TOP status

Outline:

- Operation issues: TOP backgrounds
- Operation issues: hot PMTs
- TOP software
- TOP performance
- Laser stability monitoring
- PMT aging/gain monitoring
- PMT replacement plans

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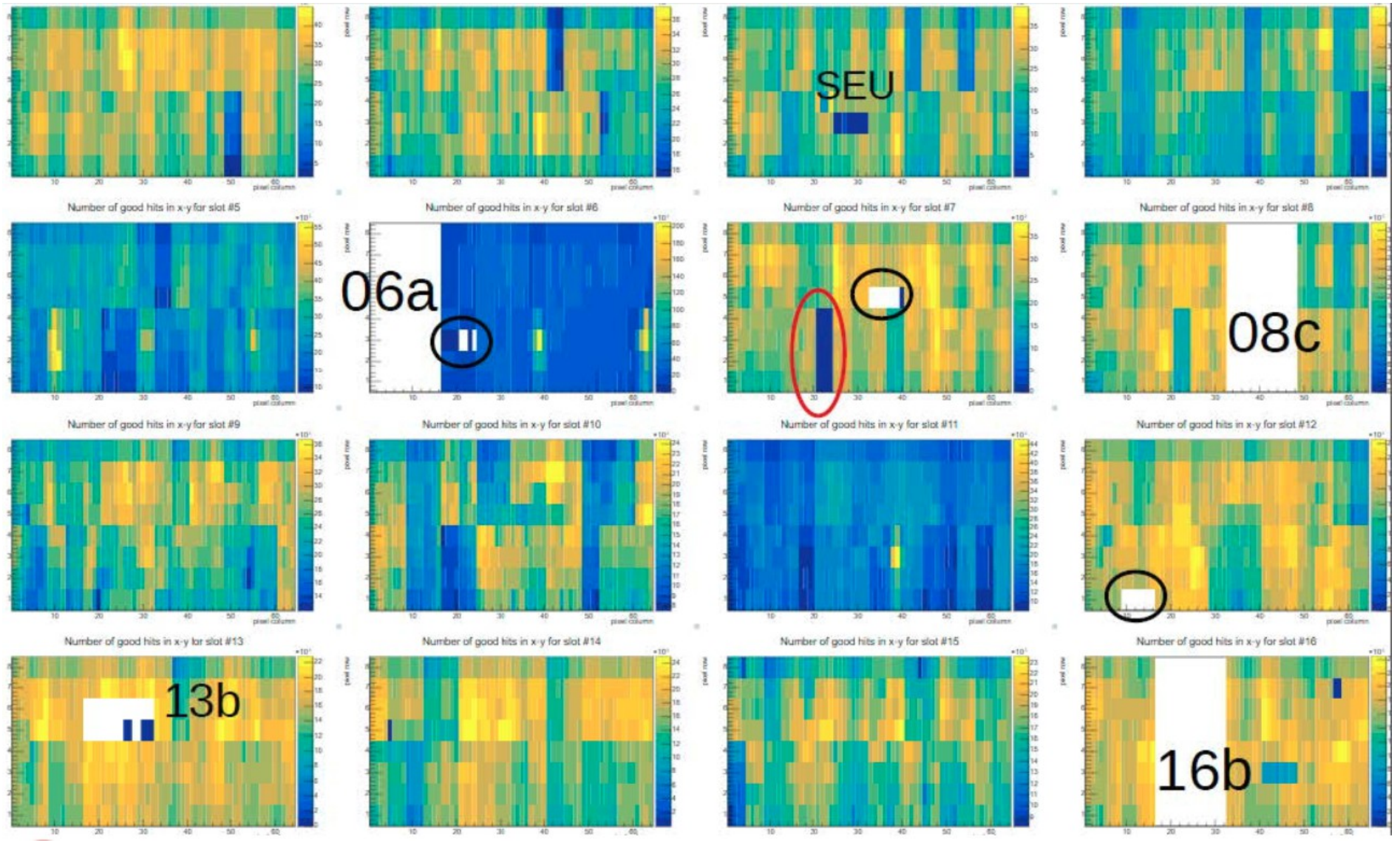
Hawaii, Indiana, IIT Hyderabad
Pittsburgh, PNNL, Ljubljana

Roberto Mussa

Referaggio BelleII Italia ZOOM, 07/09/2021

Hardware status : dead channels



PMTs off

dead asic

- Power cable 08c failed, **94.4% channels working**
- Replace 8 boardstacks during 2022 PMT replacement

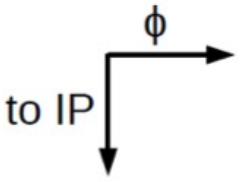
Hot PMT

s01	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s02	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s03	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s04	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s05	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s06	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s07	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s08	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

s09	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s10	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s11	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	**9**	**10**	11	12	13	14	15	16
s12	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s13	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s14	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s15	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
s16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	1	2	3	4	5	6	7	8	9	10	11	12	**13**	**14**	15	16

Pattern emerging , but causes unclear:

- Central outer channels show a slow increase in currents drawn from HV: cable routing?
- Inner rightmost channels : sudden transitions to hi rates, not directly related to beam injection. Magnetic field? Cooling?

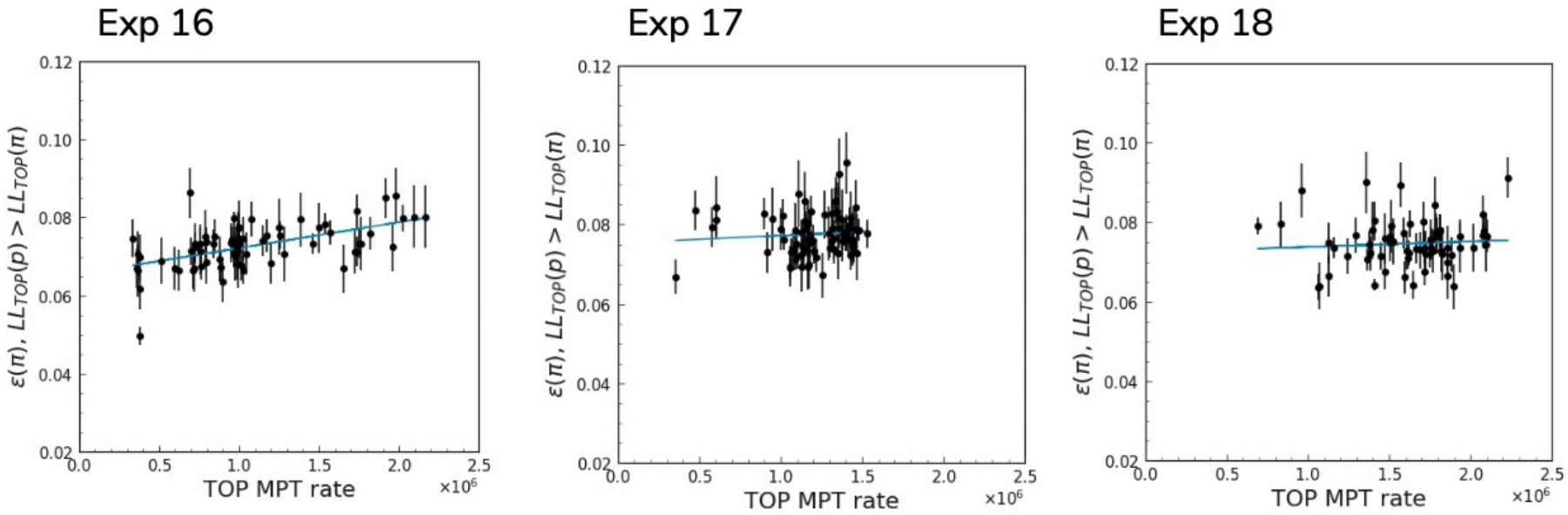


	ramping up
	HV off
	seen as hot PMT
bold	HV reduced
	long-term high rate
	slow current increase

Performance VS background rate

Back to the K_s sample

- Pion/proton mis-ID VS TOP PMT hit rate from the run database
- Visible trend in exp16, but not seen again in exp18



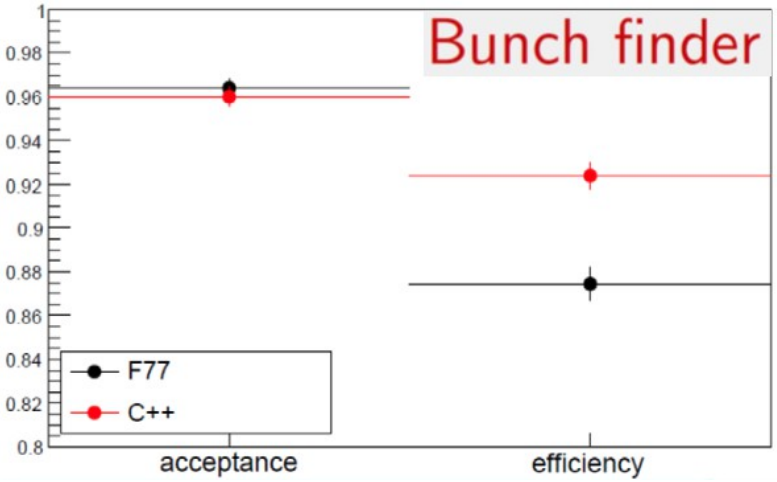
The increase in background rates does not seem to affect the overall PMT performance (yet)

