Activities on the TOP and ARICH detectors of Belle-II

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on behalf of the Belle-II TOP and ARICH groups

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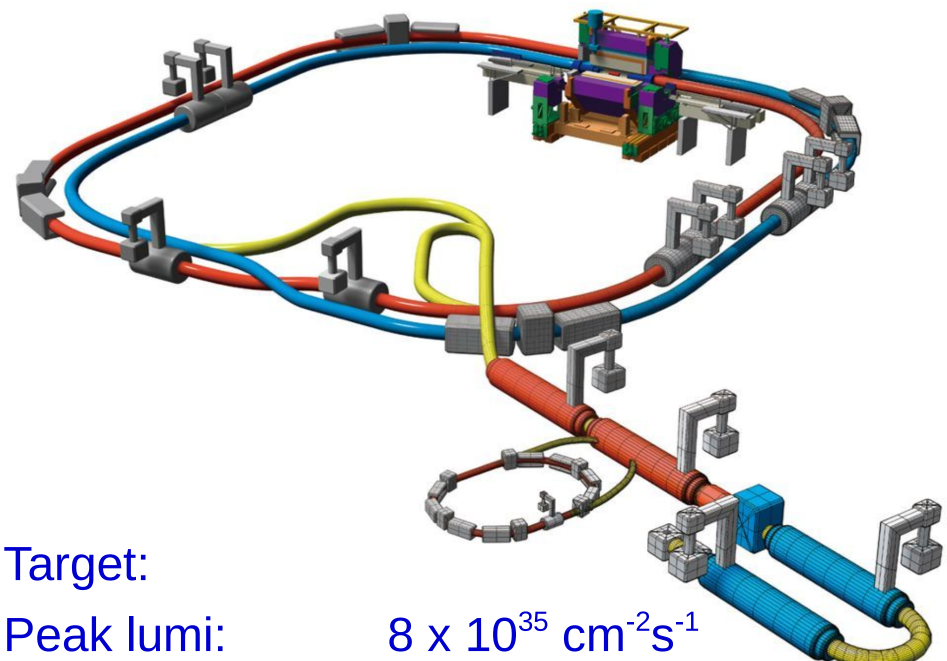
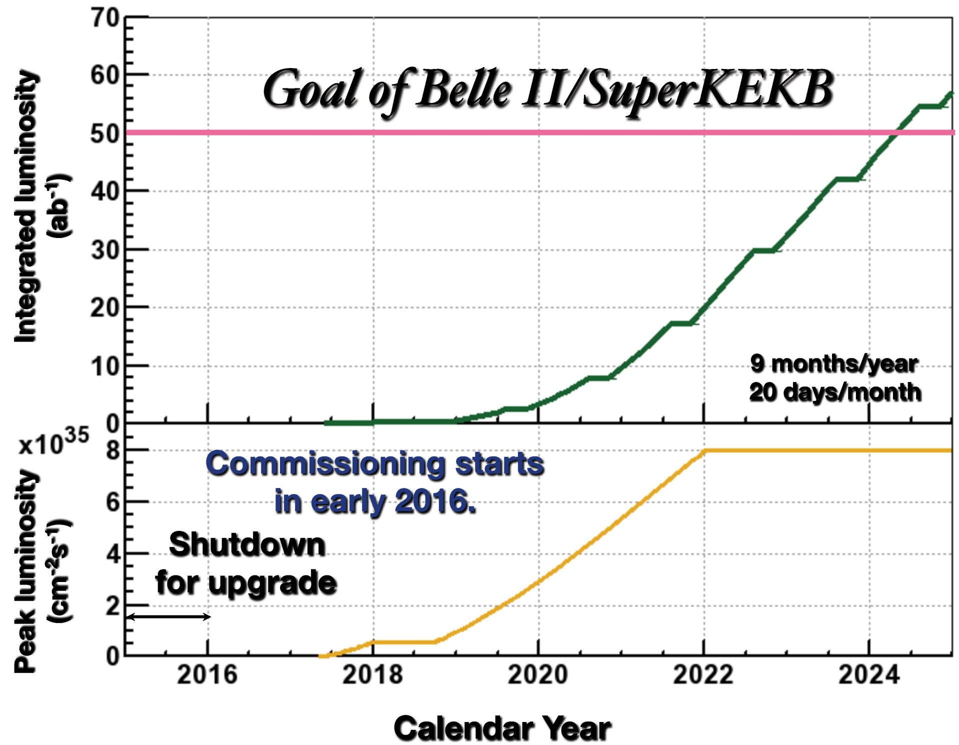
The Belle-II Experiment at SuperKEKB

- The Belle-II experiment will greatly extend the sensitivity of the previous generation of B-factories;
- This will be achieved thanks to the upgrade of the existing KEKB machine implementing the nano-beam design and larger crossing angle...;



- … plus several other upgrades!



Target:

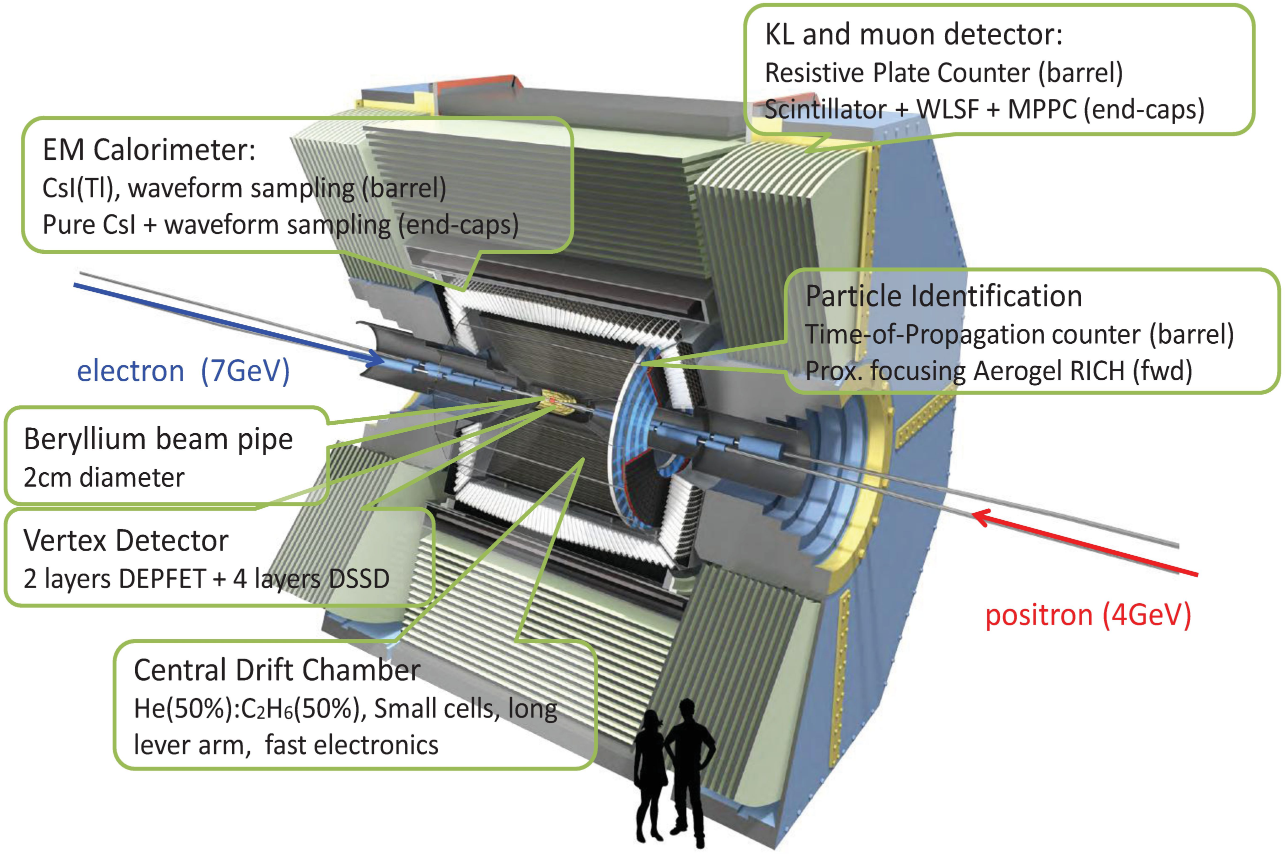
Peak lumi: 8×10^{35} cm^{-2}s^{-1}

Integrated lumi: 50 ab^{-1} by 2024 (20 ab^{-1} by 2022)

