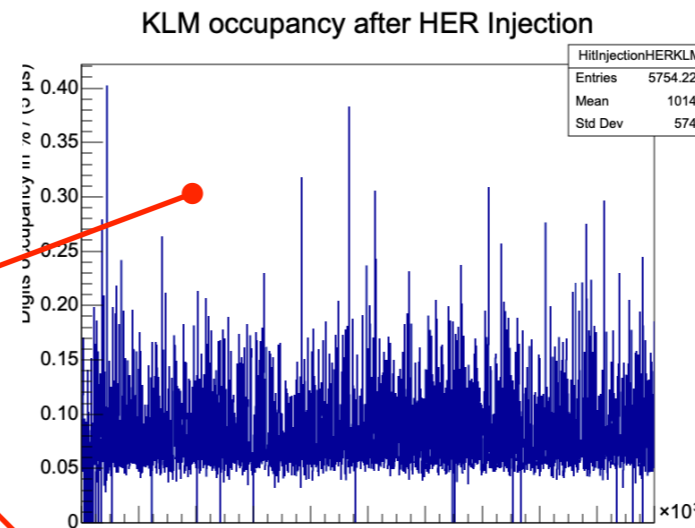
EC Scintillators

- Calibration validation (Efficiency plots) is now performed automatically

KLM Software

G. De Pietro

- Improved DQM Plots
 - More KLM Digi plots
 - Injection Background
 - EKLM 2D Hits plots
- New in release 6
 - Timing Calibration
 - Full re-write (U.Hawaii) of TSIM KLM trigger simulation
- To Do:
 - Check Event T_0
 - Background overlay files



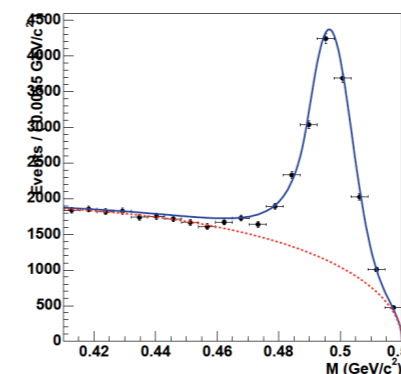
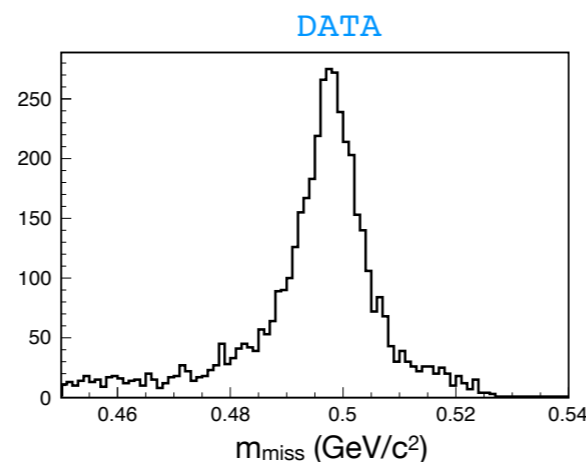
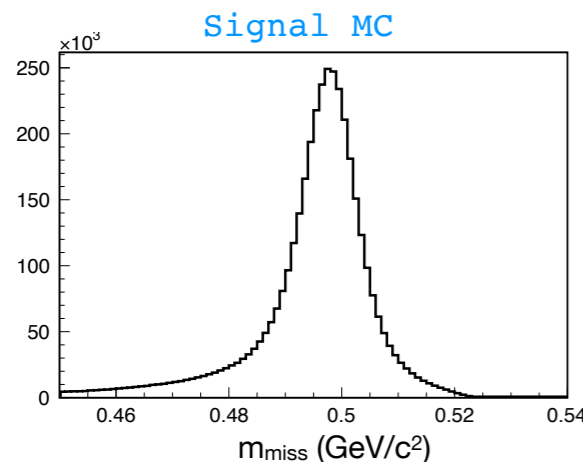
KLM – Attività 2021 in corso