TOP reconstruction software

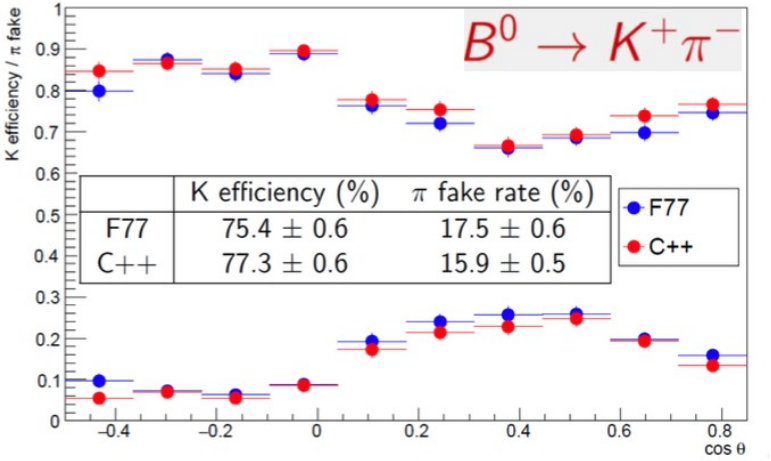
- Porting of FORTRAN reconstruction code to C++ is completed
  - new code is now used everywhere
  - FORTRAN code (incl. wrappers) has been removed completely

  → will take place in release-6
- Improvements w.r.t FORTRAN code
  - better structured code, callable also from python
  - includes also tracks crossing prism
  - improved numerical algorithms
  - some bugs identified and fixed

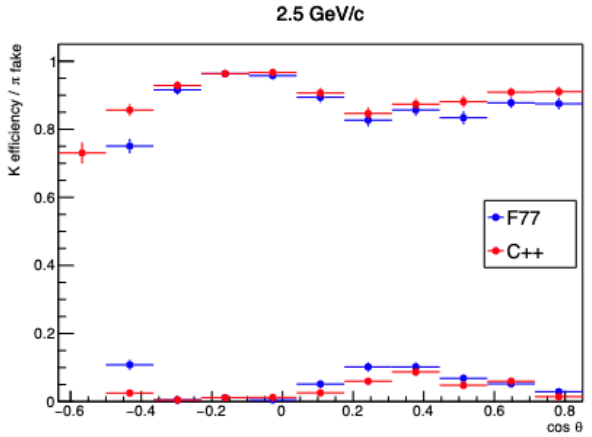
  → enhanced K/π separation above 2 GeV/c (on MC)
- Moderate increase of execution time (~20%)

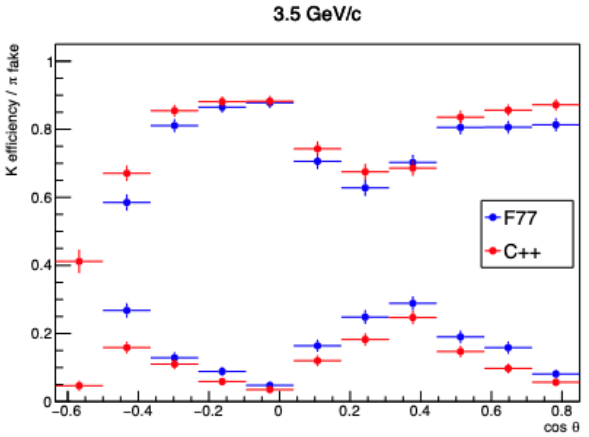


MC sample: particle gun w/ idealized tracking



	K efficiency (%)	π fake rate (%)
F77	75.4 ± 0.6	17.5 ± 0.6
C++	77.3 ± 0.6	15.9 ± 0.5





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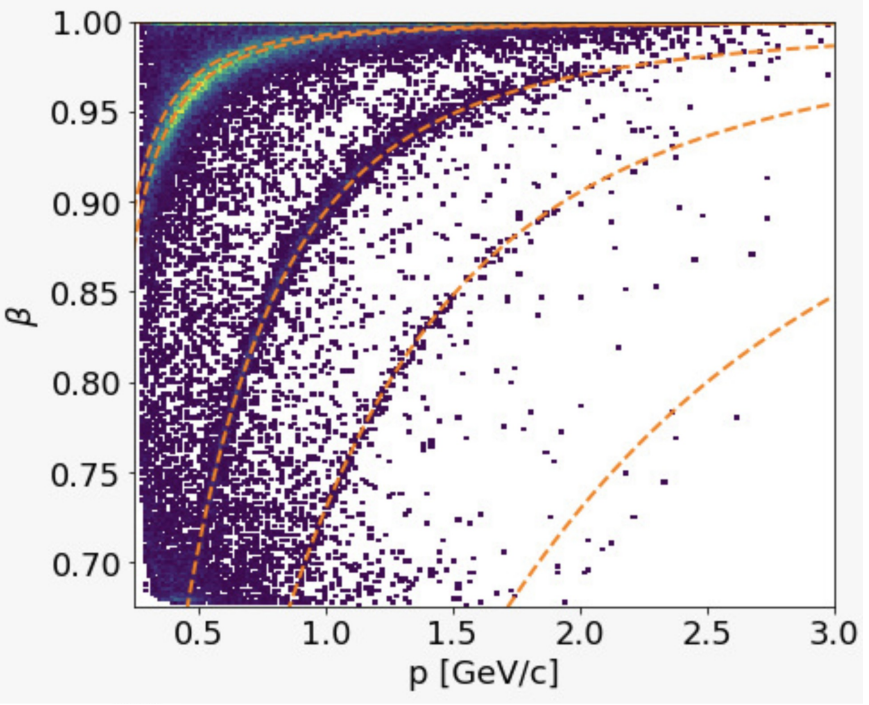
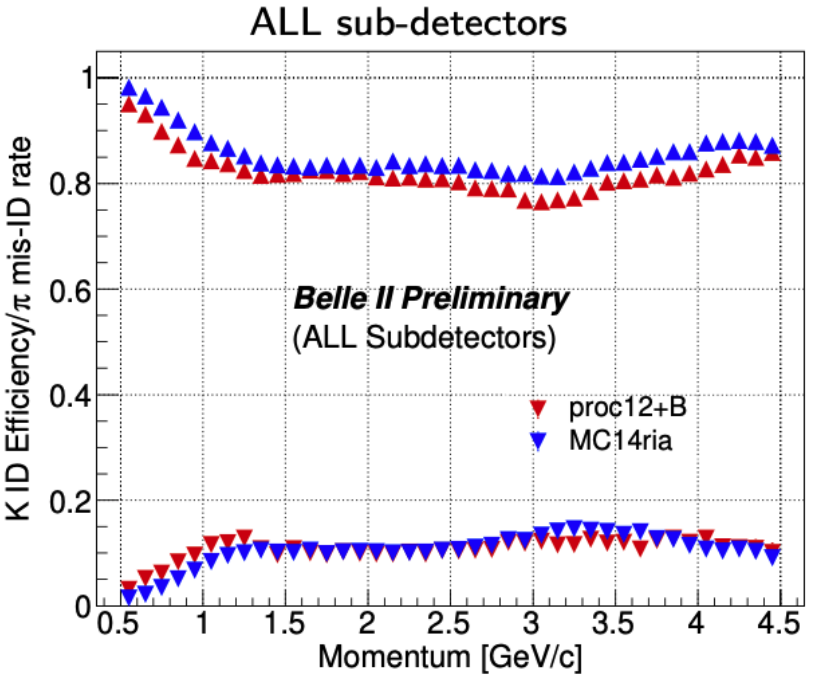
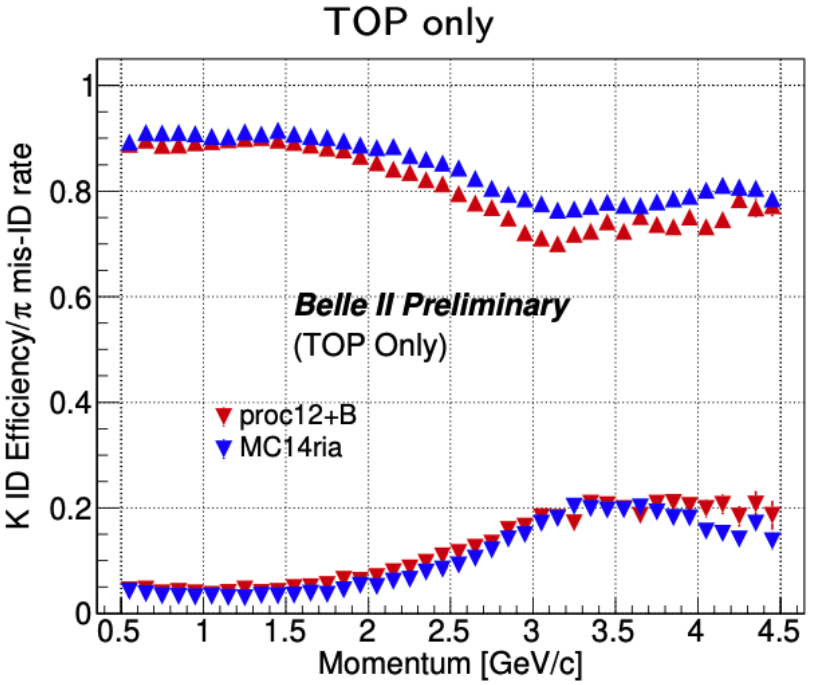