At the Y(4s): 1 ab^{-1} ~ 10^9 $B\bar{B}$ pairs

The Belle-II detector

- There is an extensive upgrade ongoing also on the detector side, to fully exploit the physics potential and cope with the more challenging machine conditions;



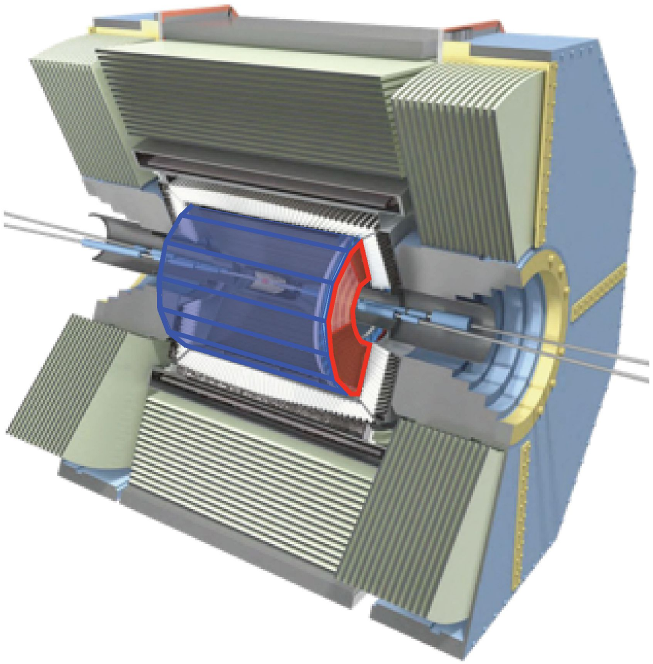
- Major upgrade on Particle Identification capabilities, crucial for the Belle-II physics programme:
  - Clean separation of final states ($B \to K\pi, \pi\pi, \ldots$);
  - Control and suppression of backgrounds;
  - B flavor tagging.

TOP and ARICH

- PID information comes from all the subdetectors: e-ID is dominated by the ECL, μ-ID comes from the KLM, the SVD and CDC trackers provide dE/dx measurements;
- The TOP and ARICH are (mostly) devoted to the separation of charged π and K;
- Common concept: measure the angle of the Cherenkov light emitted when the particles traverse a medium and derive the particle velocity:

$$\cos\theta_C = \frac{1}{n\beta}$$

- Combine this with the momentum measured by the tracking system, and discriminate between π and K.

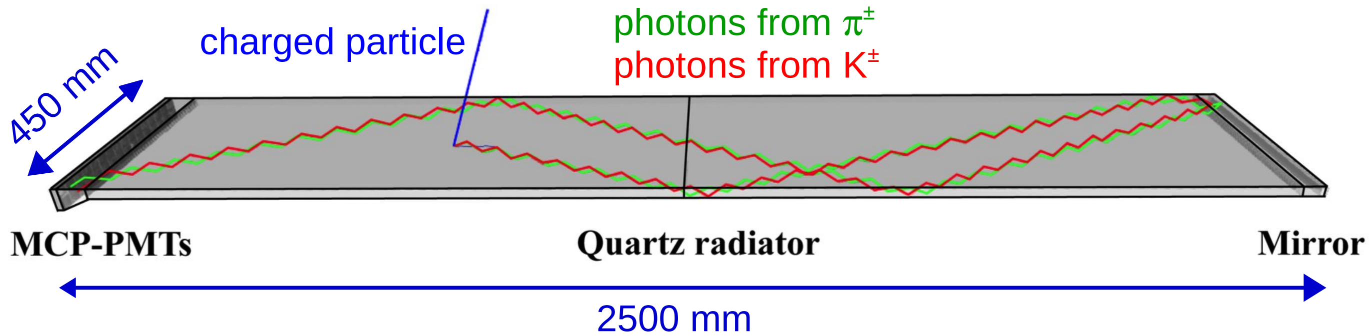


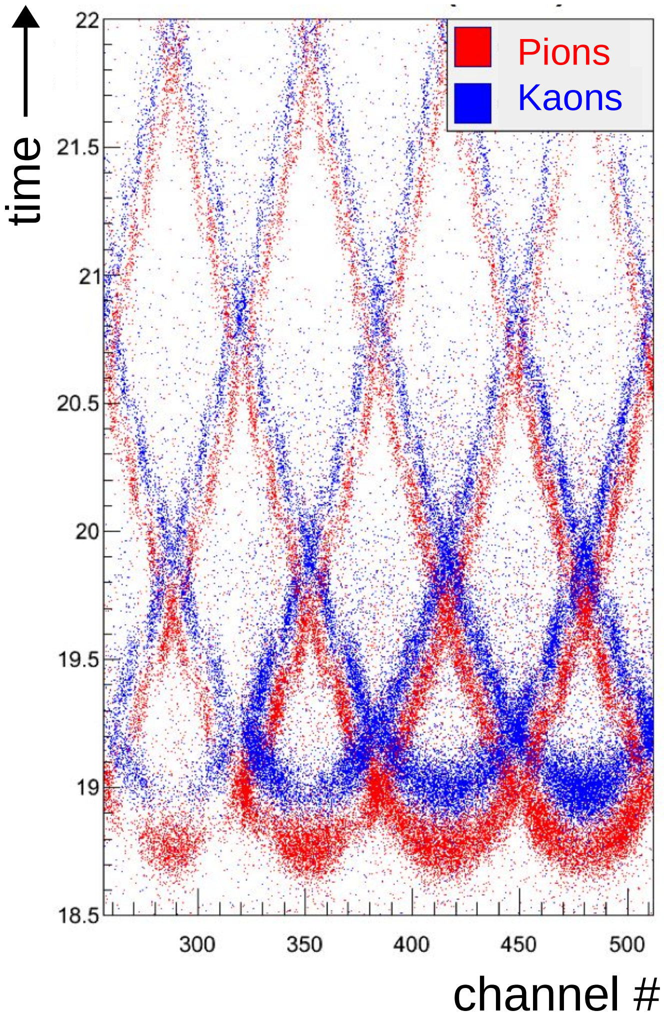
Barrel PID: TOP
Endcap PID: ARICH

Performance:	Belle-II	Belle
π/K selection eff.	$\geq$ 95%	~90%
with π/K mis-ID prob.	$\leq$ 5%	10-15%
(using also dE/dx from trackers)		

TOP: detector concept

- The charged particles emit Cherenkov light when traversing a 2cm thick quartz radiator:





- For a given direction of emission, the "Time Of Propagation" (and the number of reflections) of the photons will depend on the Cherenkov angle;
- The Cherenkov angle is derived from the measurement of the position and time of arrival of the photons at the MCP-PMT photo-detectors;
- Time resolution is crucial, must be < 100 ps!