KL ID performance with $\Phi(K_S K_L) \gamma$

G. Finocchiaro
A. Passeri, M. Piccolo

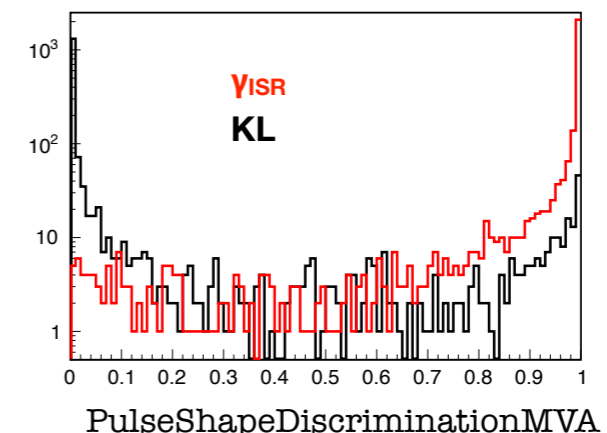
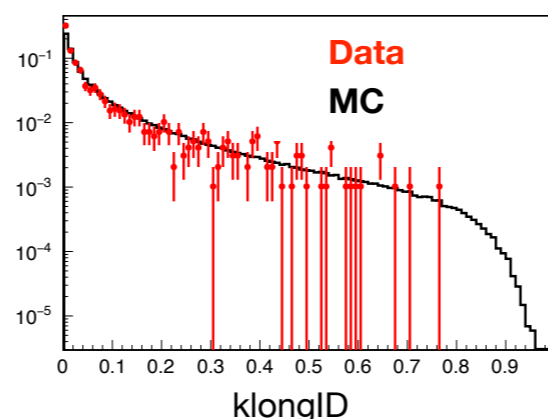
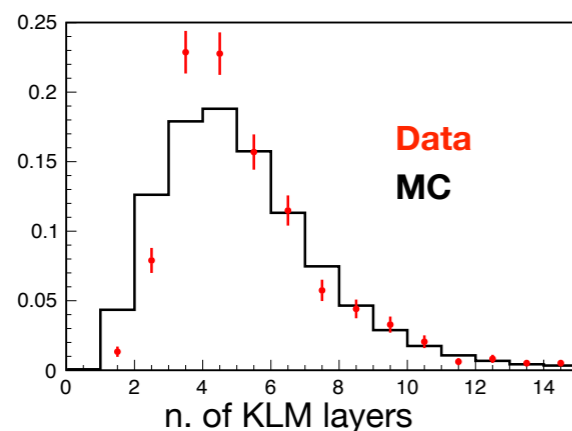
- Very simple topology, with strong signature: 1 hard photon + 2 pion tracks (K_S)
 - Constrain the γ energy using 2-body decay hypothesis of the initial (e^+e^-) and intermediate (ϕ) states, via:

$$s - m_\phi^2 = 2E_\gamma \left(E_{ee} - \vec{p}_{ee} \cdot \frac{\vec{p}_\gamma}{E_\gamma} \right)$$



Better purity than in the *BABAR* study

- No information from KLM and ECL (modulo γ_{ISR}) is used. $\sigma(p) \sim 10$ MeV/c (MC); $\sigma(\phi, \theta) \sim 3$ deg (MC, DATA)
- Constitute a clean, unbiased sample to study properties of K_L signals in the detector. Examples:



➡ Provide valuable information to tune and characterise improved algorithms for K_L identification

cdcklm1 Trigger

E. Graziani
M. Campaiola

- New trigger line for single muon trigger based on CDC and KLM information, available from Exp12, run1235 in Run 2020c
- Useful for many Dark Sector and tau analyses with muon final states
- Recent hardware improvements:
 - Threshold for KLM lowered to 4 hit layers
 - Trigger includes now End Cap KLM
 - New KLM trigger lines added to CDCKLM and KLMB2B:
 - Coincidence short CDC track-EKLM
 - Coincidence ECL-EKLM
- Study these new trigger bits efficiencies in the coming months