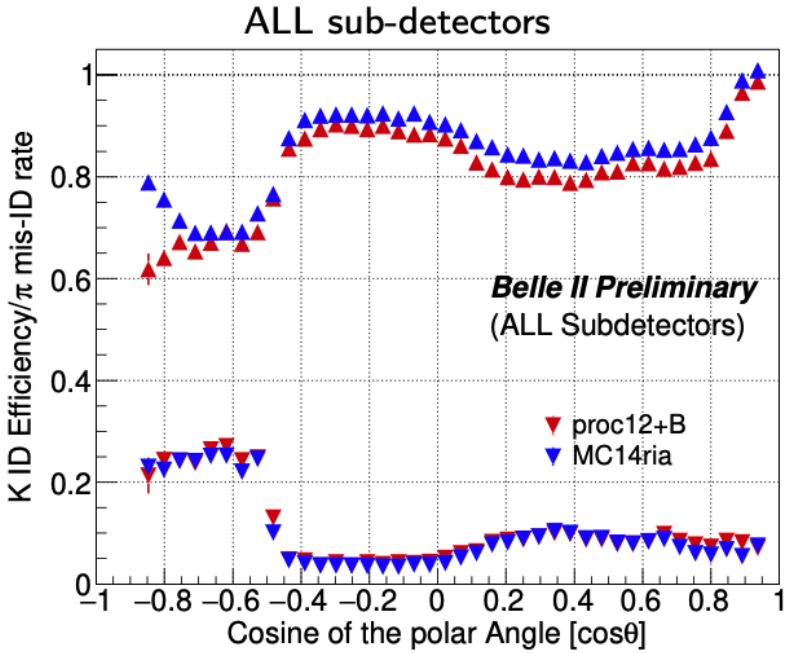
TOP Performance (from D*)