Details on the MCP-PMT's will be covered later today

TOP: construction schedule

	Mechanical Assembly		Electronics Integration
	Start	Finish	Complete
Module 1	Oct 2014	Nov 2014	Feb 2015
Module 2	Mar 2015	Apr 2015	
Module 3	April	April	
Module 4	May	May	
Module 5	June	construction underway	
Module 6	June	July	
Module 7	July	August	
Module 8	August	September	
Module 9	September	October	
Module 10	October	October	
Module 11	November	November	
Module 12	November	December	
Module 13	Jan 2016	Jan 2016	
Module 14	Jan	February	
Module 15	March	March	
Module 16	March	April	
Module 17	April	May	
Module 18	May	May	

TOP detector:

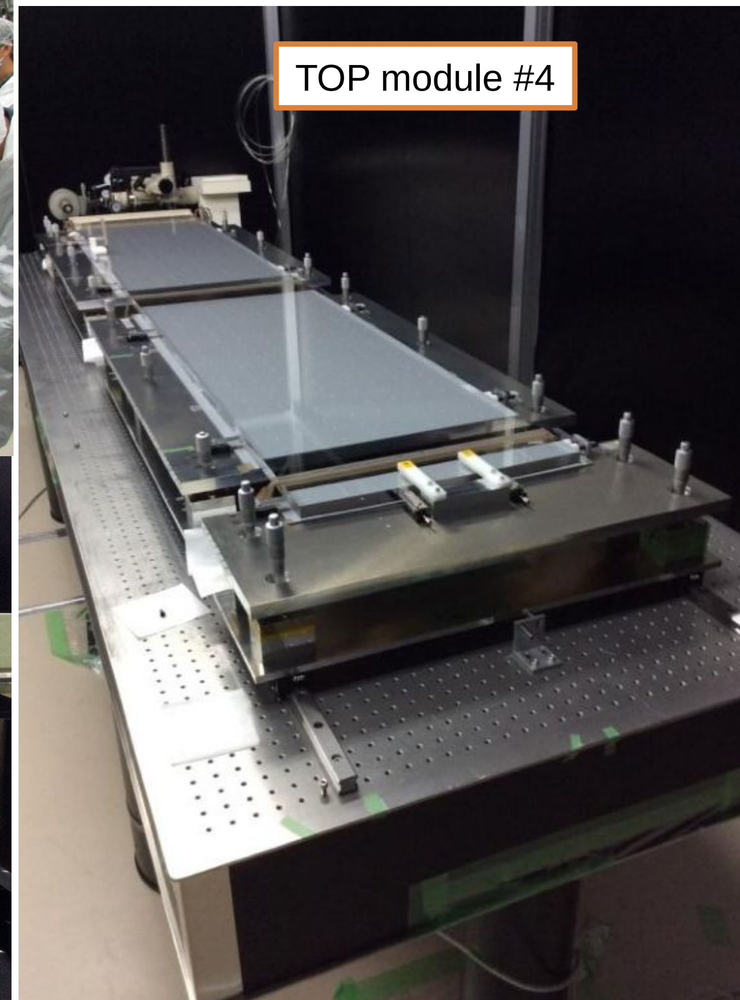
16 modules + 2 spares

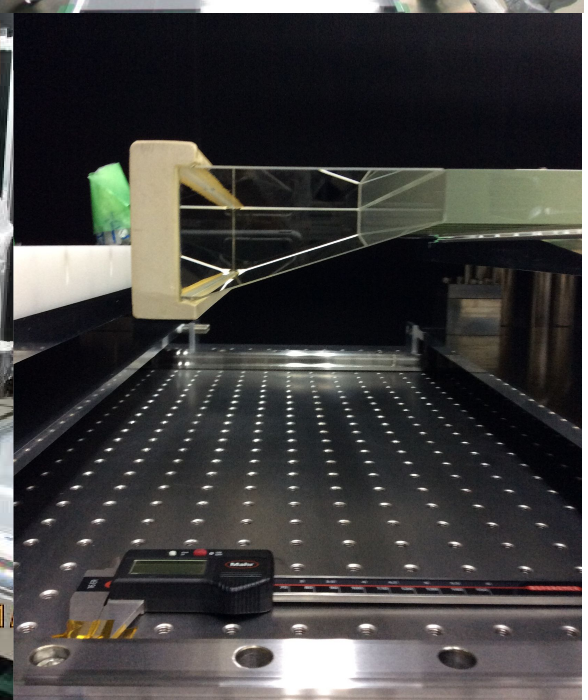
The construction of a module takes about 3 weeks.

Some initial delays due to problems in the gluing procedure can be recovered by re-organizing the construction procedure, saving some time here and there.

We are on track for having all the modules glued, instrumented, and tested by Spring 2016, in time for the installation.

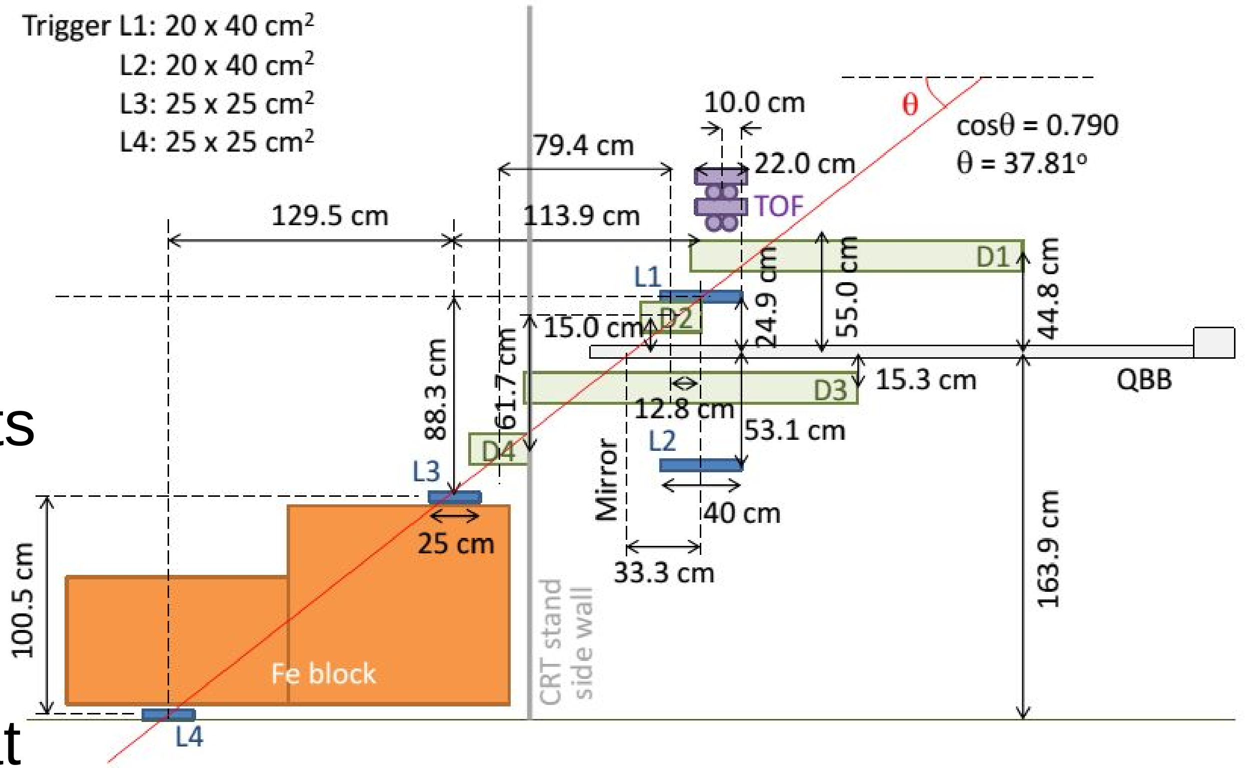
TOP: construction





TOP: Cosmic Ray Test

- A "Cosmic Ray Test" setup is in place in the Fuji Hall;
- Individual TOP modules can be tested with either laser or cosmic rays;
- Tracking is provided by sets of drift tubes;
- We can veto low momentum μ's and π's from showers requiring that they traverse a thick layer of iron;

