ECL Forward Upgrade
JENNIFER Annual Meeting
October 30 2018

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Università di Perugia & INFN-PG

JENNIFER
EU grant n.644294

Outline

- Introduction
- FE Upgrade for BelleII ECL
- Upgrade of the CsI(Tl) to pure CsI in the FWD region
- Effect of pile-up on FWD ECL performance
- Phase 2 background studies
- Summary and conclusions

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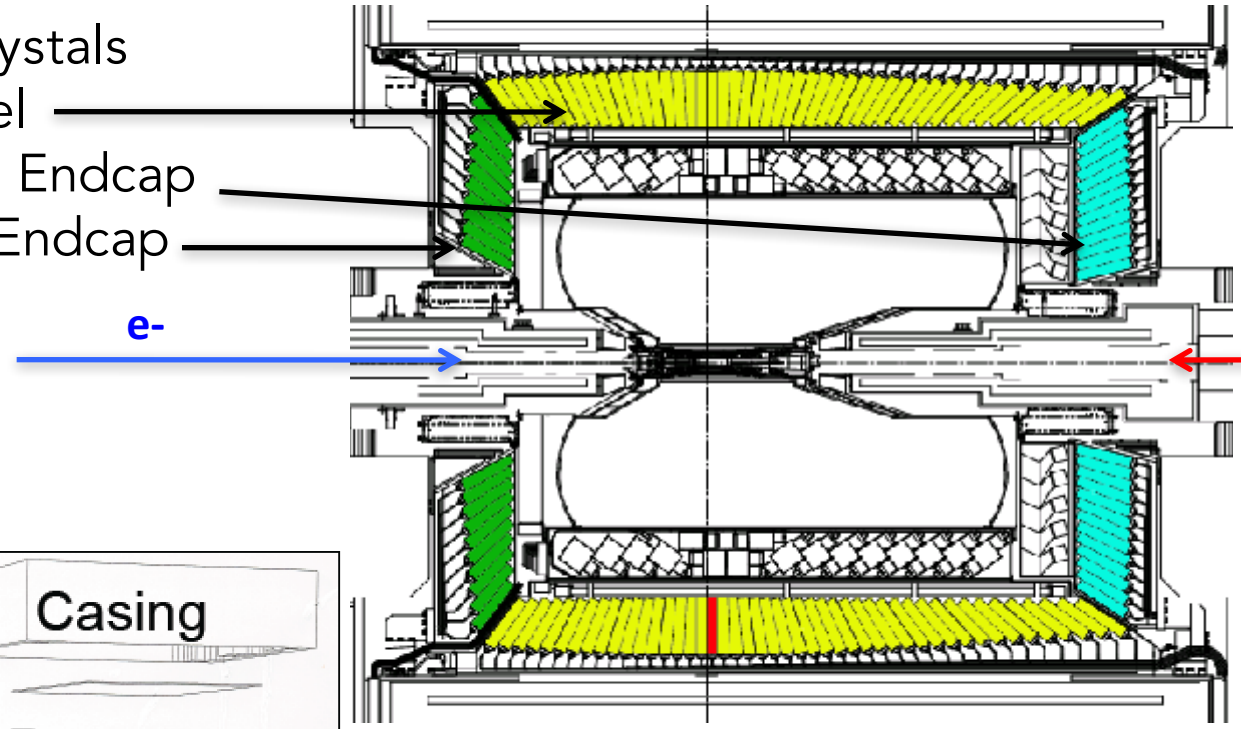
BELLE CsI(Tl) Calorimeter

8736 CsI(Tl) crystals
- 6624 Barrel
- 1152 Fwd. Endcap
- 960 Bwd. Endcap



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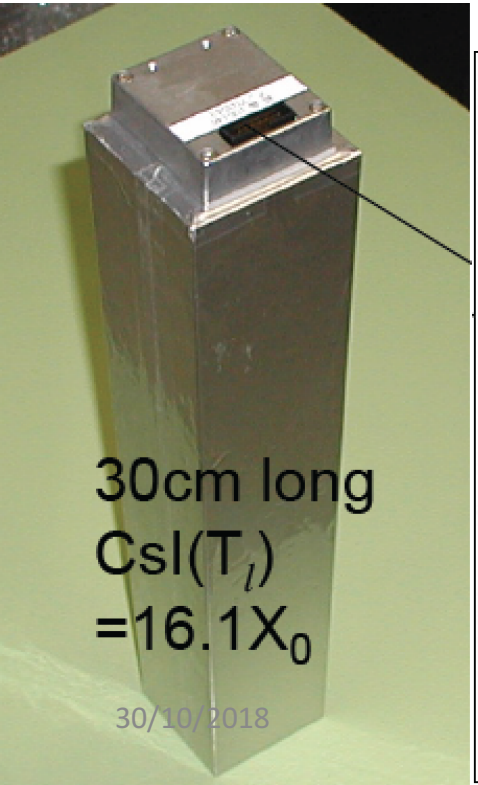