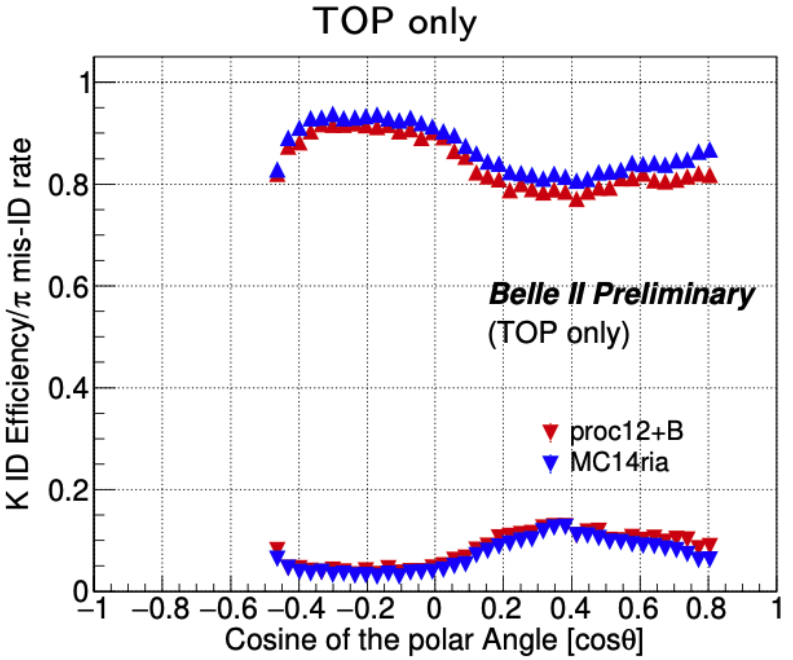
Momentum dependence





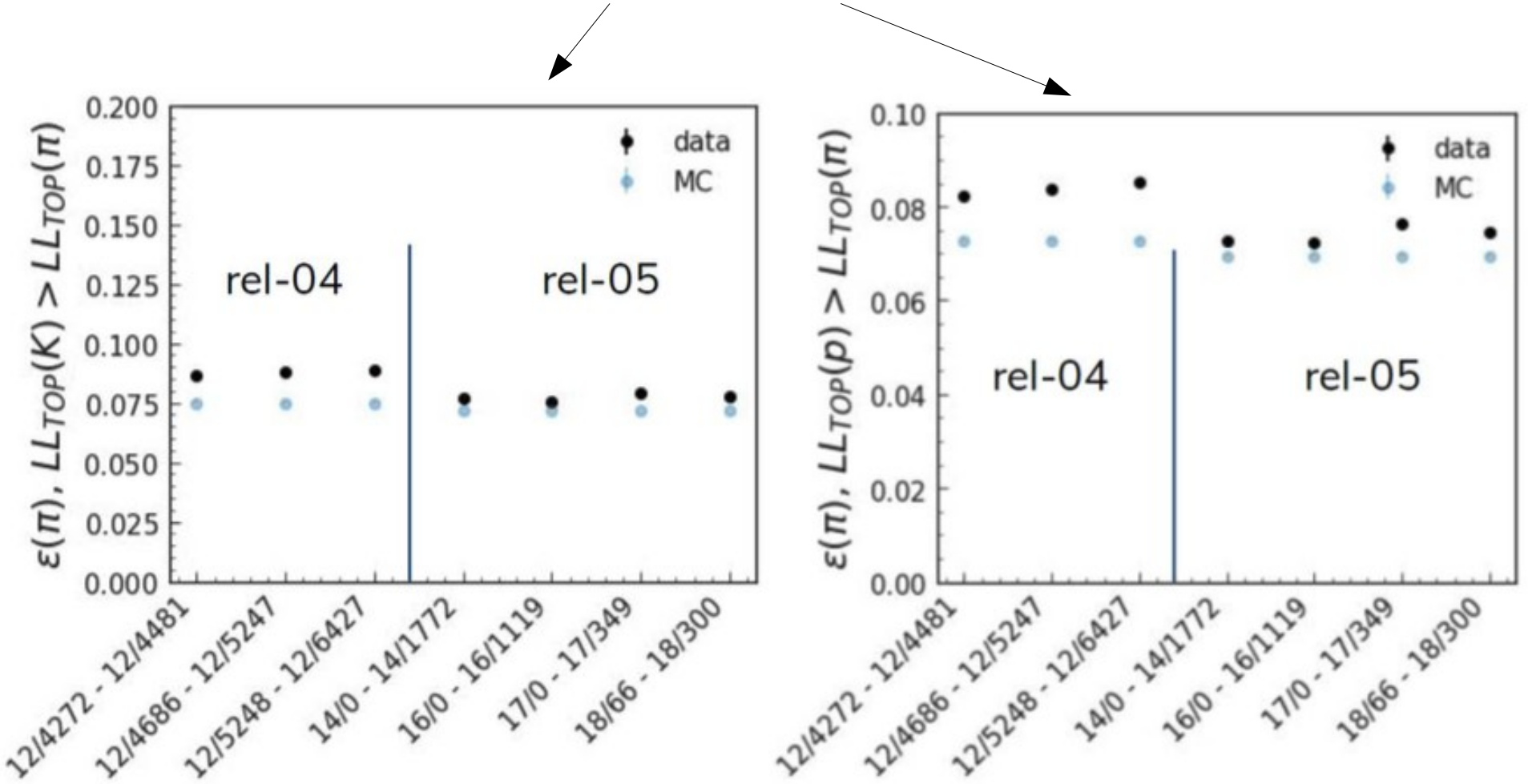
Polar angle dependence





(*) Plots with LL cut at 0.5

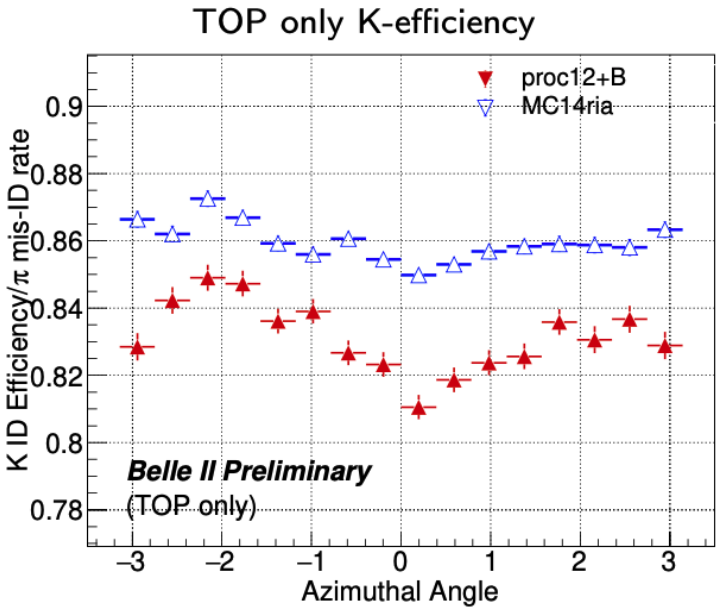
Pions mistagged as: kaons, protons

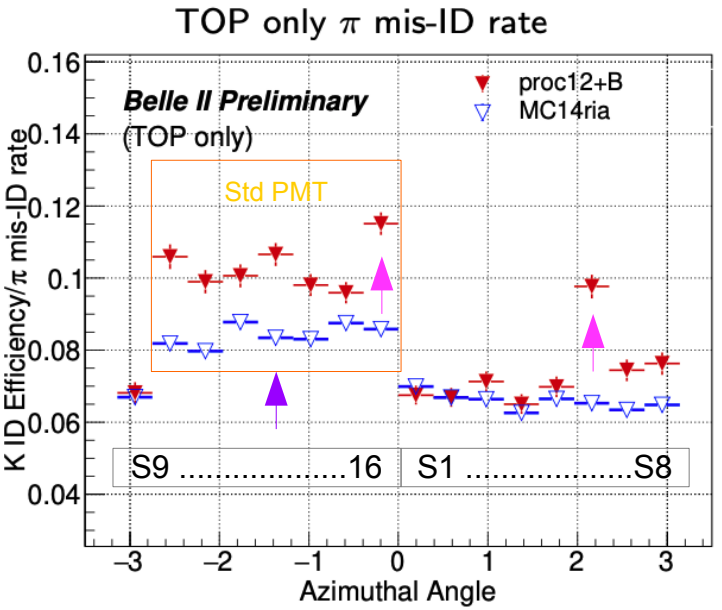


Better MC/data matching in release 5

(Software transition from F77 to C++ not yet implemented...)

TOP Performance: azimuthal dependence



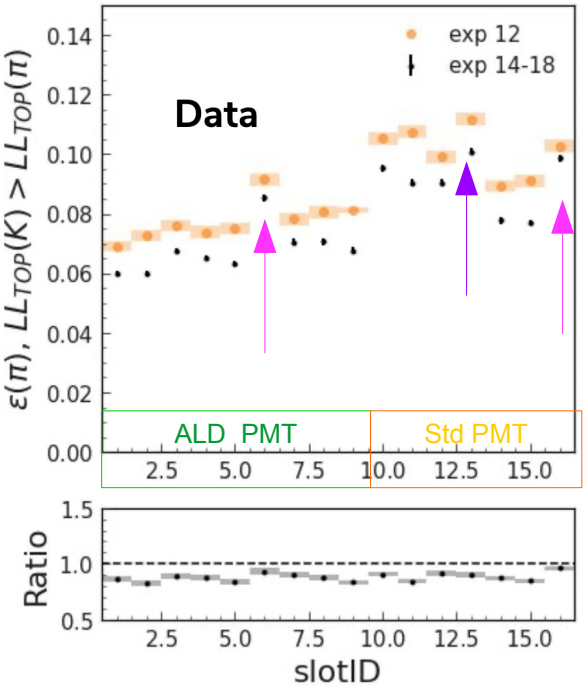


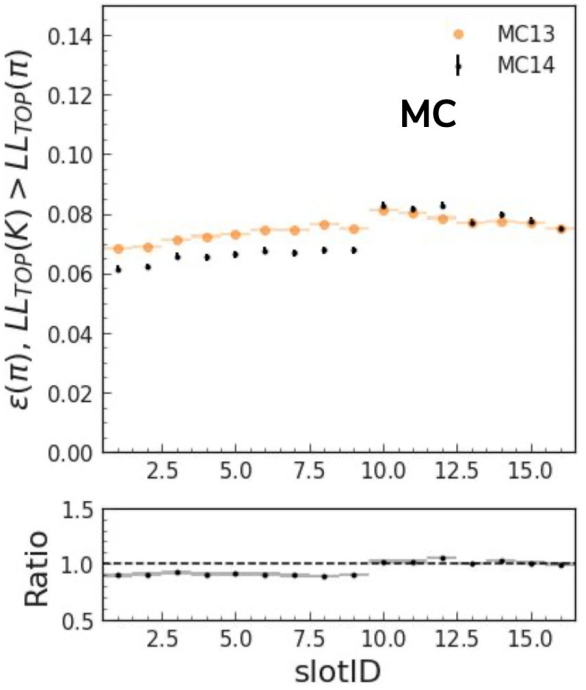
Dependence on MCPPMT type mostly due to QE