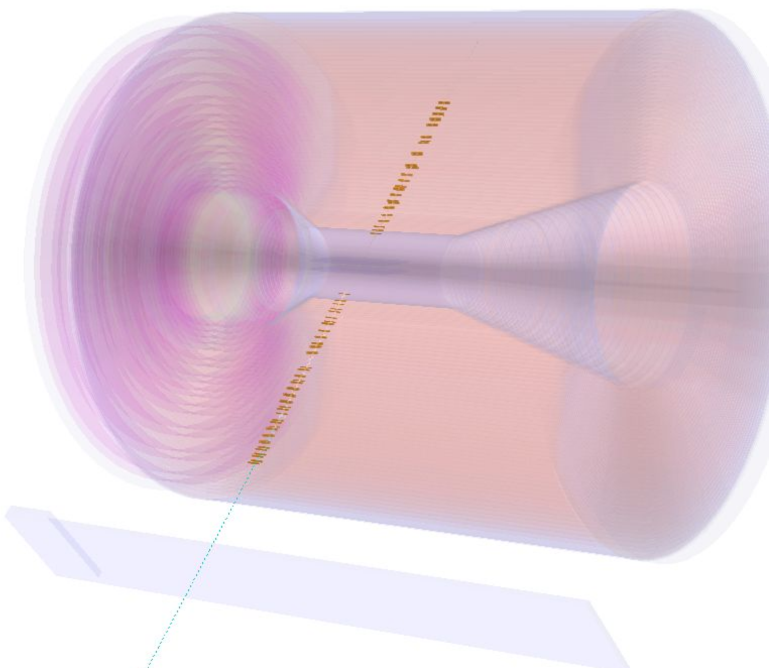


- Goals:
  - test full readout chain;
  - quality control: spot unwanted features (e.g. reflections from defect on gluing, …);
  - characterize performance on real data.

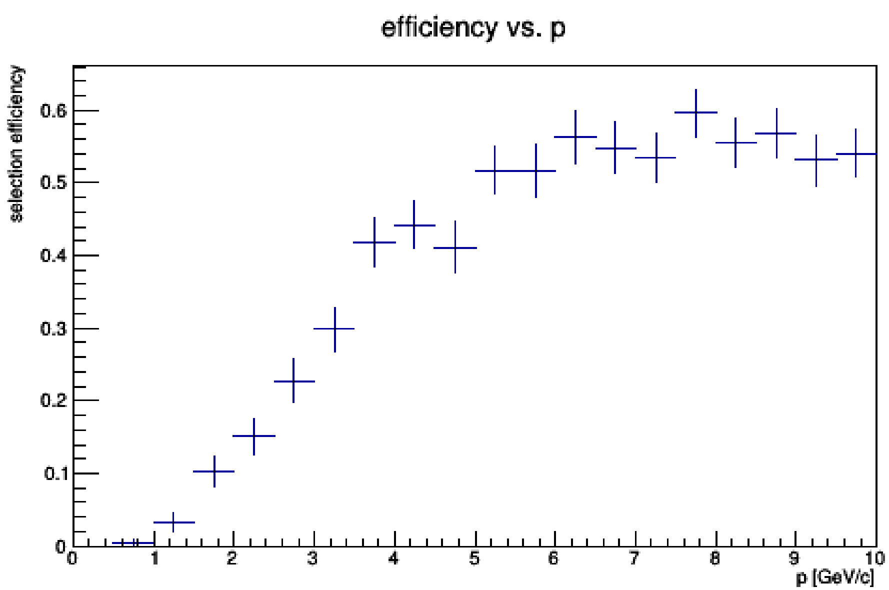
TOP: Cosmic Ray Test

- The current CRT setup is very useful for carrying out a set of important preliminary tests on each module;
- However:
  - the μ acceptance is pretty low (due to size of trigger pads);
  - the tracking capabilities of the drift tubes are quite limited (resolution ~5-10 mrad);
- To overcome these limitations, a combined TOP-CDC run, using just one TOP module, has been devised;
- Can achieve resolution at the 1-2 mrad level;
- Goal: validate PID likelihood function with realistic tracking resolution;
- It's also a good exercise towards a cosmic run with many subdetectors integrated.

Combined TOP-CDC run



- We plan to place a TOP module ~45 cm away from the outer edge of the CDC, collecting μ's at $\theta = 45^{o}$ from the zenith;
- Trigger pads and a lead absorber will be placed in the center of the CDC;
- Tracks will be selected requiring consistency between the two segments and dE/dx compatible with a MIP;
- With an expected rate of 0.7 Hz and a data-taking efficiency of ~30%, we expect to collect more than 500k good tracks;
- This sample should be sufficient for a useful validation of the TOP PID likelihood.



TOP: secondments plan

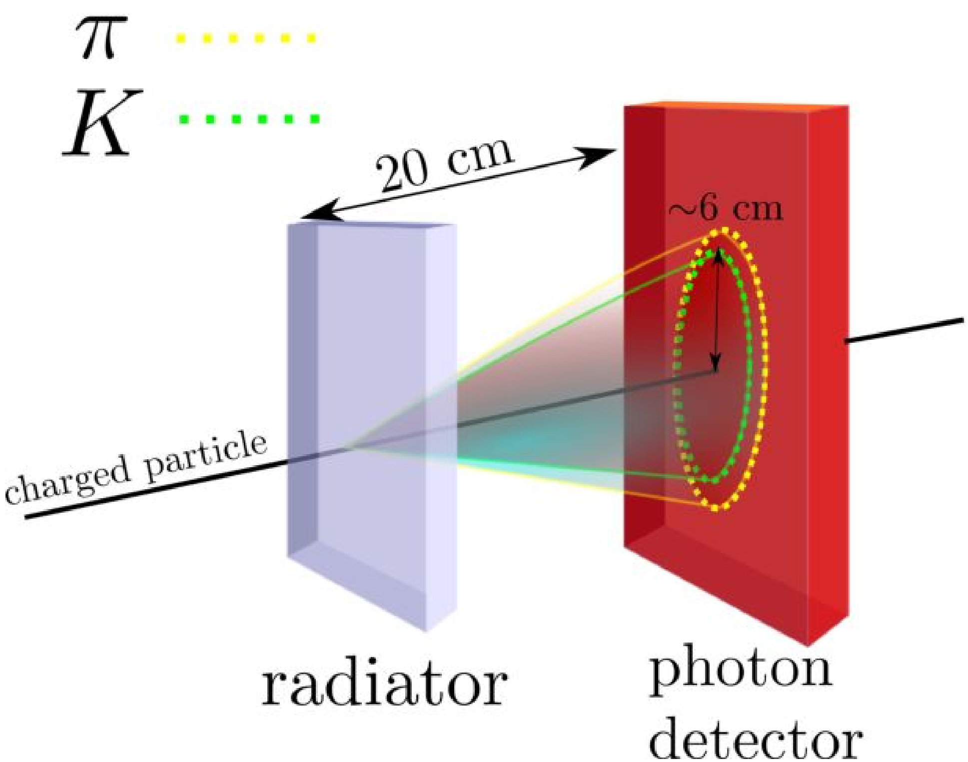
Within the JENNIFER program we plan to continue our contribution in two major areas:

- Construction:
  - ➔ continue our participation in the construction operations (alignment, gluing, electronics testing);
- Commissioning:
  - ➔ continue involvement with the current CRT setup;
  - ➔ we are going to have a major involvement in the CDC-TOP run, scheduled for this Fall;

Plans for further commissioning will evolve as we gain more experience with the current setup.