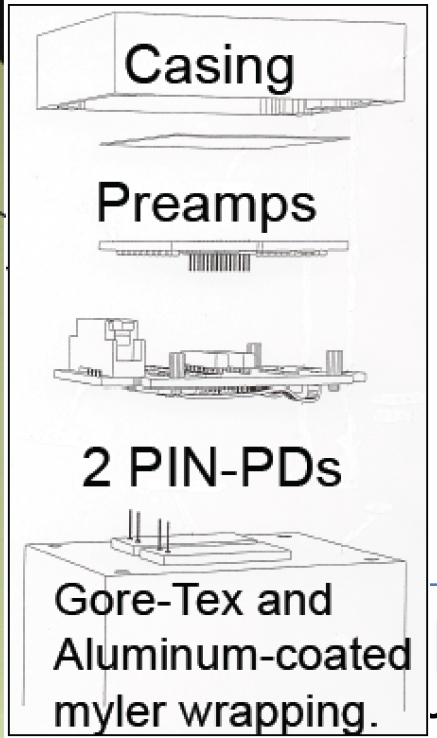

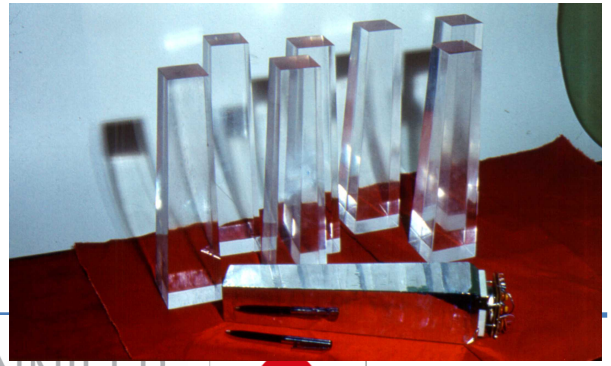

Light output – 5000 ph.el./MeV

electronics noise σ~200 keV

L_{cr} = 30 cm = 16.2X_0

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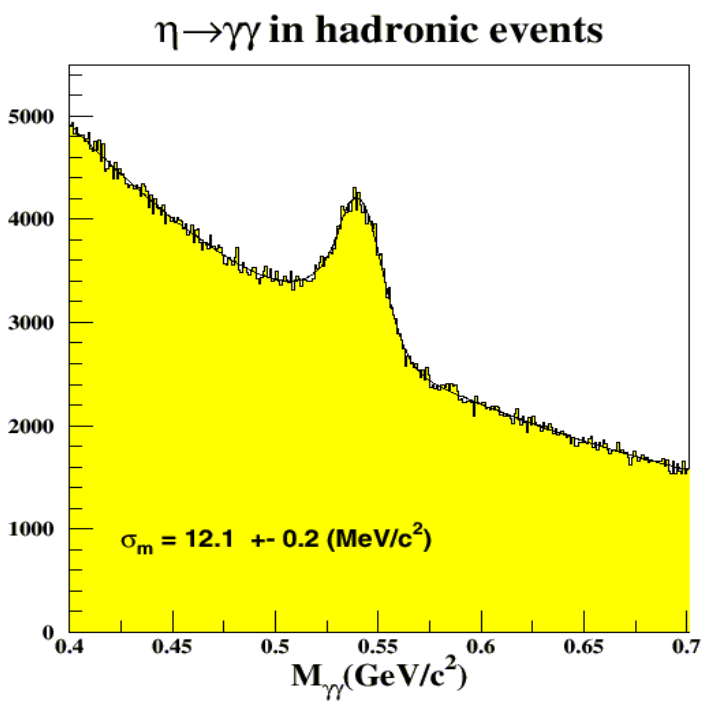
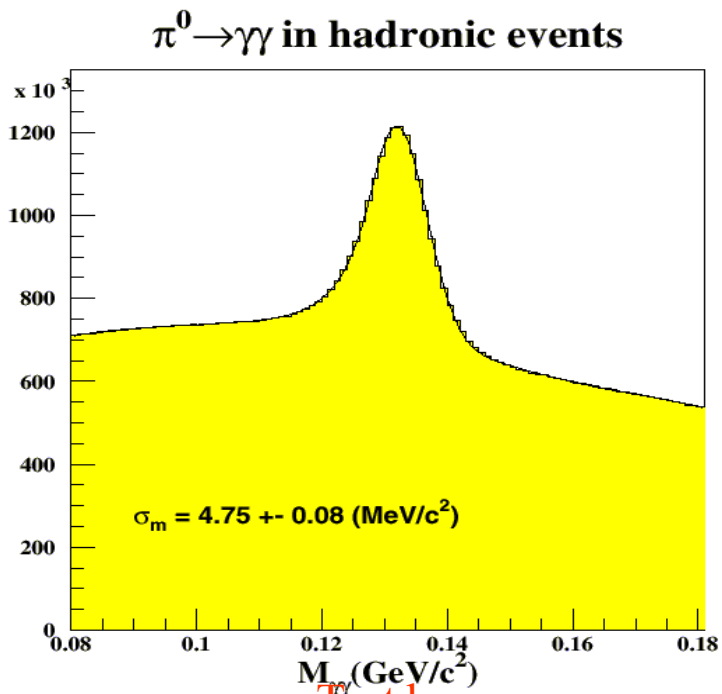
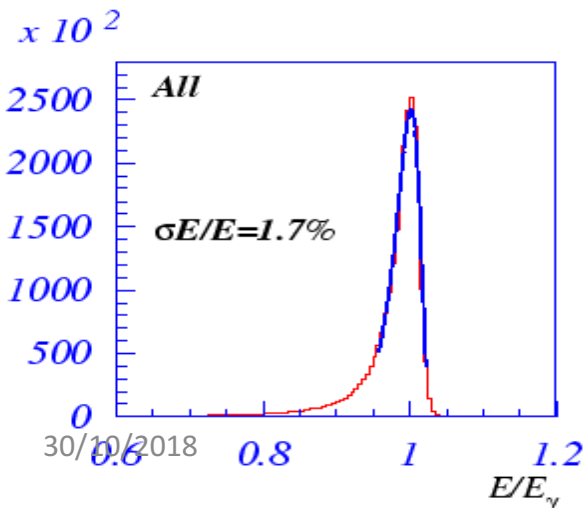
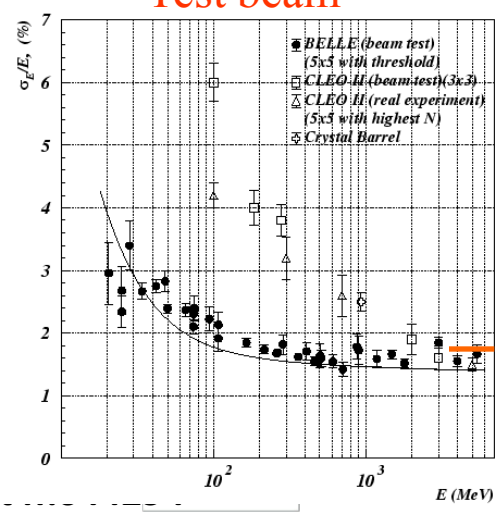
BELLE performances





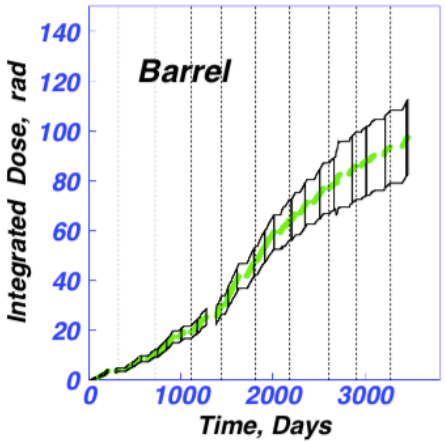


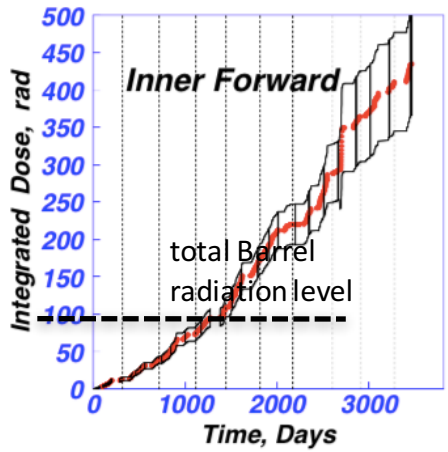
Test beam



ECL in view of luminosity increase

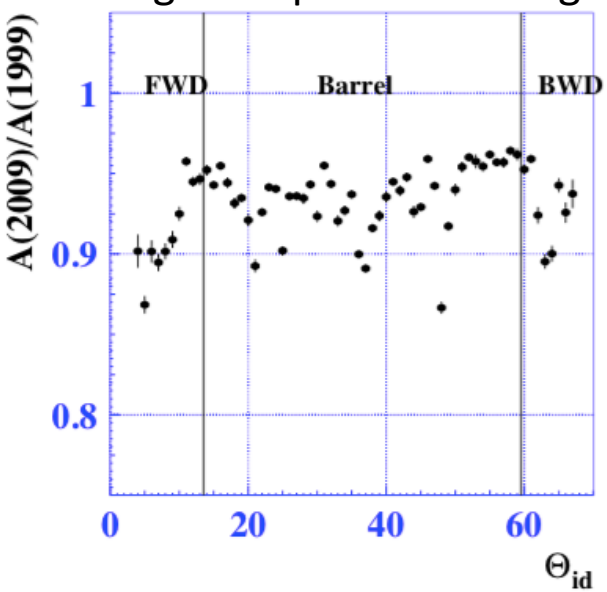
Radiation damage of crystals after BELLE (1 ab^{-1})





Expected dose in crystal @ Belle-II FWD ECL: 5-6 Gy/yr x 10 yr of data taking → a factor of 13 higher than in BELLE

Light output decreasing



In the most loaded part the light output degradation is about 10%

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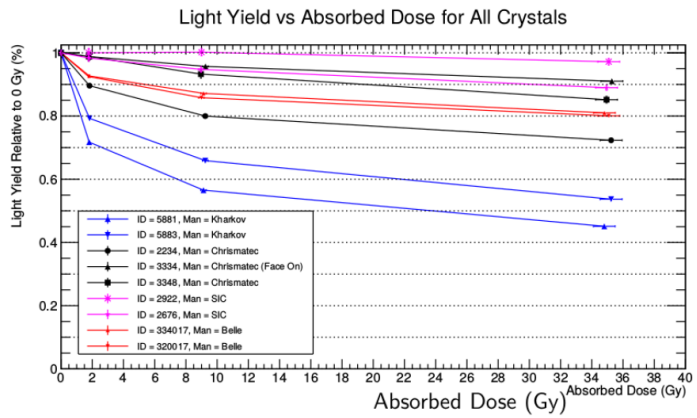
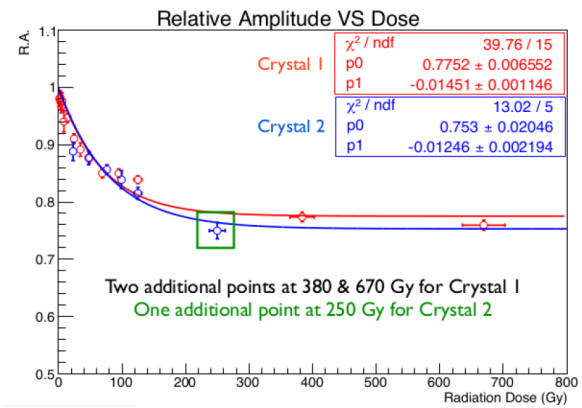
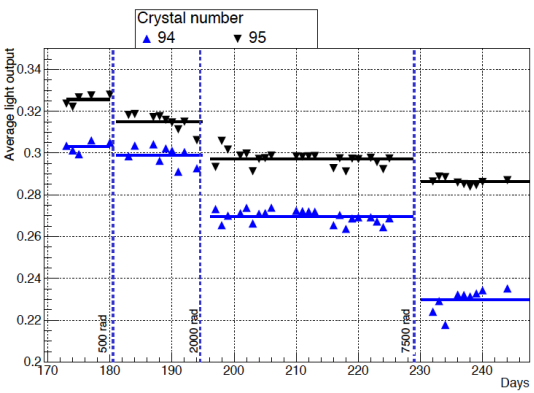
Rad Hard of CsI(Tl)