Peaks in S06,16: one BS missing
Peak in S13: firmware issues

Reduction in π misId rate observed in both data and MC

Effect on K efficiency not completely understood

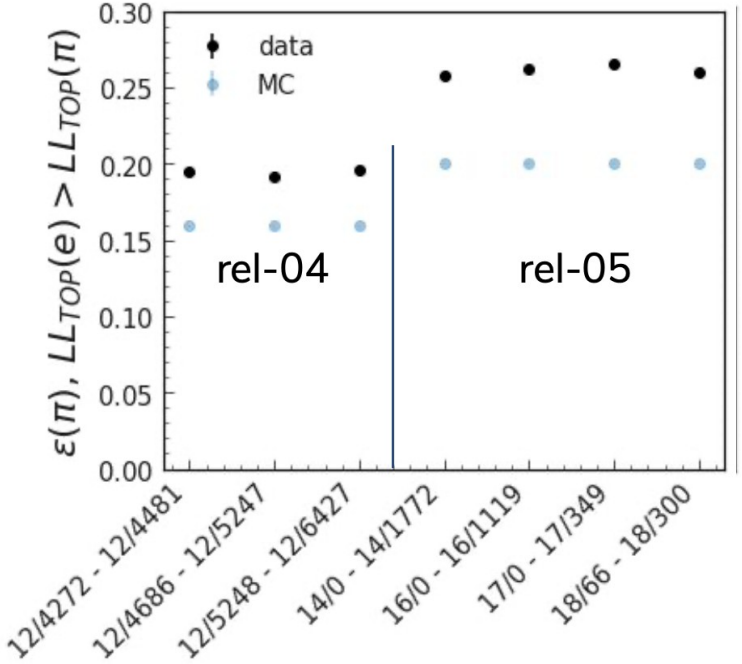


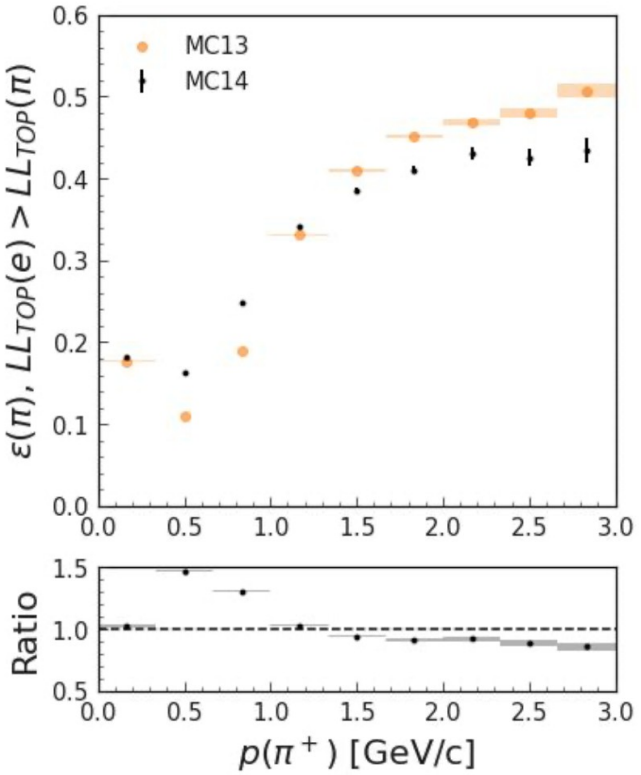


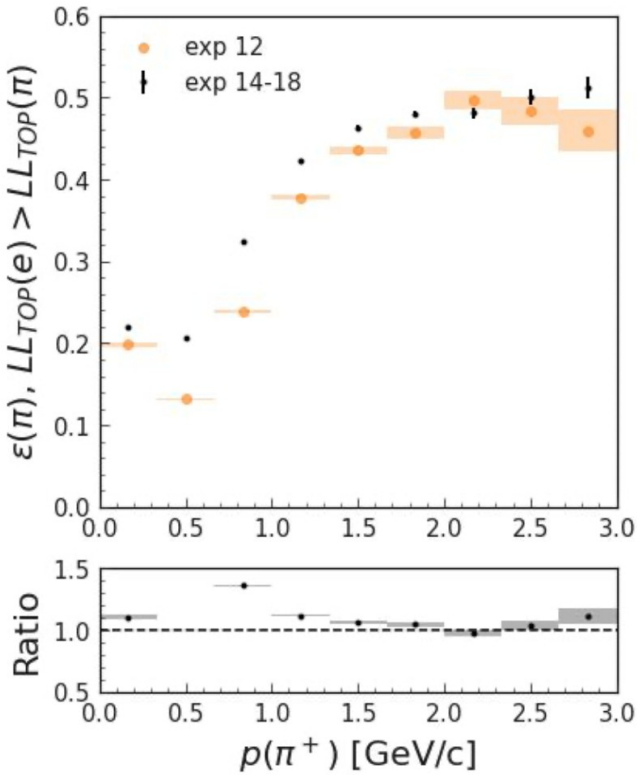
TOP Performance: electron mismodeling

Testing point: LL(e) > LL(π)
Momentum range: 0 < p < 3 GeV

Pion → electron mis-id much worst







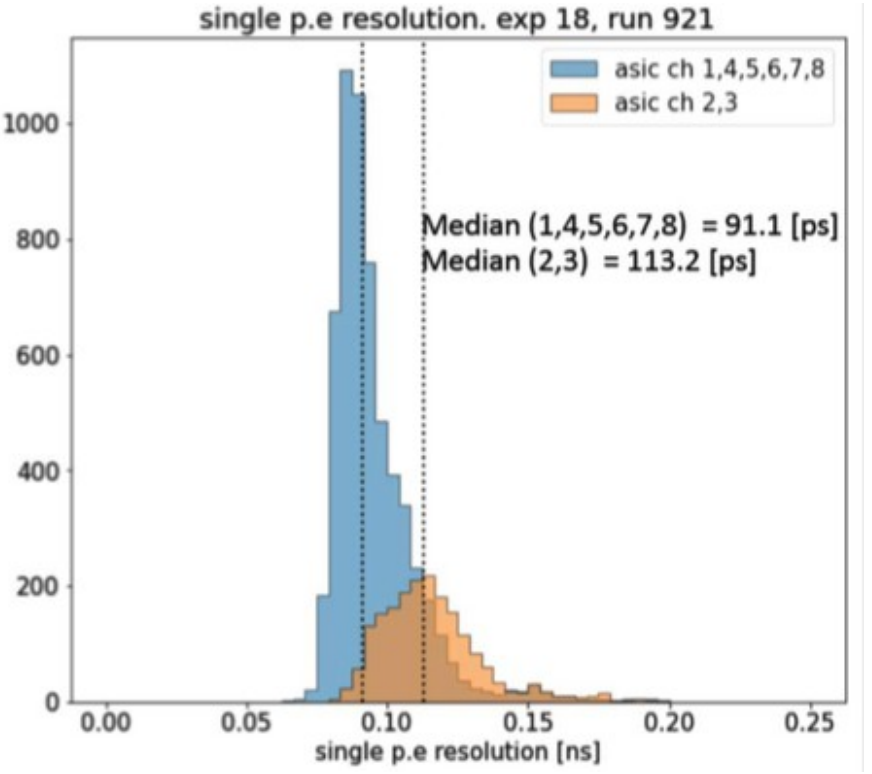
Seen also in the J/psi sample

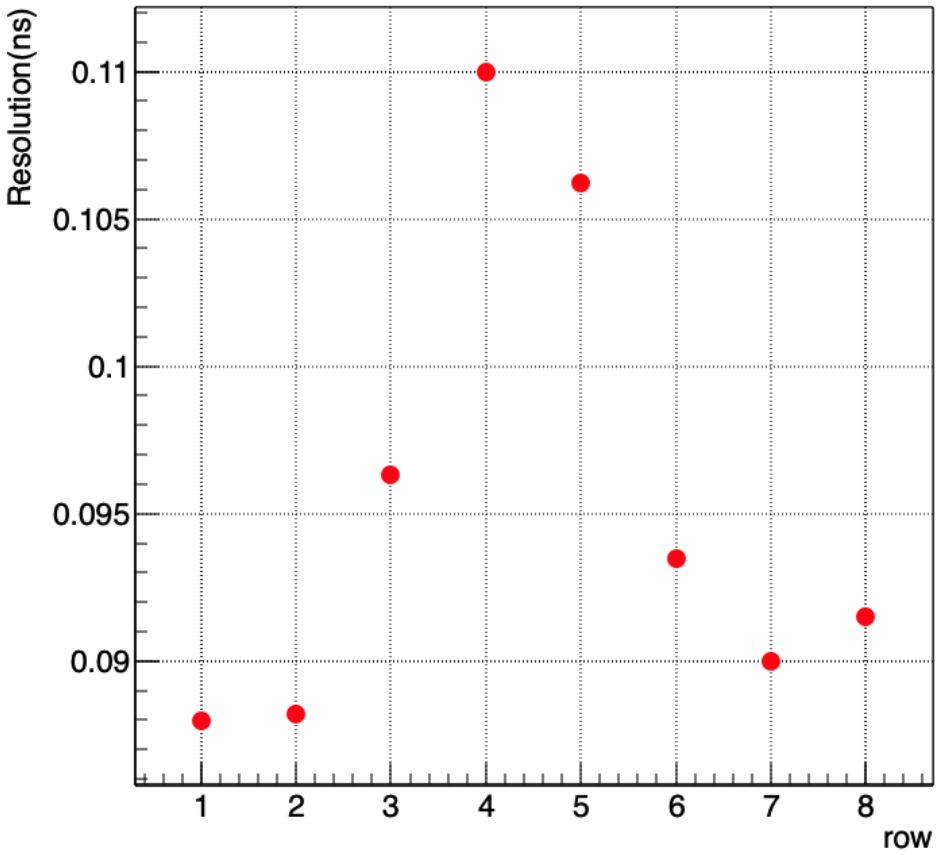
Modeling of delta electrons in pion/K/proton crossing introduced in PDF: works fine

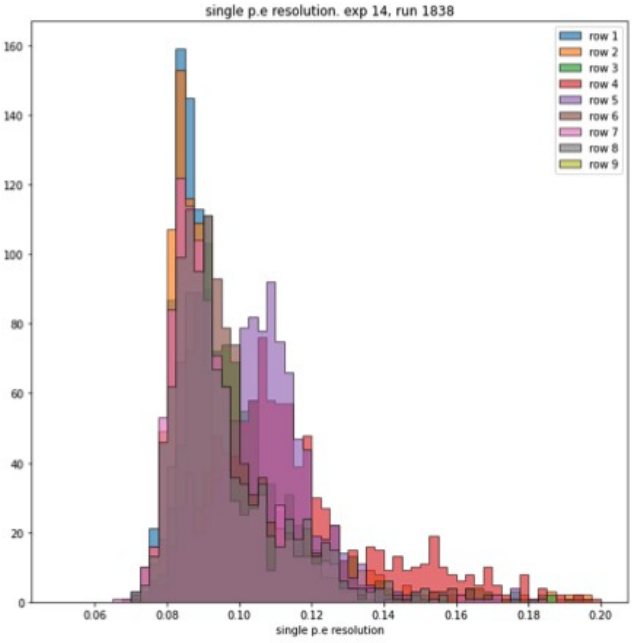
Probably some bug still sneaking in electron PDFs

TOP calibration: channel T0

- Gian Luca found a pattern in the single photon electron time resolution as function of the ASIC channel which is worse resolution in channels 2,3 of each ASIC.
- The fitter has trouble resolving the two different light path in channels with small time difference between the two and comparable probability. This problem is most present at the middle of the PMT array. This issue could bring a small bias in the channel T0.
- Changes in one BS can transmit to channel T0 in the entire module. This is specially concerning due to BS13d problems.