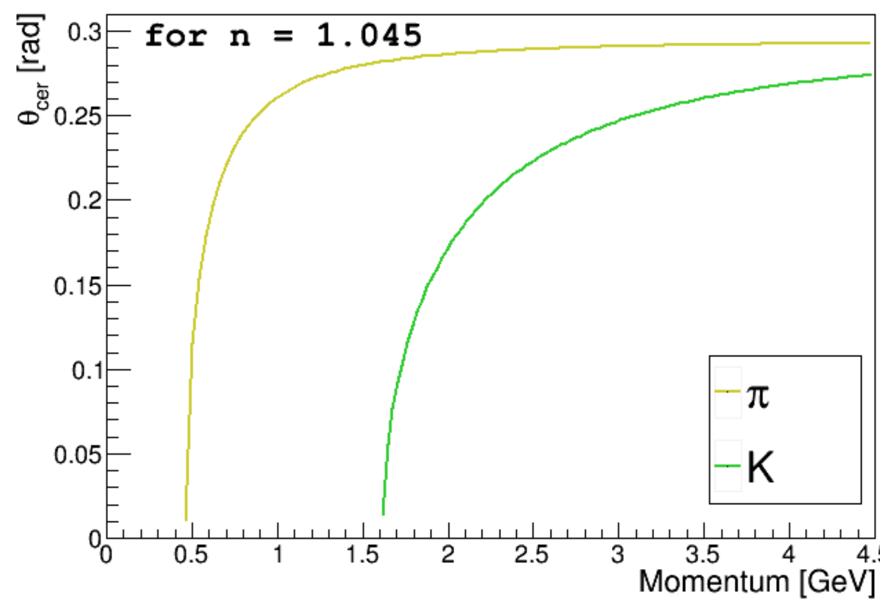
ARICH: detector concept

Goal:
4σ separation, at 1.0 - 3.5 GeV



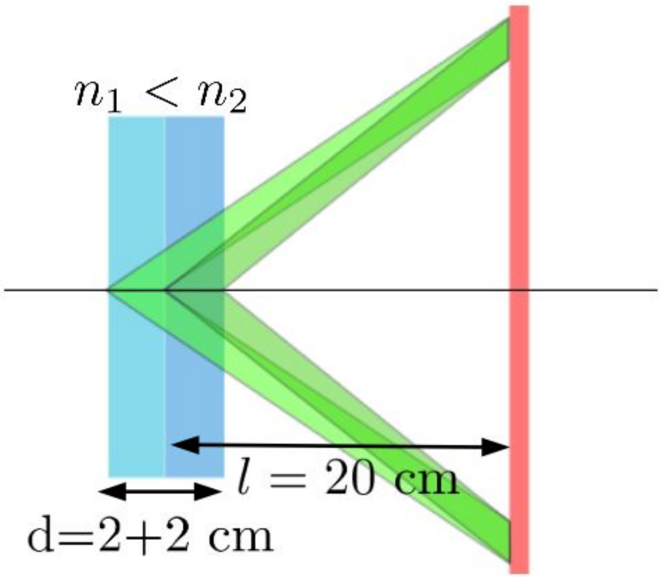
Details on the HAPD photo-detectors
will be covered later today

Constraints:
- in 1.5 T magnetic field.
- limited available space ~ 28 cm.
- radiation hardness (n, γ).



$\theta_C(\pi) - \theta_C(K) \sim 30$ mrad @ 3.5 GeV

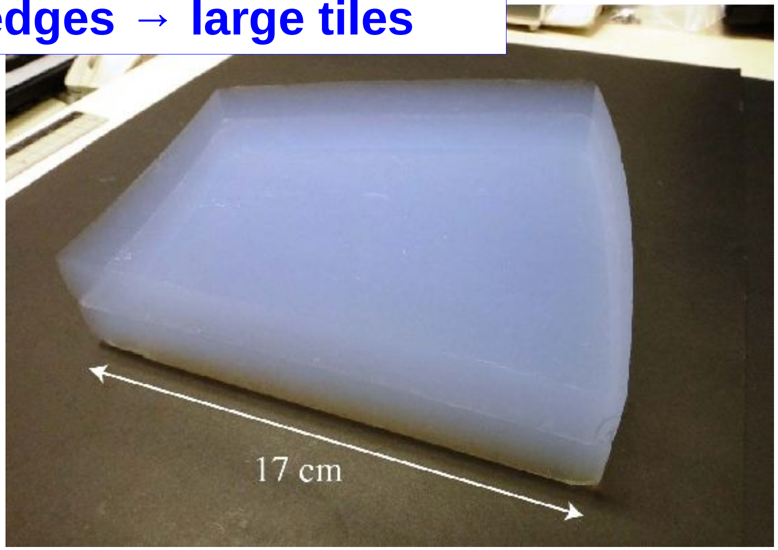
ARICH: aerogel

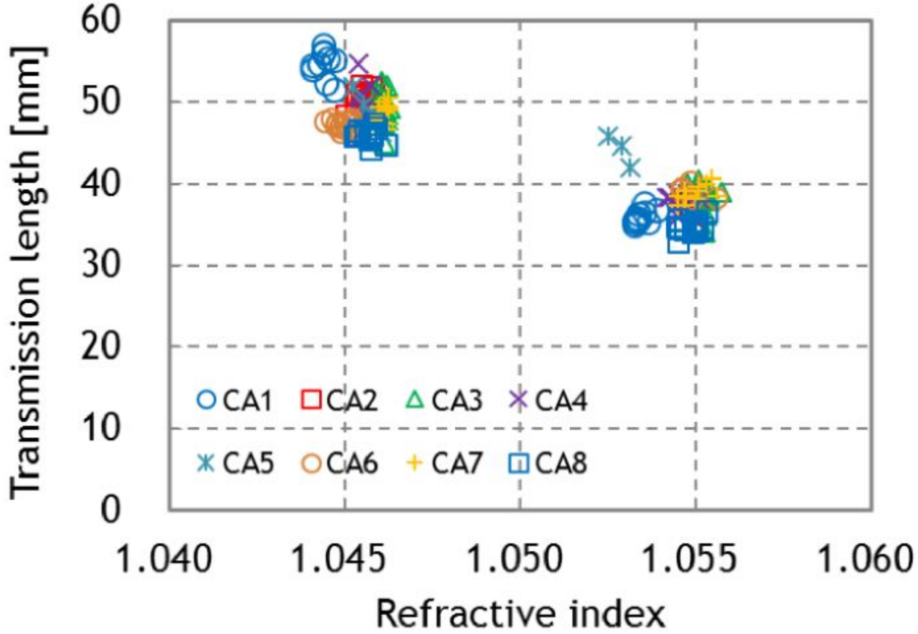


Two aerogel layers in focusing configuration:
n_1=1.045, n_2=1.055
Overlapping rings from 1st and 2nd layer
High transmission length is required (>30 mm).