BELLE2-NOTE-TE-2020-028

KLM Documentation Project

M. Laurenza

Documentation

Sphinx:

Muon-ID entirely in Sphynx

software.belle2.org/development/sphinx/klm/doc/index.html#clusterization

- 3. Command Line Tools
- 4. Belle II Python Interface
- 5. List of Core Modules
- 6. Analysis
- 7. B2BII
- 8. Background module
- 9. Calibration
- 10. The Belle II Event Display
- 11. Event Generators
- 12. Tools for Validation of the SoftwareTrigger
- 13. KLM (K_L^0 and Muon Detector)
- 13.1. Modules
- 13.2. Clusterization
- 13.3. Muon identification
- 13.4. Calibration
- 13.5. Tools
- 14. Belle II File Format
- 15. MVA package
- 16. PXD
- 17. Reconstruction
- 18. Simulation
- 19. Skims
- 20. SVD
- 21. TRG
- 22. Tools for Physics Validation of the Software
- 23. Fitting training
- 24. How to document your code with Sphinx
- 25. Online textbook

13.3. Muon identification

Muon identification for the extrapolated tracks in KLM uses differences in longitudinal penetration depth and transverse scattering of the extrapolated track. It is handled by the `Muid` module, that is part of the tracking package of `BASF2` and proceeds in two steps:

1. Track extrapolation using the muon hypothesis only;
2. Likelihood extraction for each of six particle hypothesis: μ, π, K, p, d, e .

The six likelihoods that are assigned to a given track are stored as log-likelihood values in the `KLMuIdLikelihood` data-object. In the post-reconstruction analysis, the log-likelihood differences may be used to select or reject the muon hypothesis for a give track.

Muid

Identifies muons by extrapolating tracks from CDC to KLM using geant4e

Package: tracking

Library: libmuid.so

13.3.1. Track extrapolation

The extrapolation proceeds step by step through the detector geometry, starting at the outermost point of the reconstructed track's trajectory and with phase-space coordinates and covariance matrix. Upon crossing a KLM detector layer, the nearest two-dimensional hit -if any- in that layer is considered for association with the track. If the hit is within about 3.5σ (where σ is the 2d hit uncertainty) in either of the two local-coordinates directions then it is declared a matching hit and the Kalman filter uses it to adjust the track properties before the next step in extrapolation. At the same time, the Kalman filter's fit quality (χ^2) is accumulated for the track.

The extrapolation ends when the kinetic energy falls below a user-defined threshold (nominally 2 MeV) or the track curls inward to a cylindrical radius below the beam pipe one or the tracks escapes from KLM. If the track reached the KLM, it is classified according to how and where the extrapolation ended (stop or exited and in the barrel or the endcap).

software.belle2.org/development/sphinx/klm/doc/index.html#clusterization

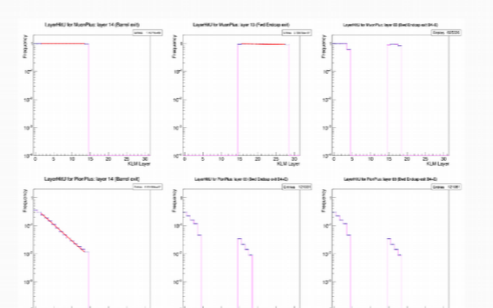
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13.3.2. Likelihood extraction

The likelihood of having the matched-hit range and transverse-scattering χ^2 distribution is obtained from pre-calculated probability density functions (PDFs). There are separate PDFs for each charged-particle hypothesis and charge and for each extrapolation outcome.

The longitudinal-profile PDF value $P_L(\vec{x}; O, l, H)$ for extrapolation ending outcome O and outermost layer l and for particle hypothesis $H \in \mu^\pm, \pi^\pm, K^\pm, e^\pm, p, \bar{p}, d, \bar{d}$ is sampled according to the measurement vector \vec{c} given by: (a) the pattern of all KLM layers touched during the extrapolation (not just the outermost one) and (b) the pattern of matched hits in the touched layers. Sample PDF for exiting tracks are shown in Fig. 13.1 for muons and pions.