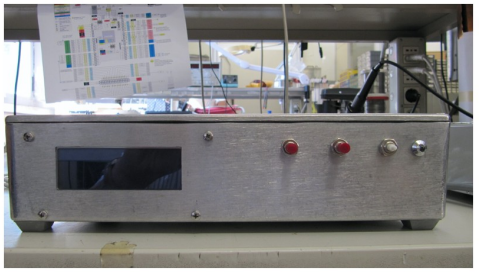


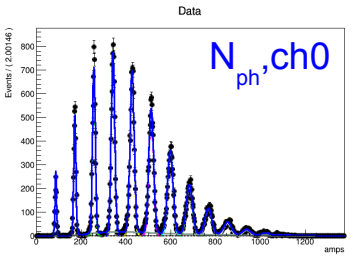


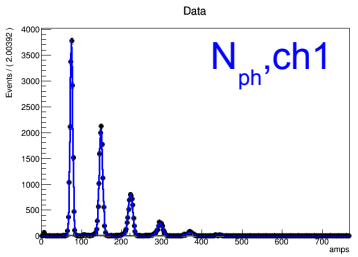


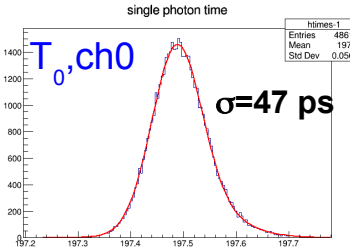
TOP Laser stability monitoring system (Padova)

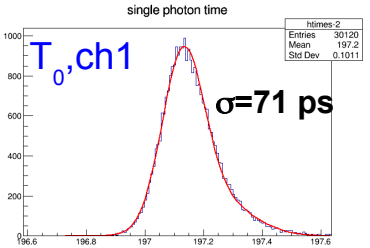
Two channel monitoring system (fully operational since Mar 13) automatically activates when a local TOP laser calibration run is launched