Mass production is finished, relatively stable transmission length and refractive index

Minimize photon loss on the edges → large tiles





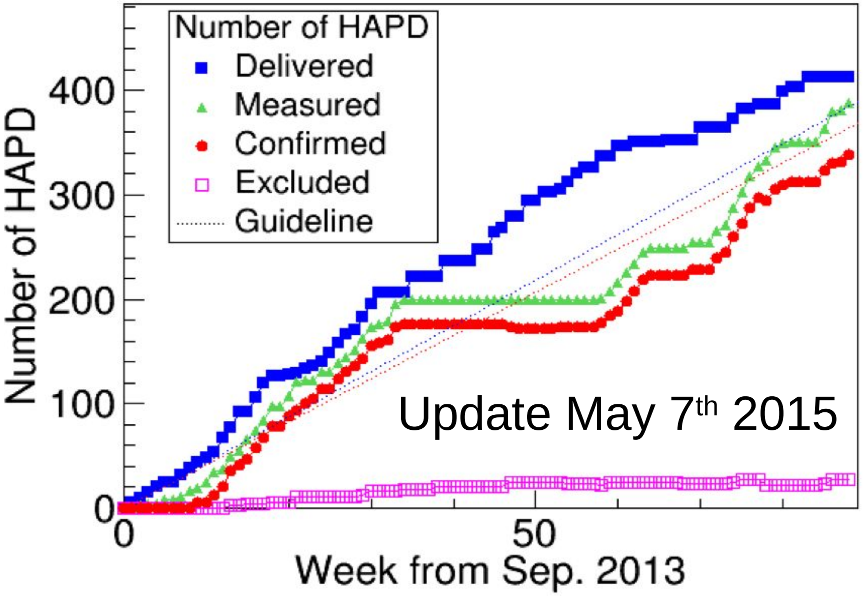
ARICH: status and plan

- Finalize the FE read-out electronics: spark protection seems to be working well, preproduction boards have been ordered;
- QA test station for FE boards has been set-up in Ljubljana, ready for the full scale test of boards once they are produced; database to store the results is ready;
- QA test station for final detector module, HAPD+FE board, has been commissioned in Ljubljana, to be transported to KEK for the full scale test. Database under preparation;
- Magnet test stand at KEK running routinely (long term studies, spark diagnostics).

ARICH: plan

- Next step at KEK: install the detector module QA test stand (this summer);
- Carry out the full scale (~400 HAPDs) QA prior to the installation in the ARICH detector (autumn);
- ARICH construction: autumn/winter;
- Commissioning with cosmics: winter/spring;

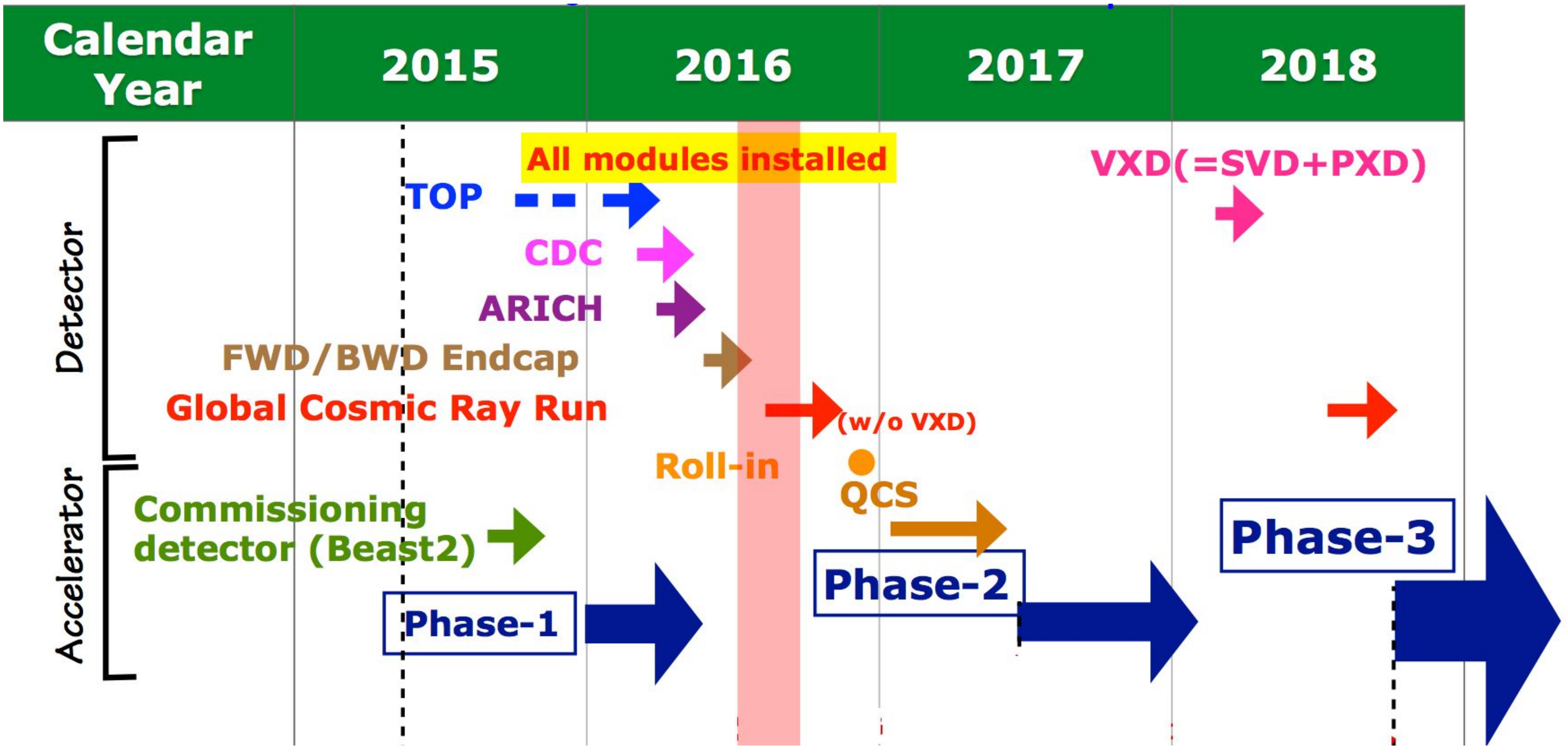
Delivered = 413 of of 450 + 26



Update May 7^{th} 2015

- The secondment plan for 2015 will match this activities, most secondments will happen during autumn.

Belle-II schedule

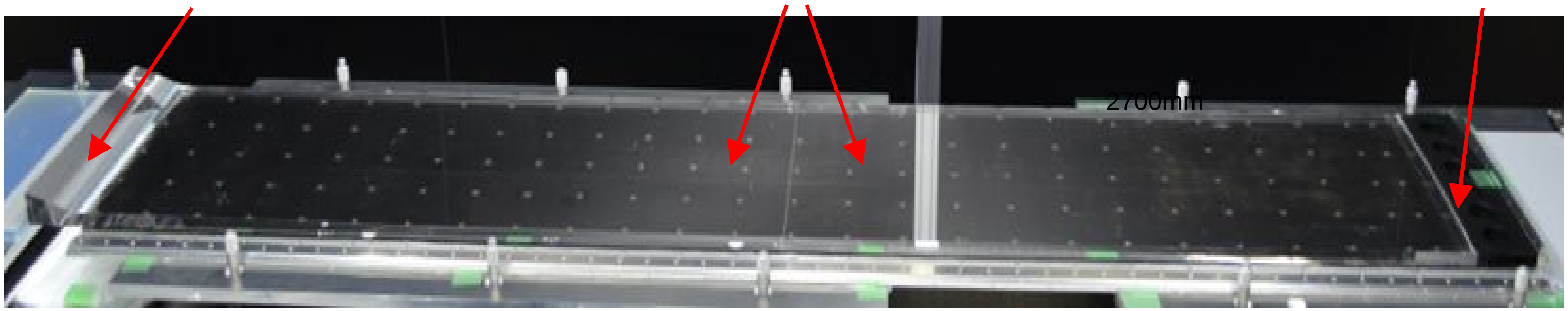


Outlook

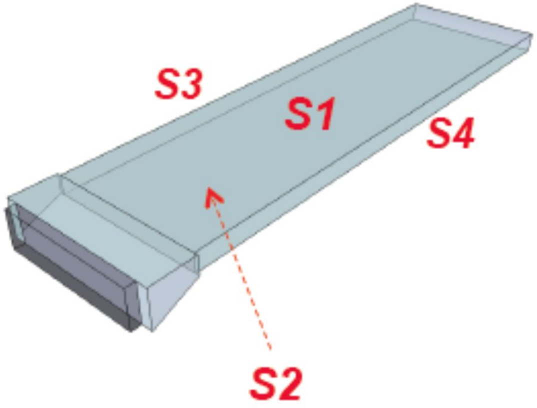
- Belle-II will be upgraded with two innovative PID detectors: TOP and ARICH;
- Strong effort within the JENNIFER project in the construction, testing, and commissioning of the detectors;
- The construction is in full swing, the schedule is tight but realistic;
- Commissioning on cosmic rays has started, now finalizing the plan for a combined CDC+TOP run, then move to the (almost) complete Belle-II cosmics run;
- The measured performance meets the expectations;
- No show-stoppers so far, we are on schedule to integrate the TOP and ARICH detector into Belle-II in Spring 2016.