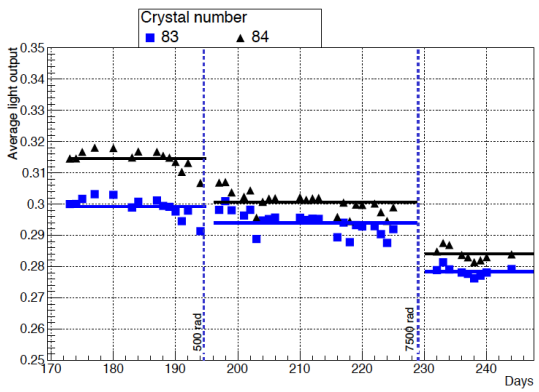
S. Longo, University of Victoria

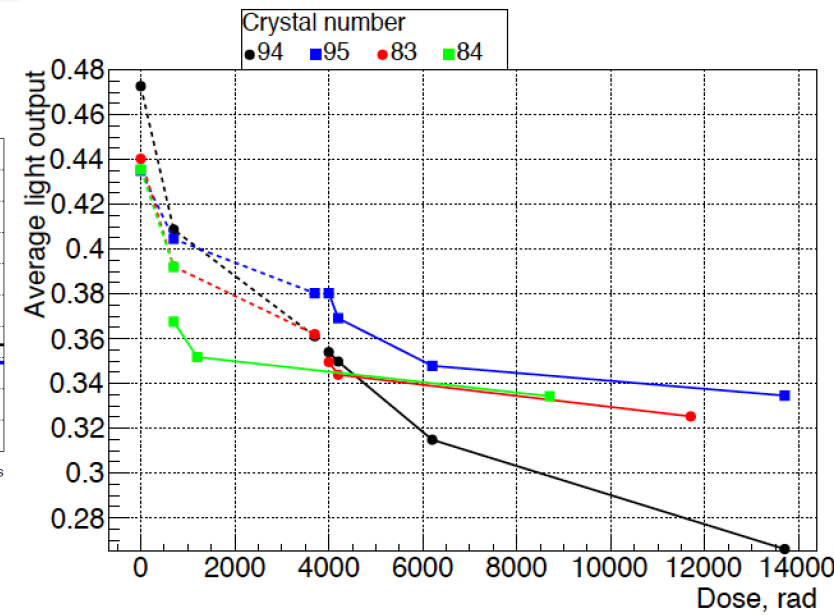


R.de Sangro, INFN - Frascati









LY decreasing for 10 Krad

N° 95 → 12%

N° 94 → 25%

LY decreasing for 10 Krad

N° 83 → 7%

N° 84 → 10%

Assuming crystal 95 has same LY after its first irradiation (3.7 krad)

Maximum 50% decreasing after 15krad → OK for the dose expected at BelleII

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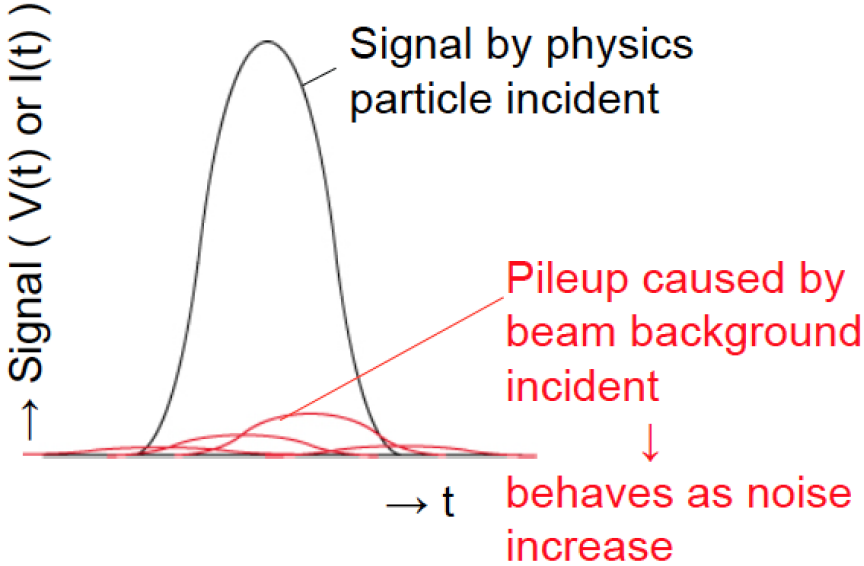
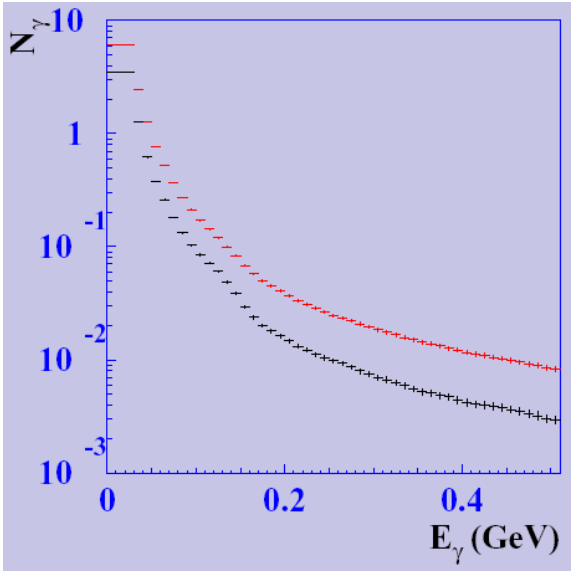
Background increase: pile-up effect

Scintillation decay time is ~1μs



Fake clusters



CsI(Tl):

- very high light output ?
- very slow device ?

Need a fast and rad-hard detector

(E>20 MeV) 6 fake clusters, 3 in barrel 3 in endcaps background

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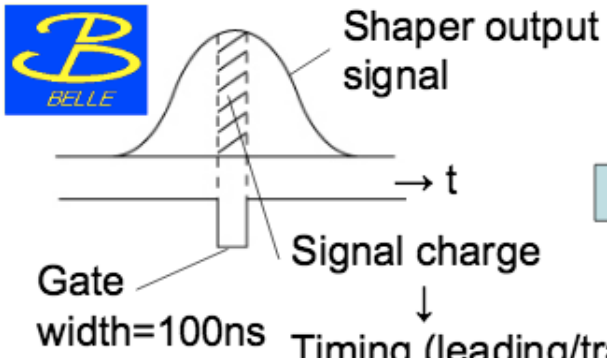
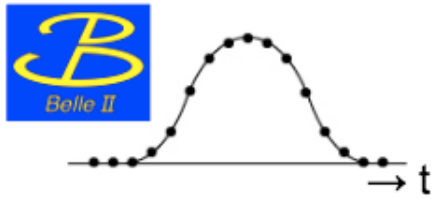
BelleII read-out electronics post-update



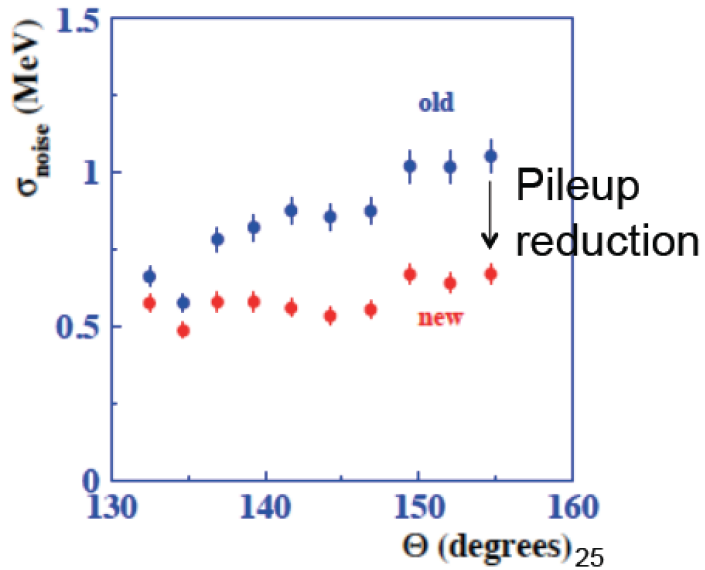
Signal charge
↓
Timing (leading/trailing edges) with range information by QtoT converter (MQT300A)
↓
Digitized by TDC

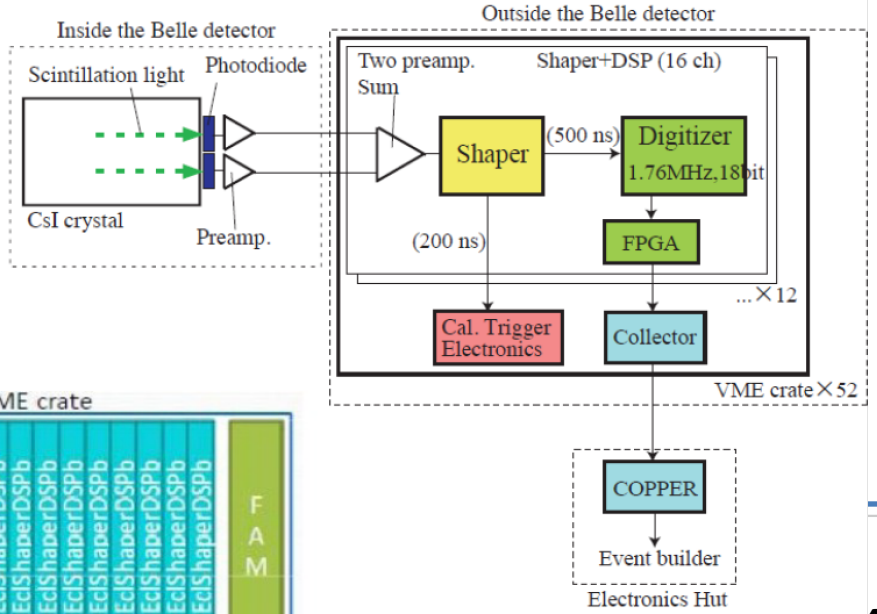


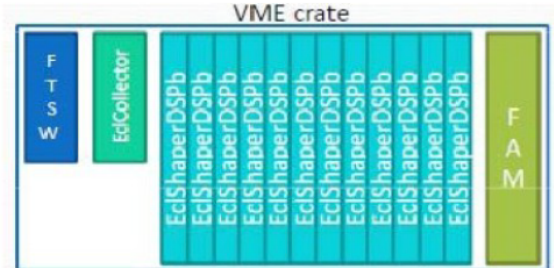
1.76MHz, 18bits digitizer, waveform fit to get energy and timing (i.e. Digital Signal Processing)