The transverse-scattering probability density function $P_T(\chi^2, n; D, H)$ for KLM region D (barrel-only, endcap-only, or overlap) and particle hypothesis H is sampled according to the measurement of χ^2 from the Kalman filter and the number of degrees of freedom, which is twice the number of matched hits. The muon-hypothesis PDF is very close to the ideal χ^2 distribution for the given number of degrees of freedom, while the non-muon hypothesis PDFs are considerably broader for low degrees of freedom. Sample PDFs are shown in Fig. 13.2 for muons and pions.



software.belle2.org/development/sphinx/klm/doc/index.html#clusterization

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13.3.3. Muon Efficiency and Pion Fake Rate

The log-likelihood difference Δ is the most powerful discriminator between the competing hypothesis:

$$\Delta = \log(L(\mu^+; O, l, D, \vec{x}, \chi^2, n)) - \log(L(\pi^+; O, l, D, \vec{x}, \chi^2, n)).$$

The requirement $\Delta > \Delta_{min}$ for a user-selected Δ_{min} provides the best signal efficiency for the selected background rejection. Log-likelihood differences for true muons and pions are shown in Fig. 13.3 as a function of the track momentum. Choosing a momentum-independent cut on Δ_{min} that is positive and non-zero will reject soft muons preferentially, and a similar behavior is seen when choosing a cut that is independent of the polar or azimuthal angles, because the log-likelihood differences are softer in the azimuthal cracks between sectors and in the barrel-endcap overlap region where KLM is thinner.

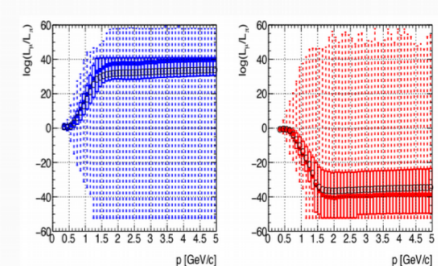


Fig. 13.3 Log-likelihood difference between muon and pion hypotheses for true muons (left) and pions (right) as a function of the track momentum in GeV/c. In each plot five features are shown: (1) minimum and maximum values (bounded by the dashed vertical line); (3) the lower and upper quartiles (below or above the rectangular box); (4) the median (the thick horizontal line segment); (5) and the mean (circle).



MuonID: Track extrapolation, likelihood extraction, Muon Efficiency and pion fake rate.



Clusterization, Calibration (<https://agira.desy.de/browse/BIKLM-188>)

+ KLM validation plots, klm confluence page update...