Backup Slides

TOP: quartz bar requirements



High quality quartz surfaces required for multiple internal photon reflections

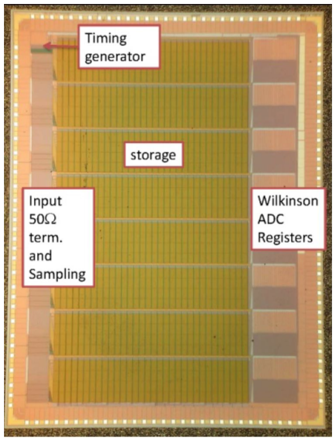


Flatness	< 6.3 μm	S1,S2,S3,S4
Roughness	< 0.5 nm (RMS)	S1,S2,S3,S4
Perpendicularity	< 20 arcsec	S1 ⊥ S3,S4
Parallelism	< 4 arcsec	S1 // S2

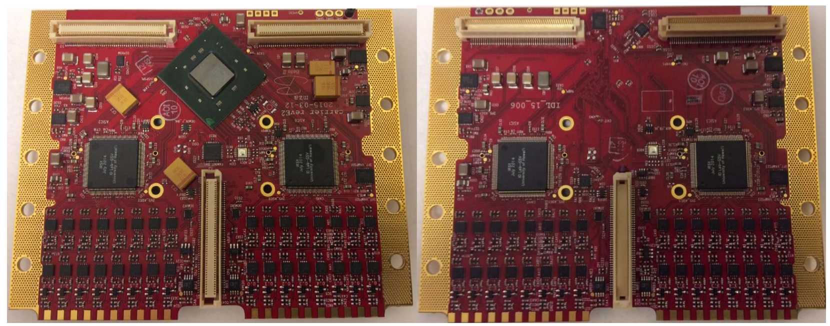
TOP: electronics

PMTs instrumented with electronics using high speed waveform sampling ASIC (IRSX)