Reduction factors;
×7 BG showers
×1.5~2 pileup noise

EARLY PROTOTYPE TESTED AT BELLE







FWD Endcap Upgrade pure CsI

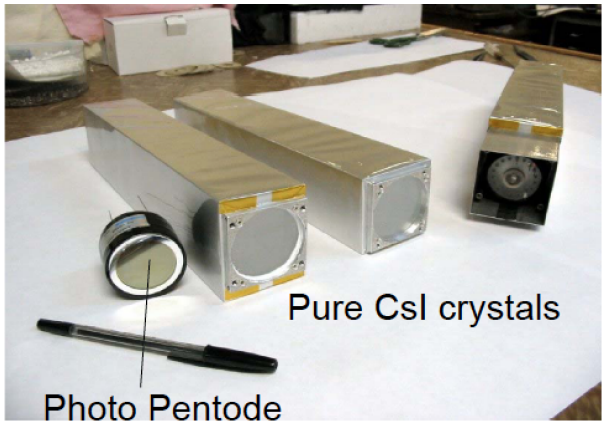
Electronics upgrade may not be sufficient for the forward endcap

Because of short scintillation decay time, ~30ns, Pure CsI crystal is almost pileup free.
Photo Pentode readout is regarded as a baseline, noise~0.2MeV.

- same density and radiation length allow to reuse Belle mechanical structure

Crystal	CsI(Tl)	Pure Csi
Light Output (% Na(Tl))	165	36
Decay time (ns)	1200	30

- much lower light yield
  - fast component of emitted light in the near-UV region
- much faster light decay time
  - but slow component is an issue for pile-up



- Use of Pure CsI requires R&D studies on:
  - photodetectors in the near-UV and wavelength shifters
  - radiation hardness of crystals, photodetectors, and wavelength shifters
  - electronics

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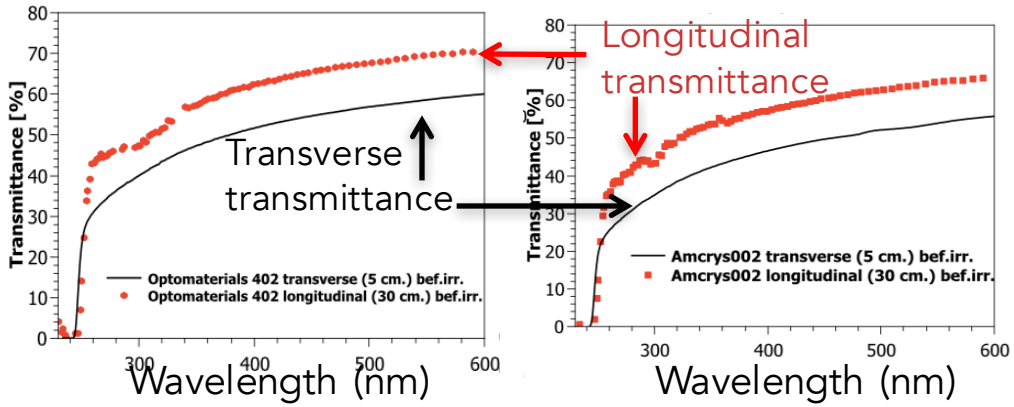
Pure CsI optical properties: transmittance

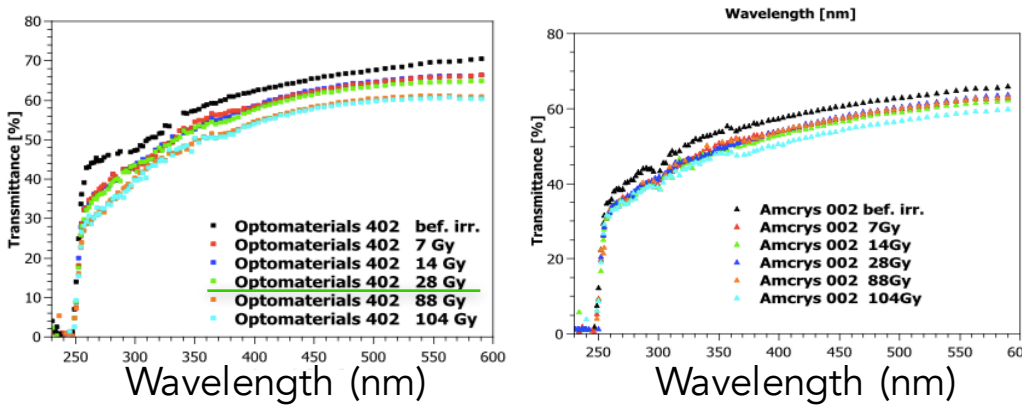
- No irradiation
- @ 310 nm: L.T. ~ 50%, T.T. ~ 40% for Optomaterials, lower for Amcrys

Optomaterials (Italy), 5x5x30 cm^3

Amcrys (Karchov, Ukraine), trapezoidal shape, ~7.5x7.5x30 cm^3



- Transverse transmittance at different irradiated doses (7 to 104 Gy)
- Saturation effects
- Completed and fast recovery for doses < 7 Gy (not shown here)



Maximum variation @ 310 nm ~ -7%

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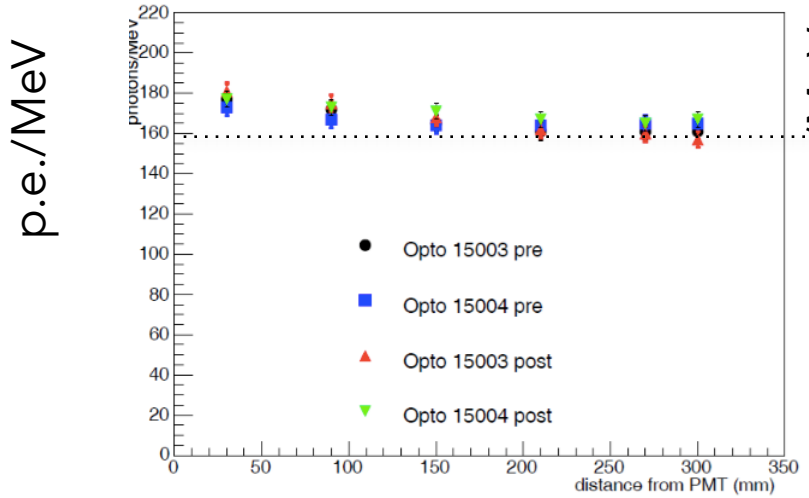
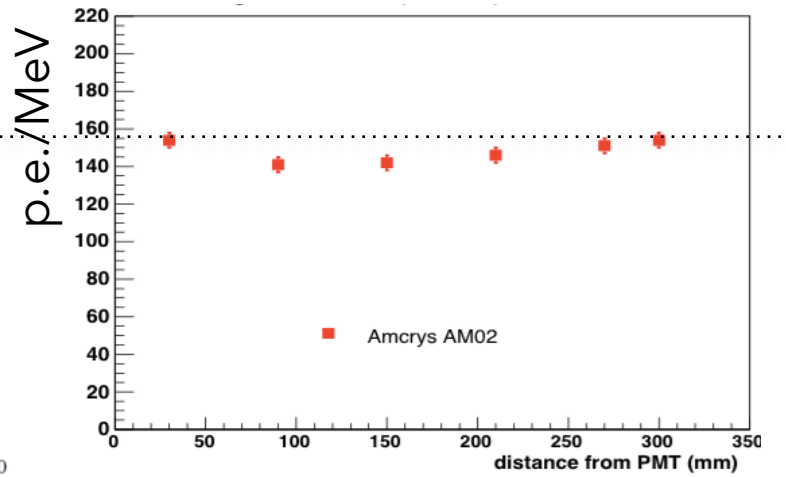
Pure CsI optical properties: Light Yield