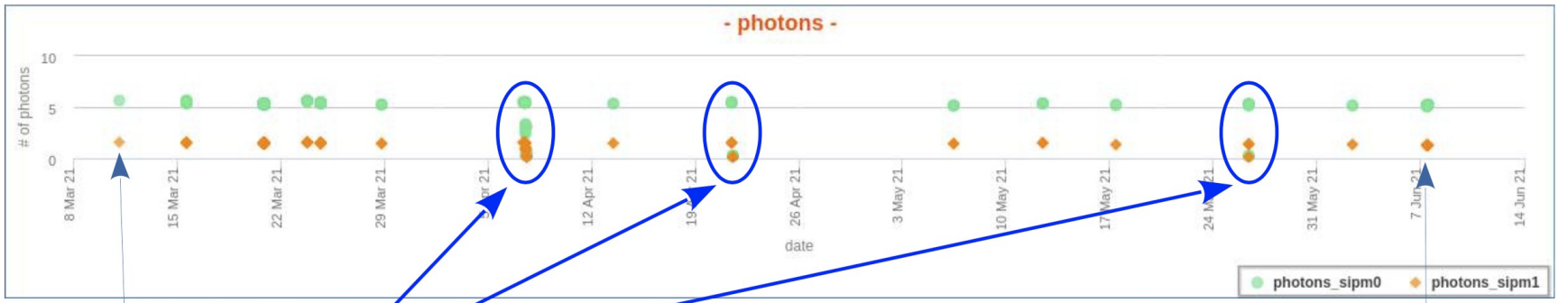








fitted number of photons



March 11th

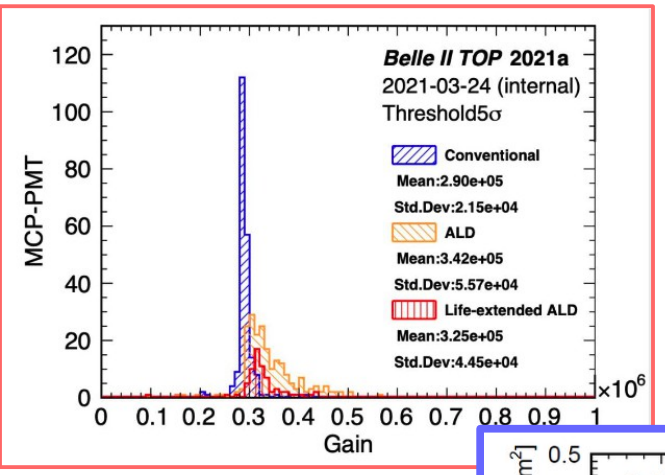
change in laser tune

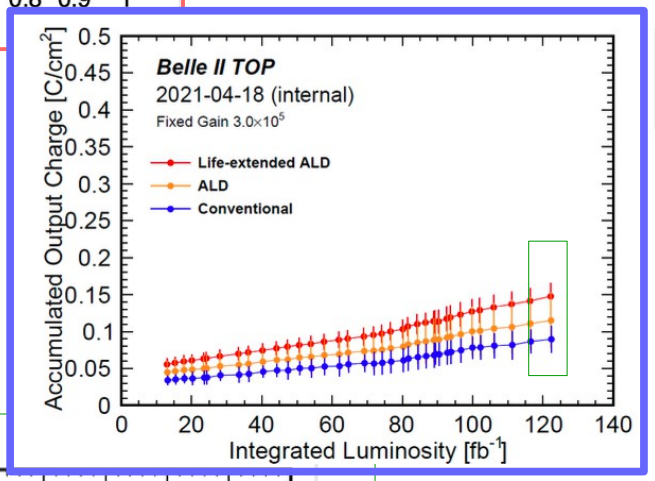
June 7th

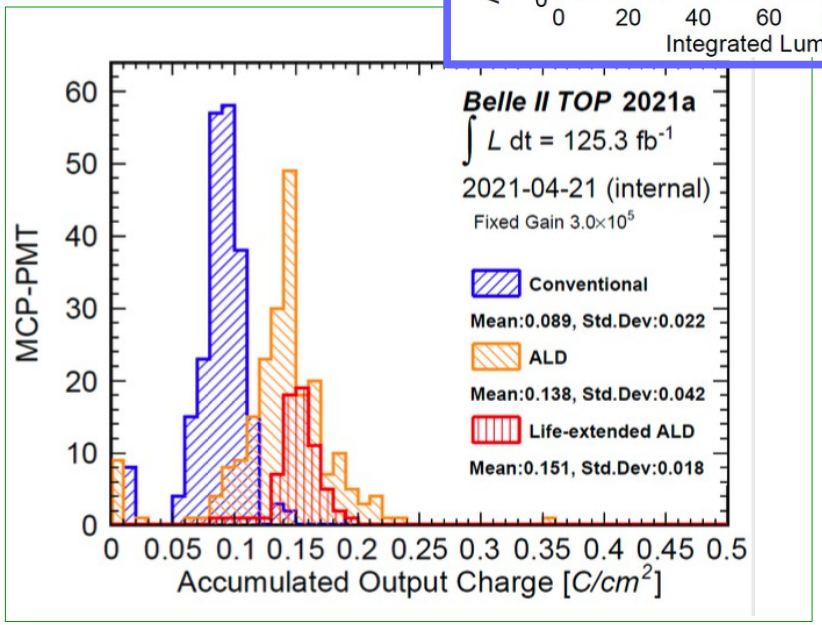
fitted photon times

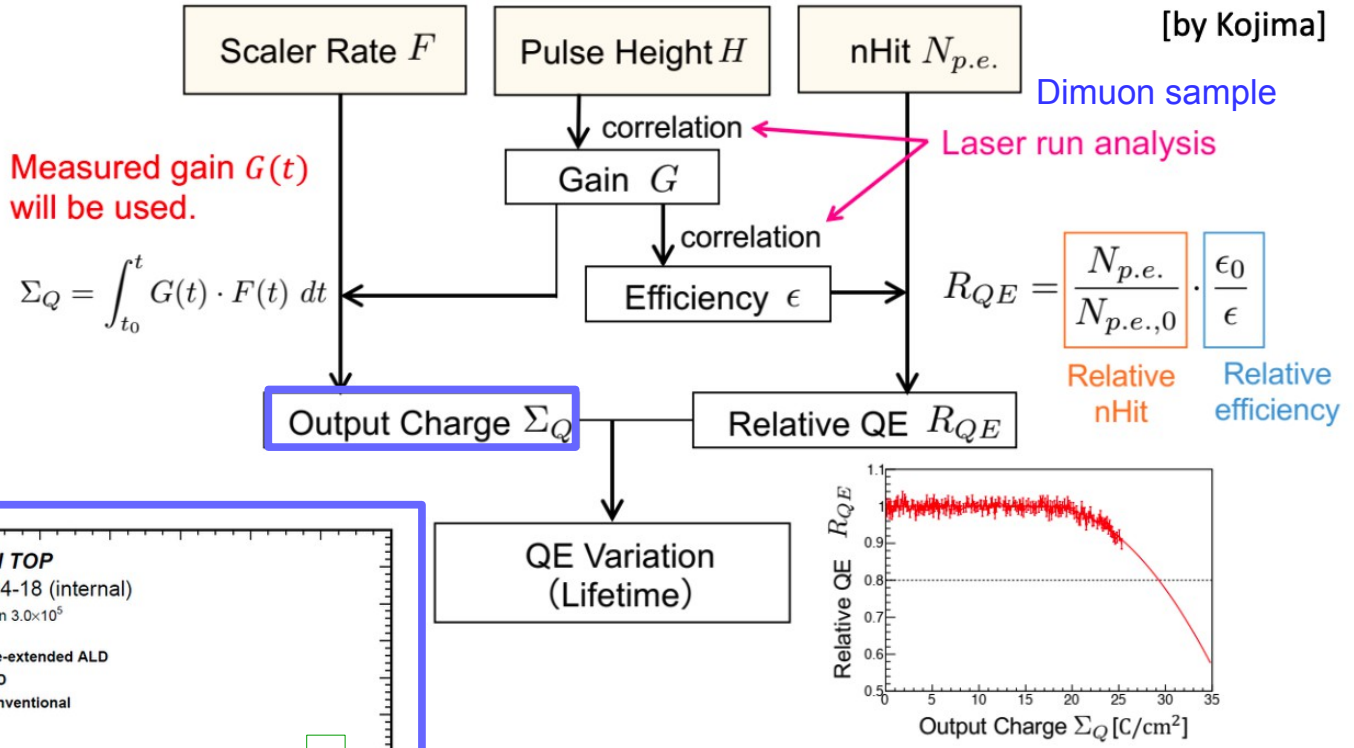
TOP aging monitor

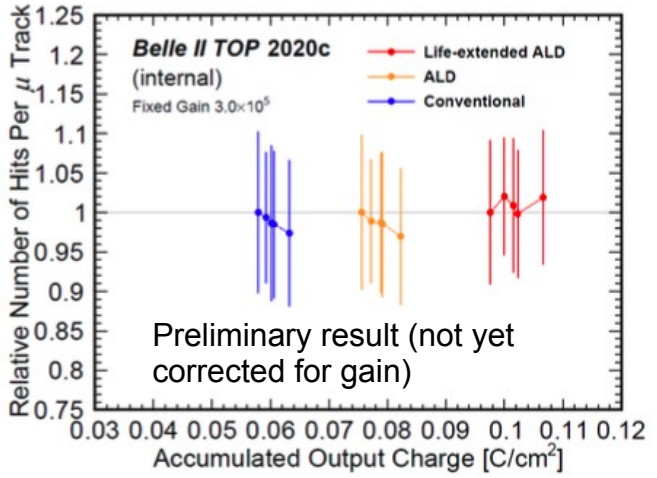
[by Kojima]









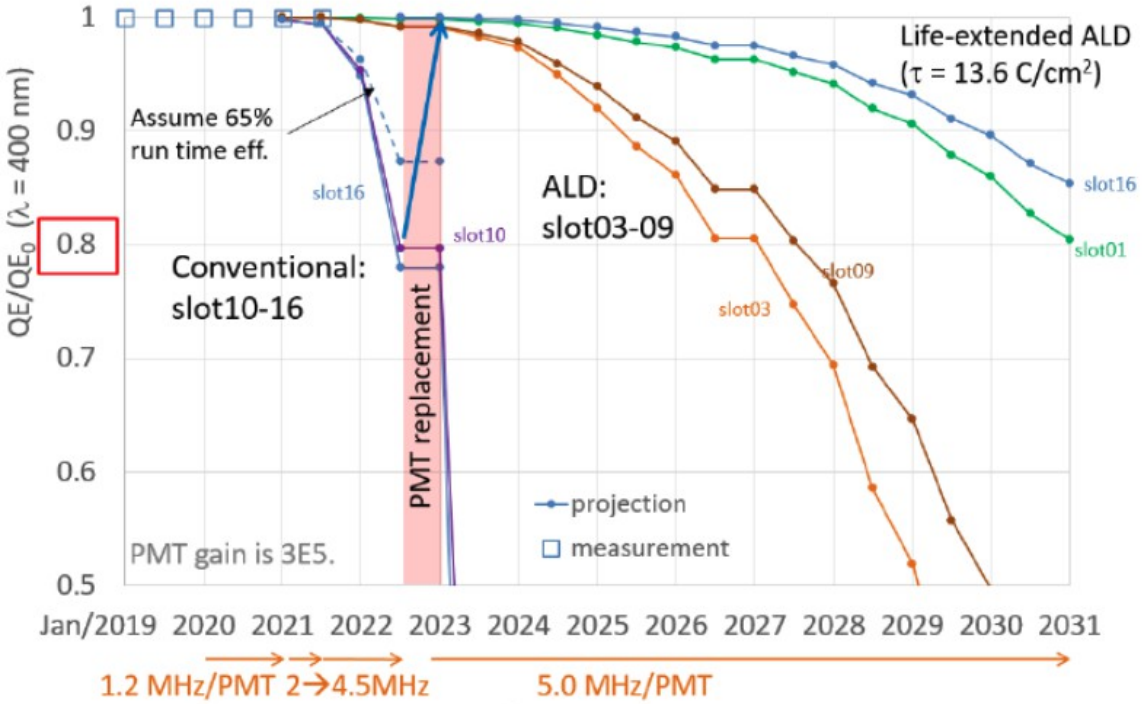


Conventional MCP-PMT accumulated 0.089 C/cm^2 so far, lifetime is ~1 C/cm^2: we should start see visible effects soon.
Effects seen only on few units : investigating ways to reduce systematics in gain monitoring measurements.

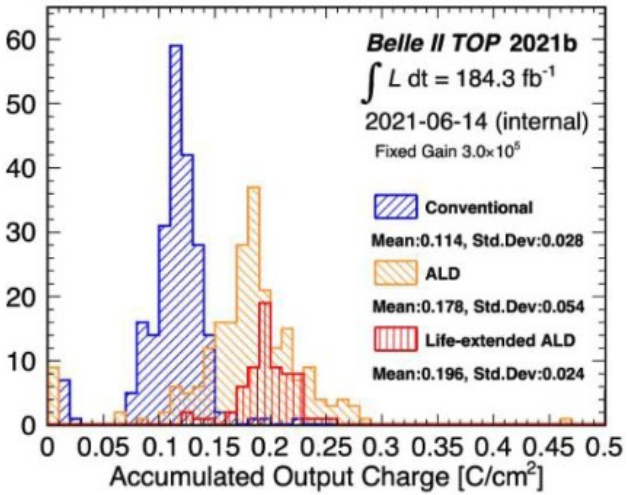
PMT lifetime projections

- **In order to have operational flexibility: request ➔ 5 MHz/PMT**
- Revised acceptable PMT hit rate based on the current accumulated charge etc.
- At maximum, 4.5MHz/PMT is acceptable.
  - If assume ~80% run-time efficiency, 5MHz/PMT should be OK.

Projection of QE degradation

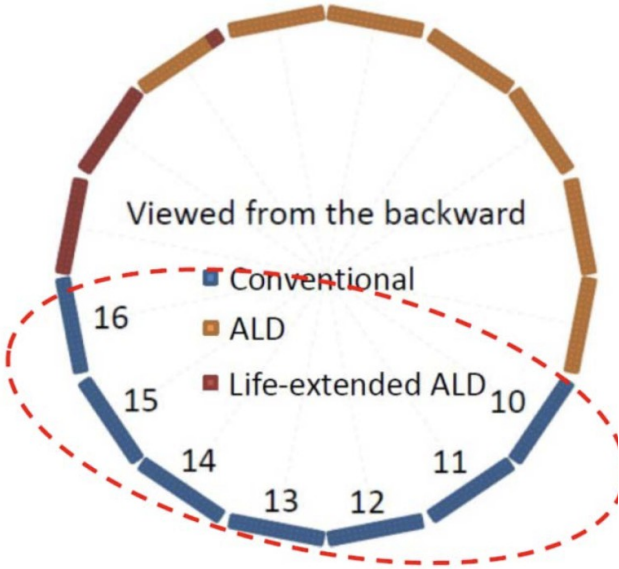


Assumption: The luminosity background follows 17th MC, scaling to the peak luminosity.
IntL~870fb^{-1}, Lp~5.7x10^{34} at 2022/June and 5months operation in 2022ab.