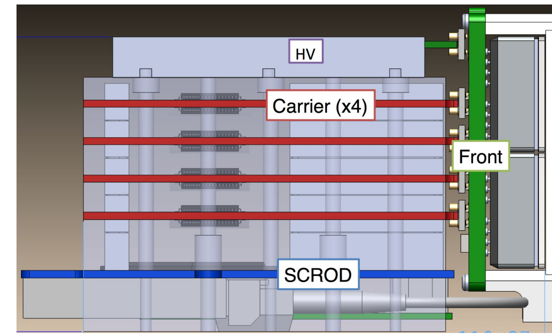
8 channels/chip 4 GHz ASIC



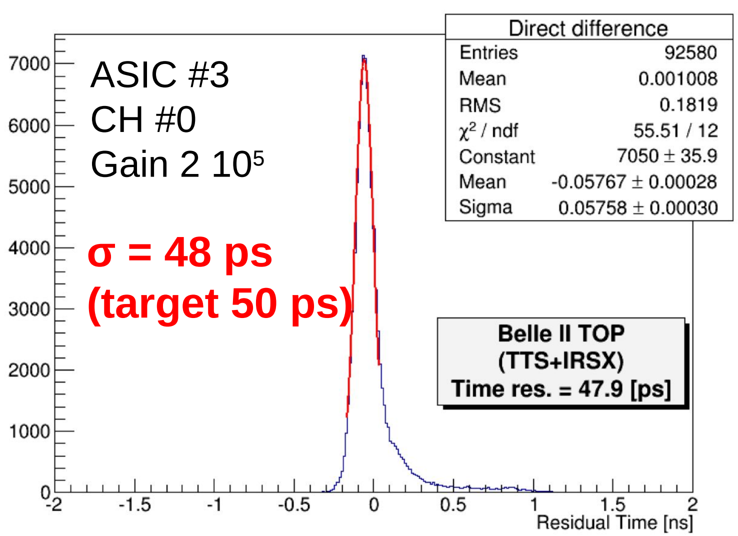
4 ASICs / Carrier board



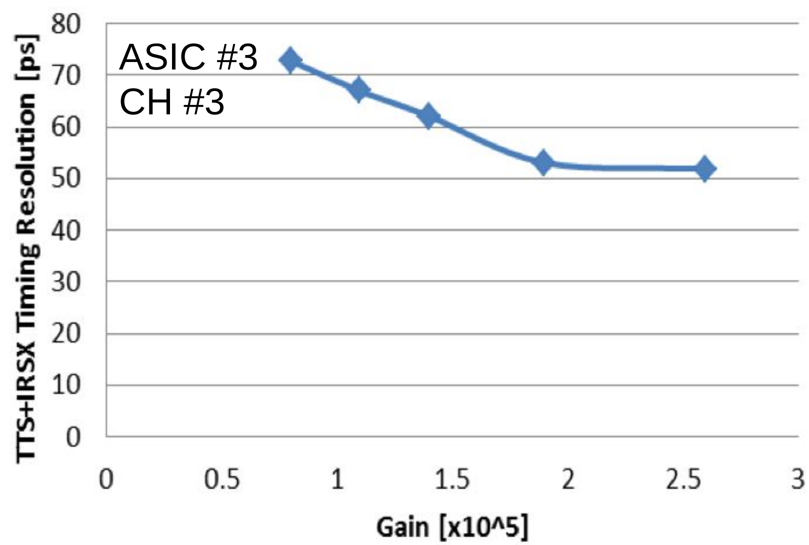
4 Carrier boards / 8 PMT



Time resolution of pulsed laser irradiation



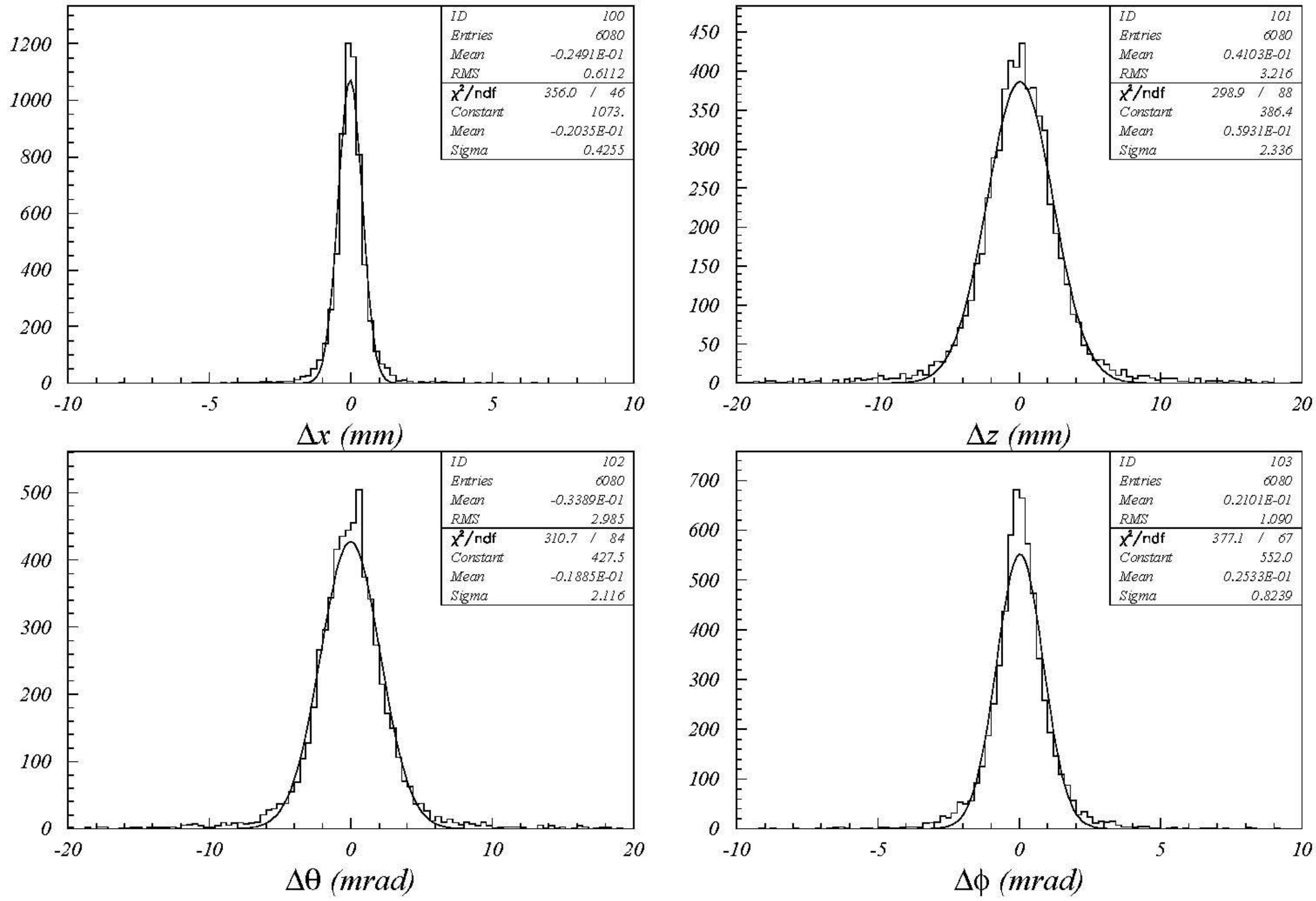
Time resolution as a function of the PMT gain



TOP: physics performance

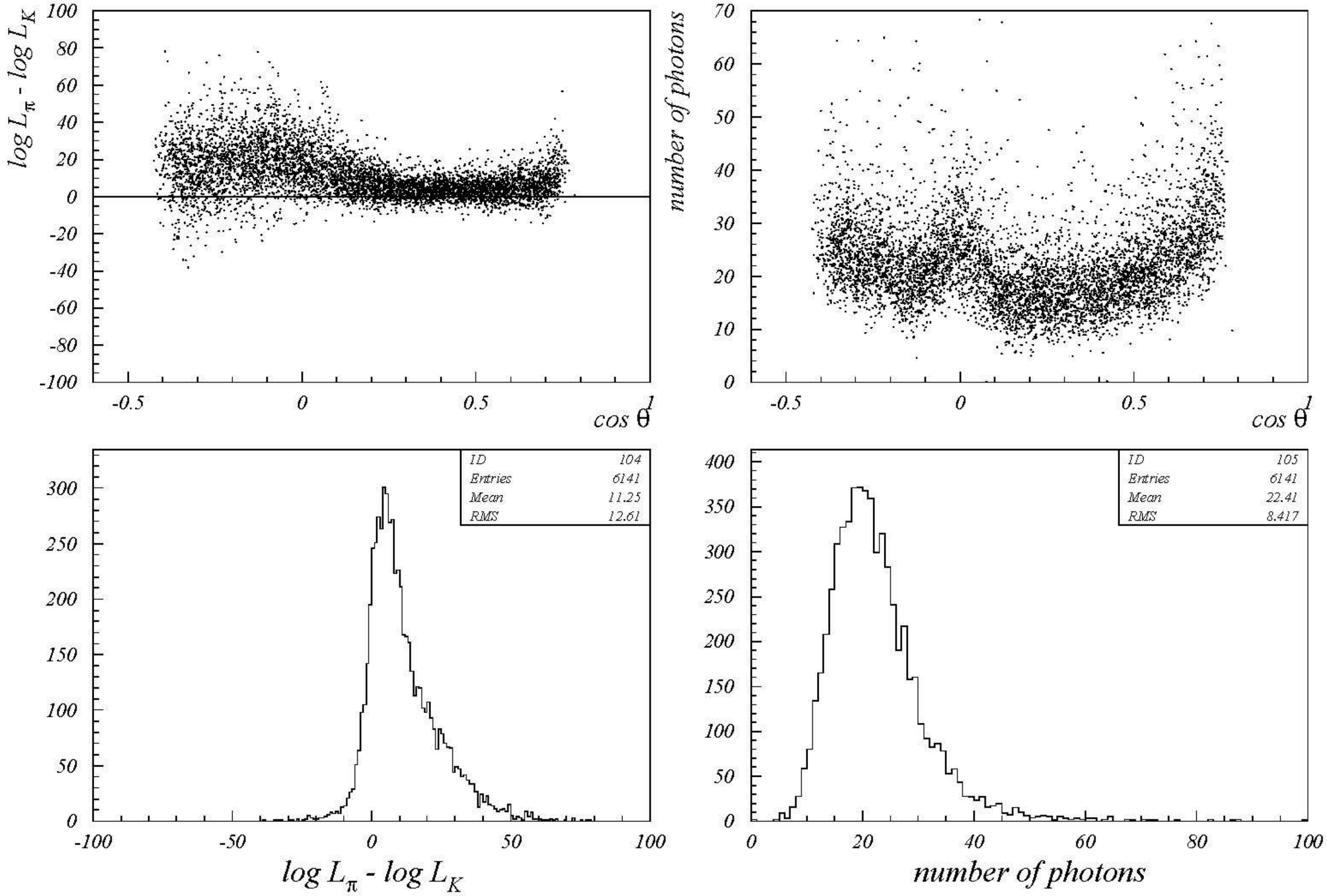
Decay mode	π efficiency with 2% K fakes π rate 100ps electronics jitter	π efficiency with 4% K fakes π rate 100ps electronics jitter	π efficiency with 4% K fakes π rate 50ps electronics jitter
$B \rightarrow \pi\eta\gamma$ vs $K\eta\gamma$	84.28 +/- 0.91	94.13 +/- 0.57	93.22 +/- 0.52
$B^+ \rightarrow \rho\gamma$ vs $K^*\gamma$	80.71+/-1.07	93.19+/-0.67	92.55 +/- 0.62
$B^0 \rightarrow \rho\gamma$ vs $K^*\gamma$	81.50+/- 0.78	92.63+/-0.49	92.13 +/- 0.46
$B^+ \rightarrow \pi\pi\pi^0\gamma$ vs $K\pi\pi^0\gamma$	83.55+/-0.76	94.03+/-0.46	93.47 +/- 0.43
$B^0 \rightarrow \pi\pi\pi\gamma$ vs $K\pi\pi\gamma$	79.50 +/- 0.67	91.48+/-0.45	92.56 +/- 0.38
$B^+ \rightarrow \pi\pi\pi\pi^0\gamma$ vs $K\pi\pi\pi^0\gamma$	75.00+/-0.72	90.50 +/-0.44	91.01 +/- 0.38
$B^0 \rightarrow \pi\pi\pi\pi\gamma$ vs $K\pi\pi\pi\gamma$	76.33+/-0.37	90.00+/-0.33	92.20 +/- 0.31

TOP-CDC cosmic run



Expected resolutions for a TOP module positioned at r = 165 cm

TOP-CDC cosmic run



Expected TOP performance for a TOP module positioned at r = 165 cm

ARICH: focusing configuration