Optomaterials (Italy),
5x5x30 cm^3

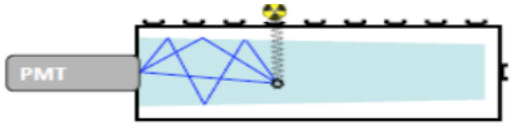


distance from PMT (mm)

Amcrys (Karchov, Ukraine),
trapezoidal shape,
~7.5x7.5x30 cm^3



distance from PMT (mm)



Measured without wrapping
and without optical grease

- Longitudinal LY uniformity (Irradiated)
- before irr. : ~ 6-10%
- after irr: ~ 7-15%

- No irradiation
- Longitudinal LY variation < 10%

LY variation before and after irr.: ~1-5%

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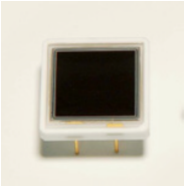
Photodetector options

Requirement: photodetector ENE < pile-up noise (O(1MeV))

Photodetector options:

Hamamatsu photonics
R11283 photopentode
Belle-II baseline

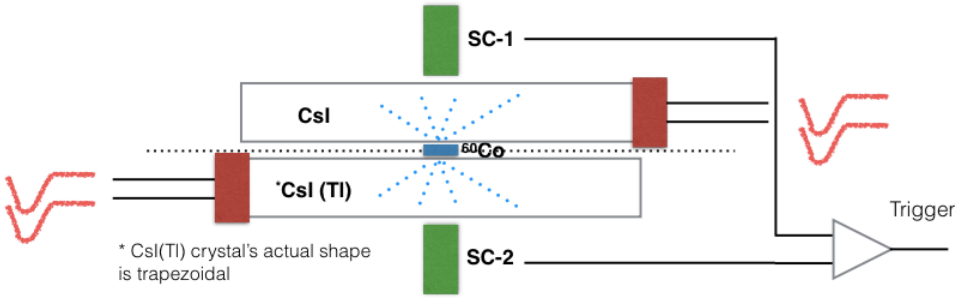
Hamamatsu photonics
Large Area APD
R8664-1010



	PhotoPentodes	Large Area APD (LAAPD)
C (pF)	10	270
Gain@V_{op}	150-250 [*]	50 [**]
Q.E.@310 nm (%)	25	50
Area (cm^2)	20	10x10
Comments	• [*] gain reduced by 75% in 1.5T magnetic field • 1 PP per crystal, no redundancy • back plane of the mechanical structure need to be replaced	• [**] special production with G=200 • 2 LAAPD per crystal

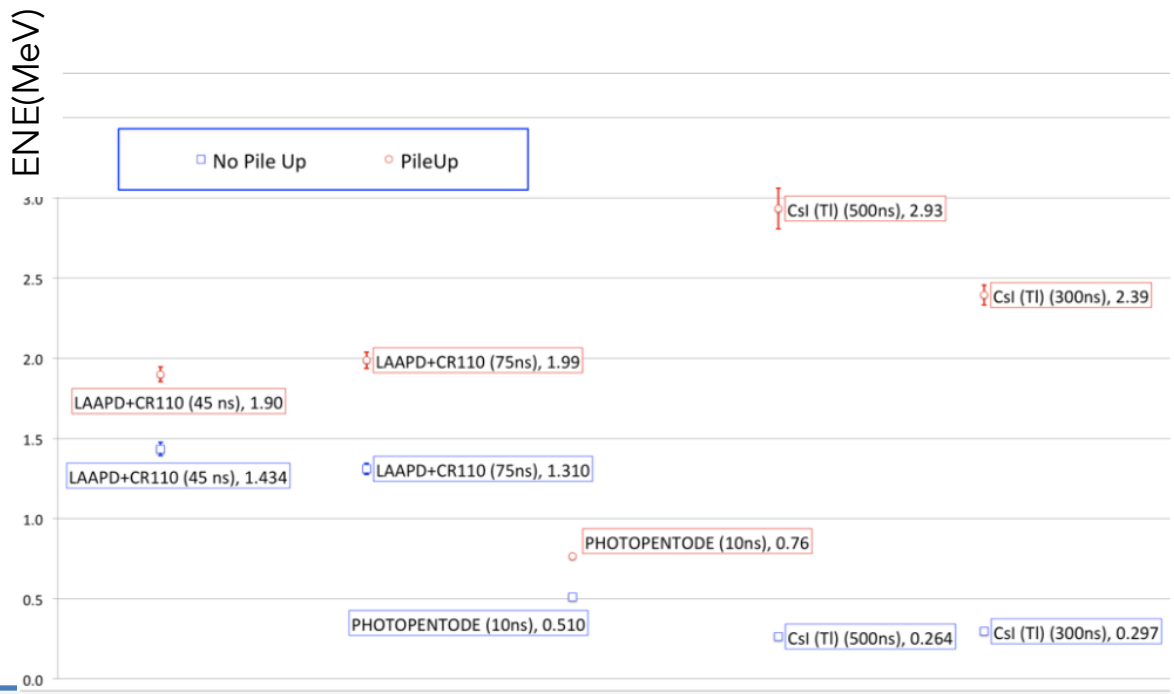
Pile-up study: cosmic+source

- Signal from cosmic rays superimposed to 1.33 and 1.17 MeV g produced by ^{60}Co
  - 1.77±0.04 hits/μsec from source



- From the difference in quadrature of the meas. with and without source, pile-up effect can be estimated: CsI(Tl) shows twice the ENE of pure CsI

- [nb: wrt to pag 12 (ENE=0.77MeV), different shaping times and signal window used, optimization of such parameters underway]

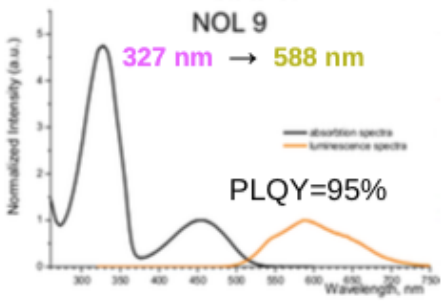


Measurements performed without WLS → improved values next slides

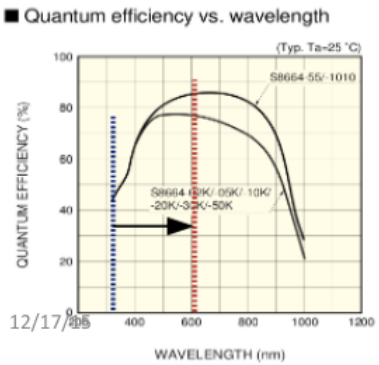
R&D on Wavelength Shifters

- Novel wavelength (WLS) plates containing nanostructured organosilicon luminophores provides essential increase in light output

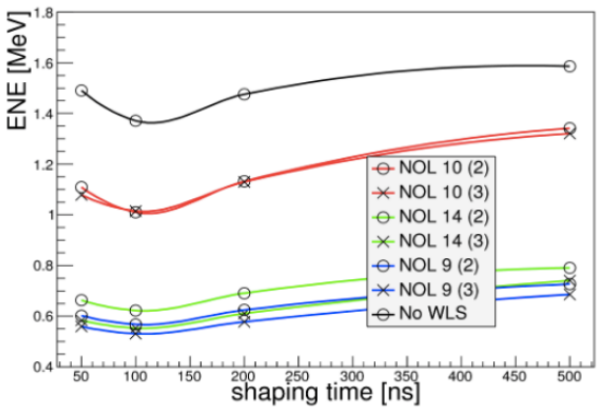
LuminoTech Co, (60x60x2 mm^3) WLS plates



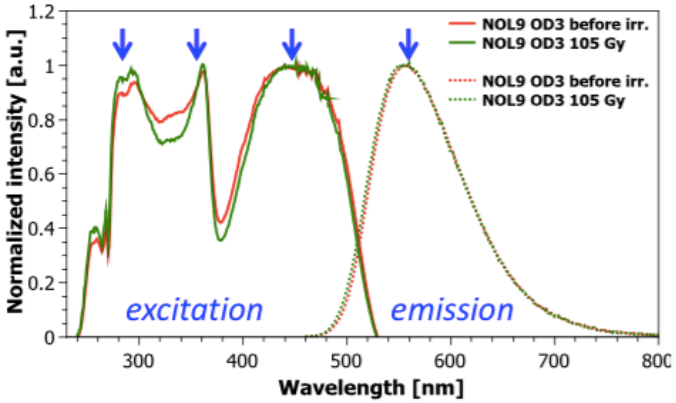
Select mainly the short time emission and cut the long tail



- Results:



Enhancement on signal of a factor of about 3 (n.b. test performed with G=50 LAAPD)



Radiation hardness tests on NOL9 WLS: no irradiation effects on excitation/emission peaks up to 105 Gy