At ~10% expected lifetime Conventional MCP-PMT

2022 Replacements

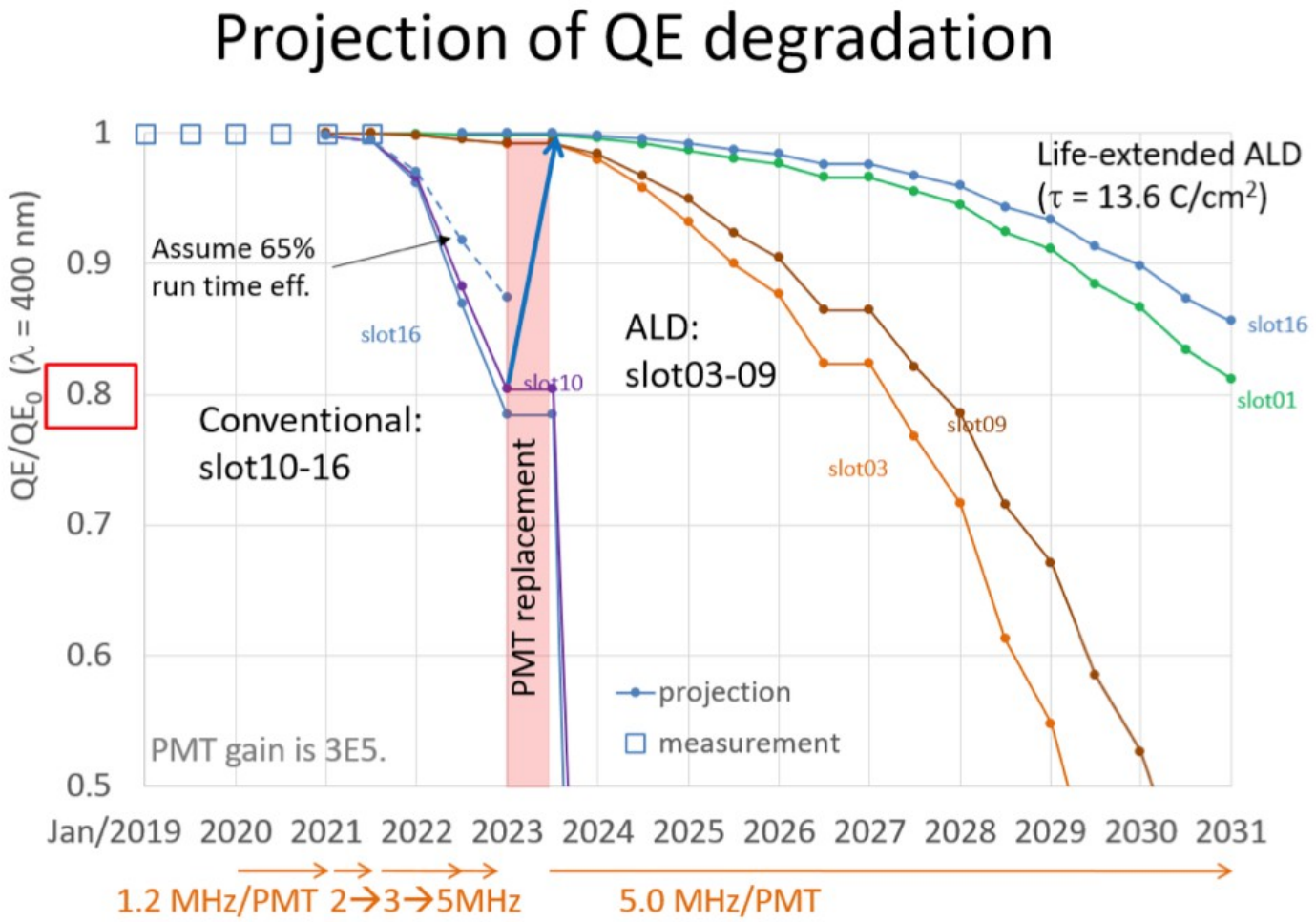


- **224 (of 512) MCP-PMTs (~44%)**
  - **All procured, testing complete**
  - **Assembly into modules (details below)**
- **Some number of readout boardstacks**
  - **Spare/replacements tested multiple times in Hawaii**
  - **Now staged at KEK and ready**
    - PMT module assembly
      - Around 2021 winter; by Nagoya member (Nakano, Okubo and Inami)
      - Need 11 days to assemble

	2021 4 - 6	2021 7 - 9	2021 10 - 12	2022 1 - 3	2022 summer
Improvement R&D	→ (Initial training)				
Optical cookie production		→			
PMT module assembly			→		
Installation work	→ (CDC mockup)	→ (Training with mockup)			

QE degradation IF TOP replacement is delayed

- In case that LS1 starts from 2023 January.
- At maximum, 3MHz/PMT by 2022ab, 5MHz/PMT by 2022c looks OK.



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TOP summary , prospects

- TOP ALD PMT rate limit is raised up to 5 MHz/ PMT .
- We DO NOT observe performance deterioration with high rate
- HOT PMTs are increasing, in one side of each SLOT : causes not clear
- Outer layer PMTs at the center of each slot are drawing increasing currents
- TOP performance : improved hadron modeling including photon emission from delta rays; some bug is affecting electron modeling. Azimuthal and charge asymmetries under investigation.
- Porting core code from Fortran to C++ completed, will be fully implemented in the next MC releases and PDFs.
- Aging effects on PMT QE and gains are being monitored (Nagoya) : changes in QE are observed only in few clusters of bad channels, but systematic errors still prevent a clear assessment. Work is in progress to evaluate SiPM replacement on the long term.
- The plan for PMT replacement is currently unchanged: covid-19 have slowed down PMT testing, but will be ready for installation in 2022
- A plan for Boardstack replacement is ready, using UH spares
- The PD SiPM laser stability monitor system is installed , and working smoothly in automated mode.

Richieste 2022

Per PD+TO:

18 kEu MISS Turni sottorivelatore TOP : 3 m.u. (assumendo 4.5 mesi di presa dati) assumendo di dover garantire 2 TOP Experts al giorno, frazione italiana :1/3

Per Padova :

6 kEu MISS Contributo installazione PMT @ KEK (4 settimane/uomo)

6 kEu INV Stage XY motorizzato, per test di uniformità nella risoluzione temporale di SiPM di grandi dimensioni

Per Torino:

6 kEu MISS Contributo installazione PMT @ KEK (4 settimane/uomo)

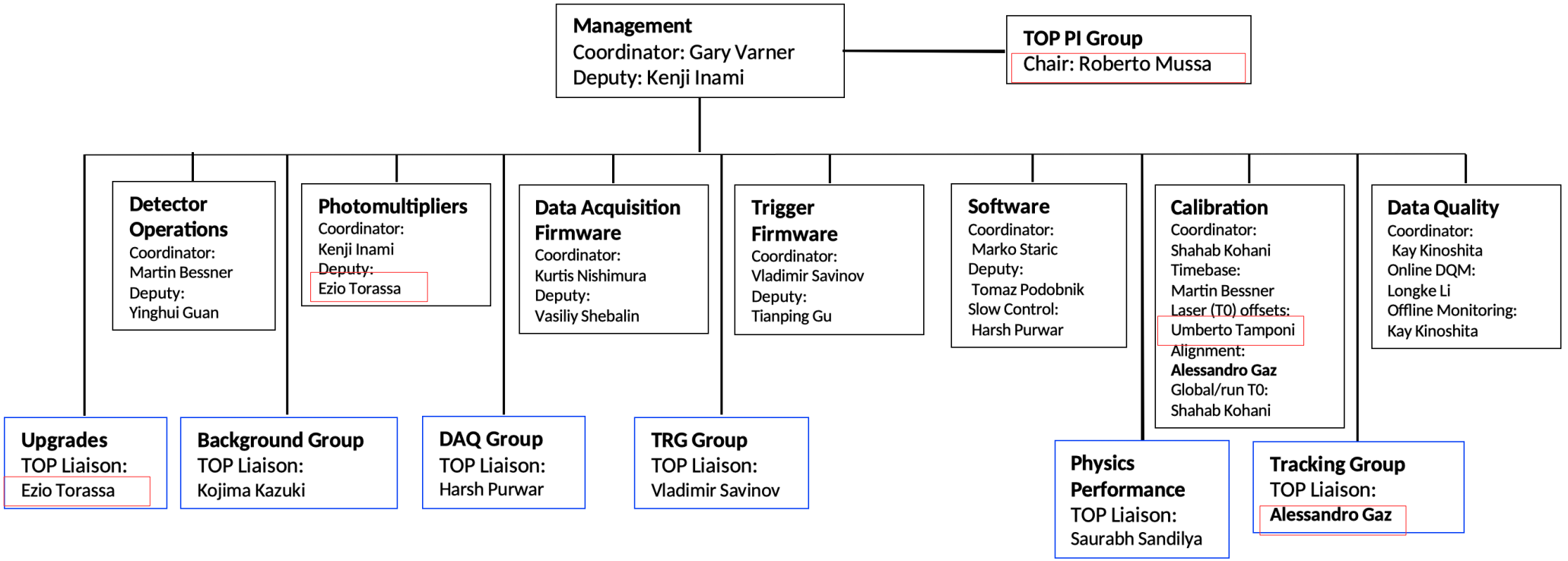
5 kEu INV Front End Boards per Test su SiPM (*)

(*) In sinergia con AIDAinnova*

Ruoli italiani nel TOP

Belle II TOP Organisation

24-JUN-2021



Current TOP Calibration Sub-tasks and Personnel

Type	Calibration	Source	Expert
Local Calibrations	Time-base calibration (TBC)	Double pulse	*Martin Bessner*
	Channel T0 Calibration (Local T0)	Double pulse	*Gian Luca Pinna Angioni / Umberto Tamponi*
	Pulse Height Calibration	Double pulse	*Gian Luca Pinna Angioni*
Channel Masking	Channel Masking	Run-dependent local DB	*Martin Bessner / Marko Staric*
Post-tracking Calibrations	~~Geometric alignment~~	~~cdst~~	*Alessandro Gaz*
	BS 13d calibration	cdst	*Umberto Tamponi*
	Module T0 calibration	cdst (bhabha or di-muons)	*Shahab Kohani / Alessandro Gaz*
	Global T0 calibration	cdst (bhabha or di-muons)	*Shahab Kohani*

CAF Script Expert: *Marko Staric*
TOP Calibration Coordinator: *Shahab Kohani*