MPPC Front End Controller

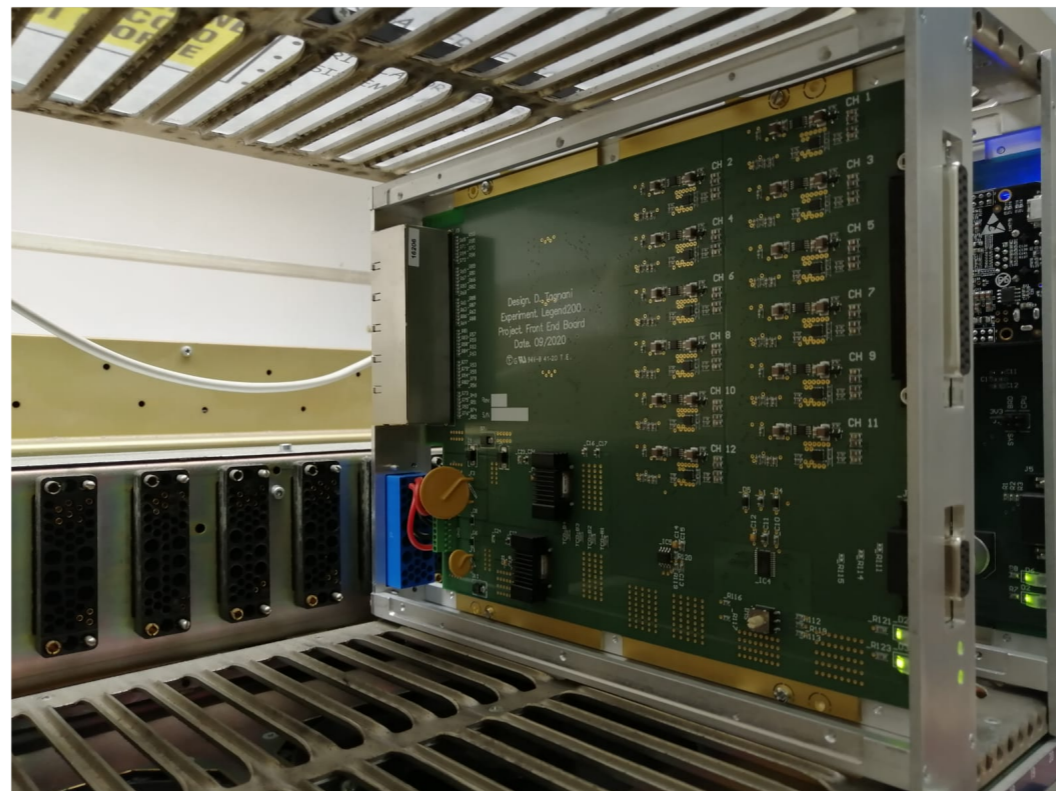


KLM Upgrade

- Prodotte a Rome Tre 1 FE board (12 canali) e 1 MPPC FE controller

MPPC
Front End board →
↓

MPPC Controller



KLM Upgrade

Detector R&D

- Qualify and check scintillators and MPCC
 - Raw material scintillation process study (Roma3), Cosmic ray stand LNF
- KLM Software upgrade (simulation and reconstruction)
- Rad had studies at ENEA (neutrons and photons)
 - ENEA Casaccia (neutrons and photons)
 - ENEA Frascati (neutrons FNG) **Frascati Neutron Generator**

Software

- Define new geometry and simulation to study
 - Optimal detector configuration
 - Realistic performances of new detector
 - Improvement of performances vs beam background

KLM Upgrade

Detector R&D

NB: Chiediamo un gettone per mantenere questa attività in attesa di possibili sviluppi futuri

- Qualify and check scintillators and MPCC
 - Raw material scintillation process study (Roma3), Cosmic ray stand LNF
- KLM Software upgrade (simulation and reconstruction)
- Rad had studies at ENEA (neutrons and photons)
 - ENEA Casaccia (neutrons and photons)
 - ENEA Frascati (neutrons FNG) **Frascati Neutron Generator**

Software

- Define new geometry and simulation to study
 - Optimal detector configuration
 - Realistic performances of new detector
 - Improvement of performances vs beam background

Anagrafica 2022

LNf (4.6 FTE)

M. Beretta (T) (0.1)
A. Calcaterra (0.7)
R. de Sangro (*) (0.9)
A. Di Cicco (AR) (1.0)
G. Finocchiaro (0.9)
C. Martellini (1.0)
I. Peruzzi
M. Piccolo

+2.4 FTE!

Roma Tre (5.4 FTE #)

E. Bernieri (0.5)
P. Branchini RN (0.7)
A. Budano (T) (0.5)
S. Bussino (0.5)
G. De Pietro AR (1.0)
E. Graziani (*) (0.7)
M. Laurenza Dott (1.0)
A. Passeri (0.5)

(#) strictly KLM

(*) Resp. Locale

Richieste Finanziarie KLM

KLM	Missioni (k€)		Consumo (k€)		Commenti
	LNF	Roma Tre	LNF	Roma Tre	
Mantenimento Elettronica KLM	6 SJ	12 SJ			
Turni Sottorivelatore	6				4.5 mesi di run 1*pers./giorno=4.5 MU*0.20 (12/60) frazione IT
Setup Cosmici per misure pre/post irraggiamento			3		Lavorazioni meccaniche e materiali di consumo
Costo-macchina irraggiamenti				3	Enea Casaccia

Totale: 6k€ + 18k€ SJ Missioni, 6k€ Consumo