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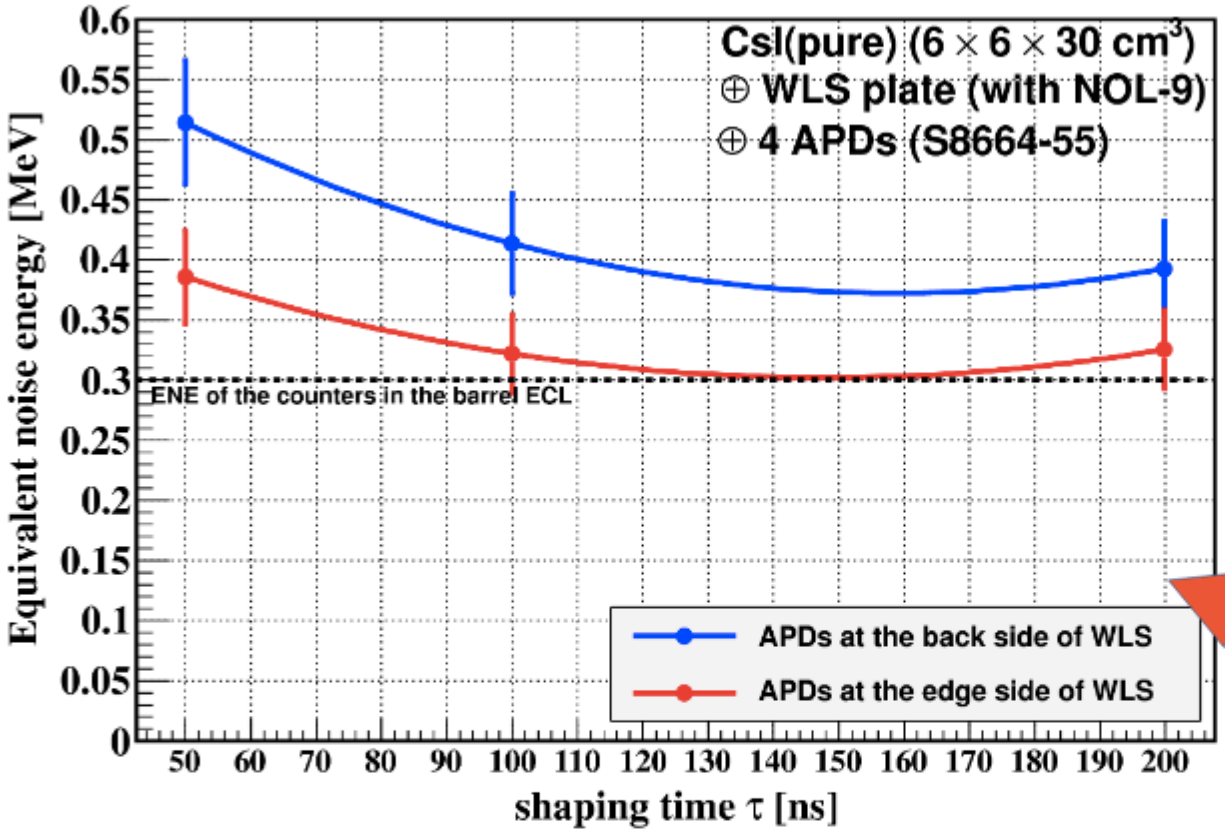
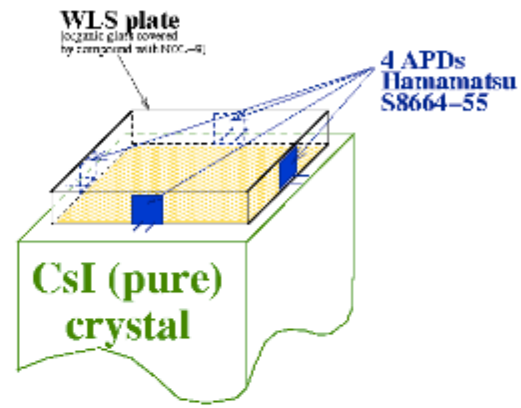
Attaching APD's on edge side



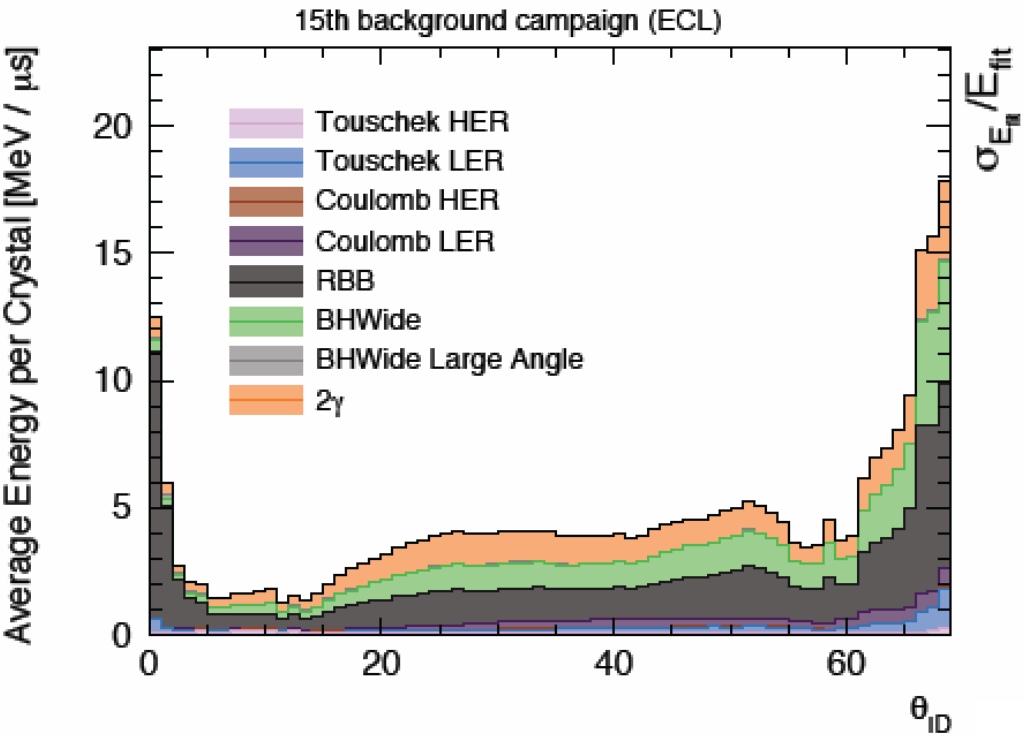


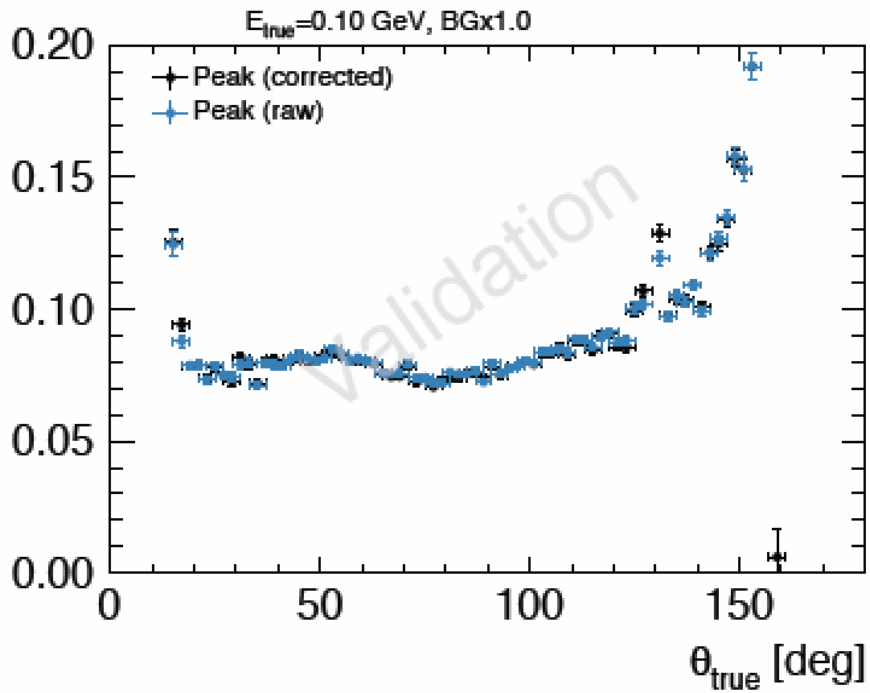
In this measurement, the APD's are attached on one side of the edge due to the limited space of our shield box.

A factor of 1.3 is earned by this configuration.

In total, in comparison with the coupling of APD's to the crystal, we earned a factor of 4.

MC campaign 2017 and performance





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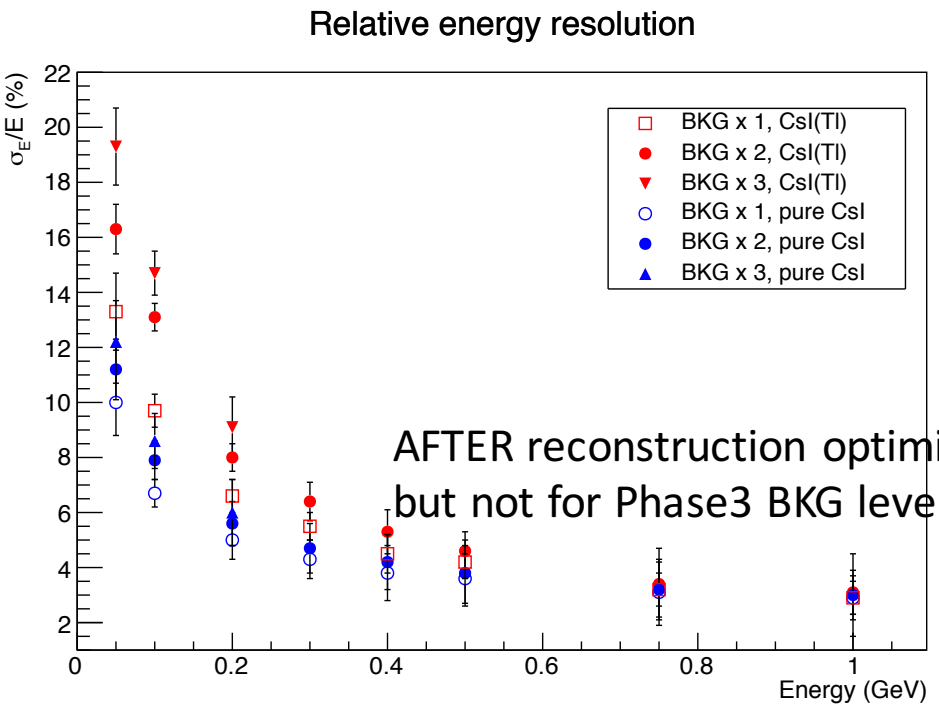
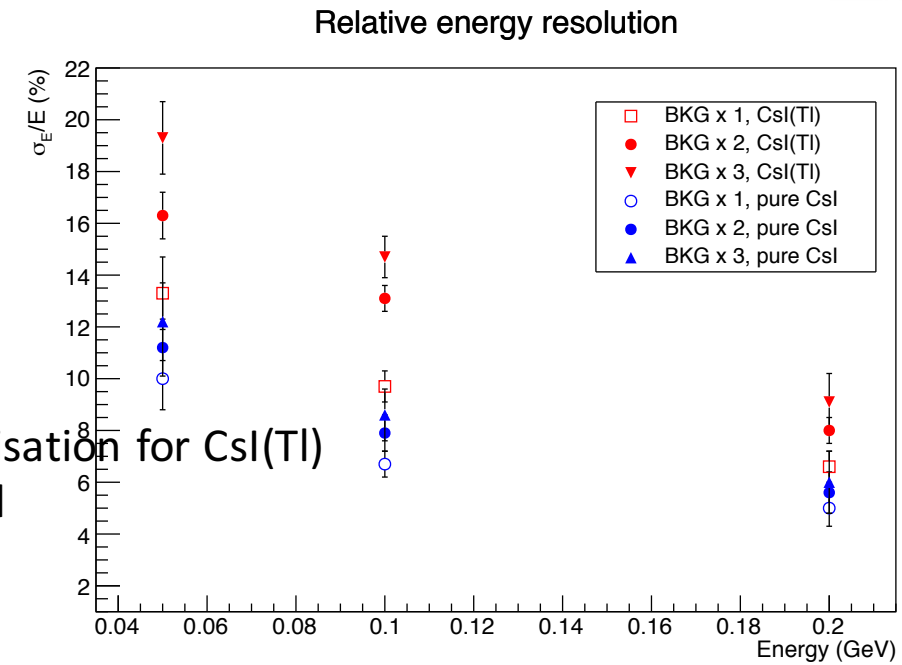
FWD CsI(Tl) vs pure Cs(I) phase3 BKG x1, x2, x3





AFTER reconstruction optimisation for CsI(Tl)
but not for Phase3 BKG level

Reconstruction used for pure CsI has not been optimised

Pure CsI@100MeV (BKGx2) = 8% → which is the best reachable resolution?

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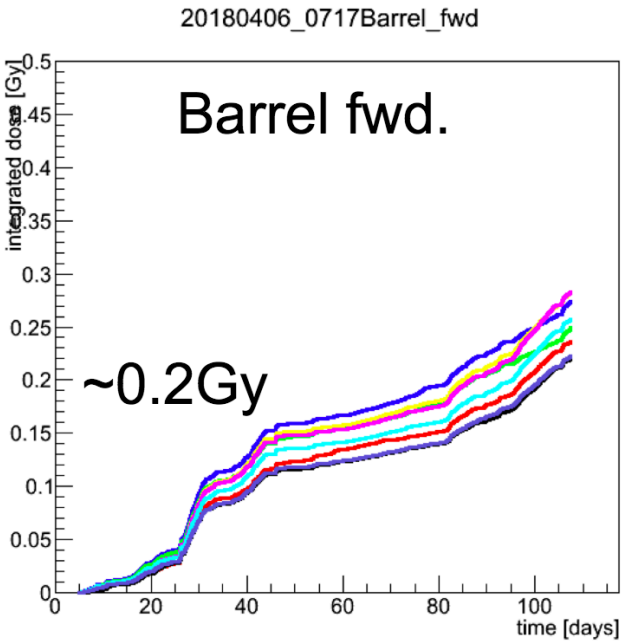
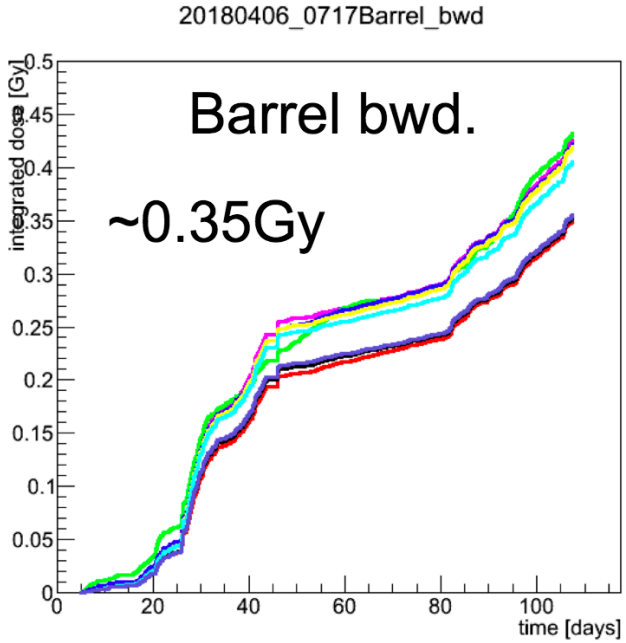
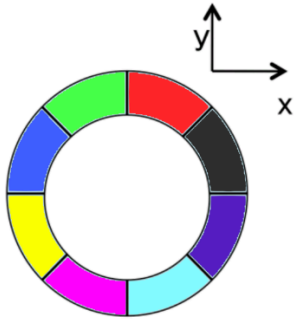
Study of Phase 2 Background







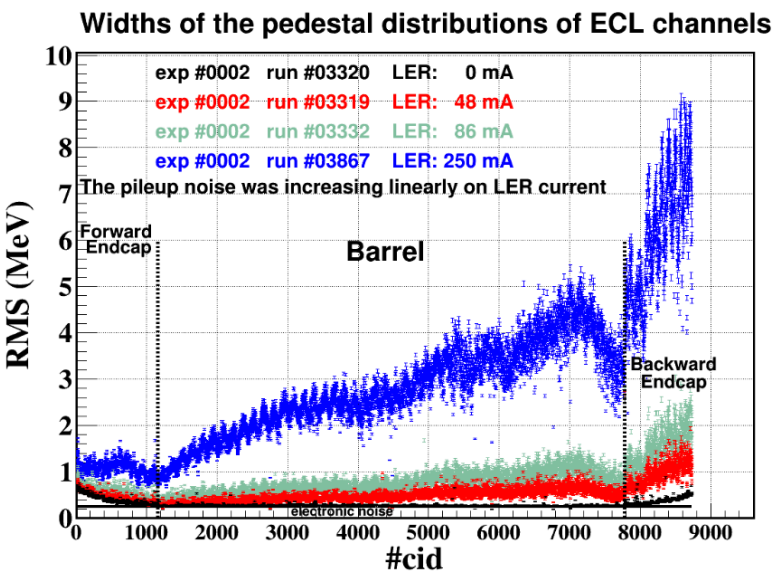
BELLE 0.1 Gy/year

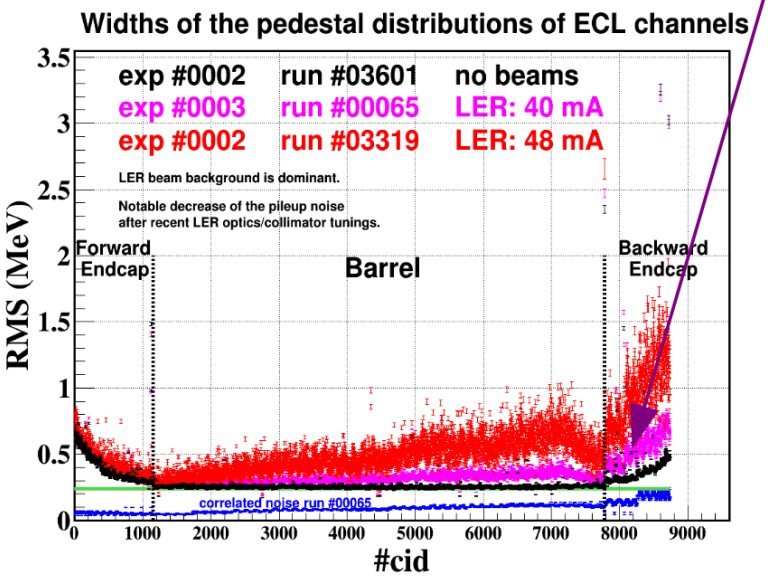
EU grant n.644294

Study of Phase 2 Background

- We monitor the widths of the pedestal distributions for 8736 ECL channels. The width is determined by the electronic noise (0.25 MeV in the Barrel, up to 0.6 MeV in the Endcaps) and pileup noise, which is sensitive to the beam background.
- **HER doesn't provide notable background even during HER beam injection (pileup noise is smaller than the electronic noise)**
- **LER beam background is large, pileup noise is proportional to the LER current**
- For the LER current of 250 mA the pileup noise reaches 9 MeV in the inner backward endcap !
- Such a large pileup noise will notably degrade ECL energy resolution
- **Before collision run the LER optics/collimator was tuned, pileup noise became several times smaller**

For the larger LER currents further tuning was necessary to reduce background





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Conclusions

- R&D on pure CsI is quite in the finishing line and requirements on equivalent noise energy and signal to noise have been fulfilled
- Best option for APD readout is 4-small APD's on the edge of the WLS
- Test beam at Novosibirsk in beginning of 2019 of a matrix of pure CsI

- Reconstruction used to study the pure CsI performance has not been optimised

- The big unknown = background level
  - First step measure background in Phase2 → compare again performance CsI(Tl) and pure CsI
  - Study of background phase 2 with collected data is ongoing

- JENNIFER Deliverable for March 2019 will be a Proposal for the future TDR containing a detailed summary of the R&D and the Performance and Physics perspectives of the Belle 2 Detector with the upgraded FWD ECL.

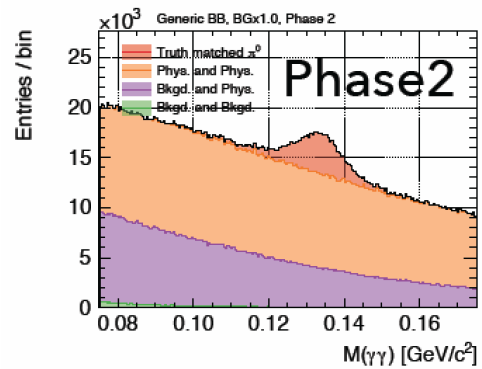
EU grant n.644294

BACKUP SLIDES

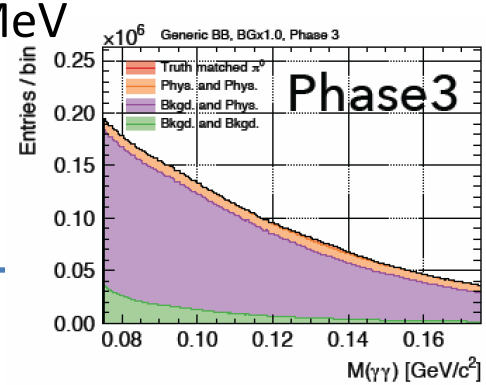
EU grant n.644294

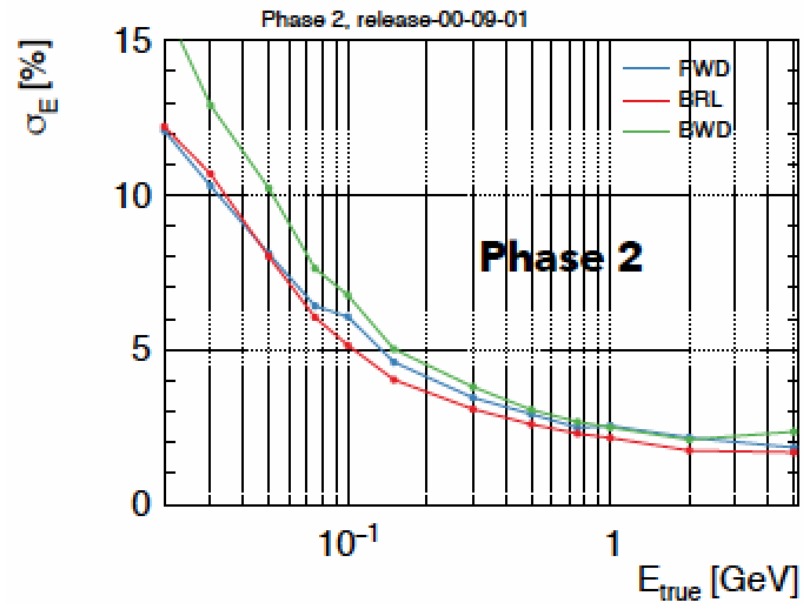
Effect of pile-up increasing

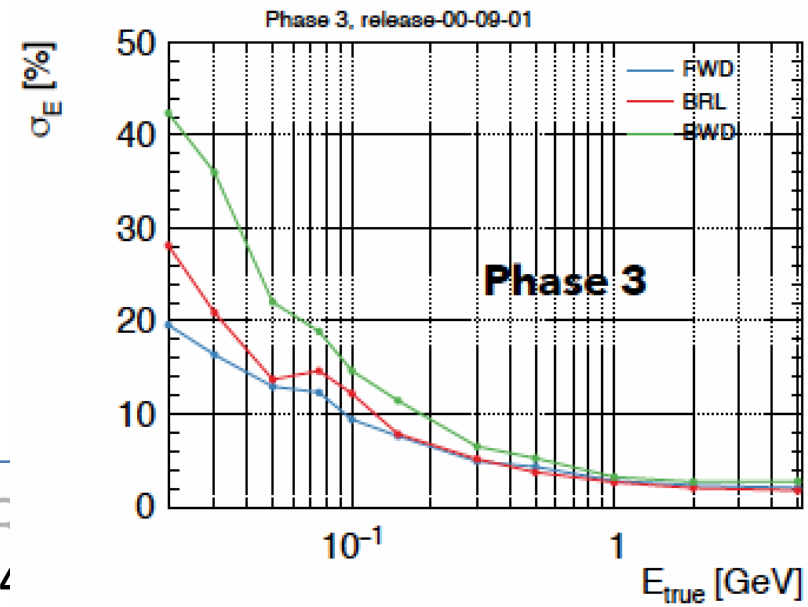
- Optimization of the reconstruction for phase2 and phase3 needed once BKG better known
- Efficiency → has to be as highest as possible including low energy photons in presence of high beam background



Π^0 reconstruction
All photons with E>20 MeV





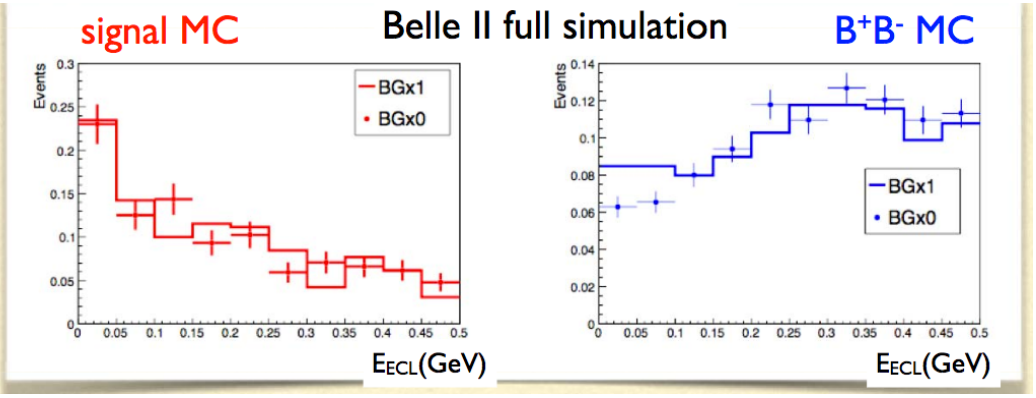


B→K*νν

- Significance and shape variables not change observed from no BKG to BKG1

1 ab^{-1} equivalent statistics

	"BGx0"	"BGx1"
N_{bkg}	6415 ± 80	3678 ± 61
ε (10^{-4})	10.3 ± 0.3	5.38 ± 0.23
$N_{sig}/\sqrt{N_{bkg}}$	0.16	0.15
UL (10^{-4})	2.6	3.8



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