First JENNIFER General Meeting
WP2-ECL

C. Cecchi

- Introduction (actual status and upgrade)
- study of the actual ECL FWD detector: CsI(Tl) + PiN diodes
- upgrade: pure CsI crystals: production and quality
- upgrade: Photodetector choice and FE development
- Status and BelleII schedule
- Conclusions

BelleII ECL detector

- 1/3 of B decay products = π^0 or other neutrals producing γ in [0.02,4] GeV energy range!
- Reuse Belle Calorimeter
  - CsI(Tl) crystals red by PIN diodes
  - Performances (E in GeV):

$$\frac{\sigma_E}{E} = \sqrt{\left(\frac{0.066\%}{E}\right)^2 + \left(\frac{0.81\%}{\sqrt[4]{E}}\right)^2 + (1.34\%)^2}$$

- Higher luminosity means
  - higher event pile-up

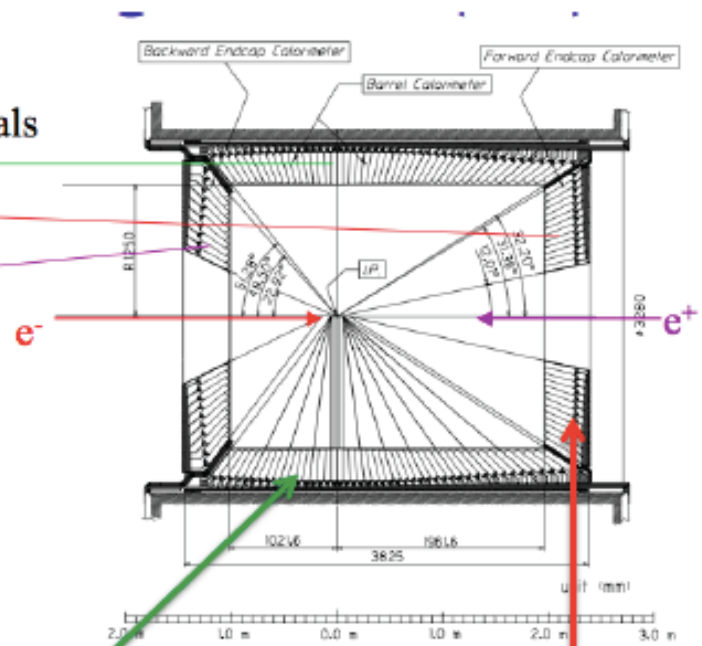
  → faster electronics
  - higher radiation dose absorbed by detectors

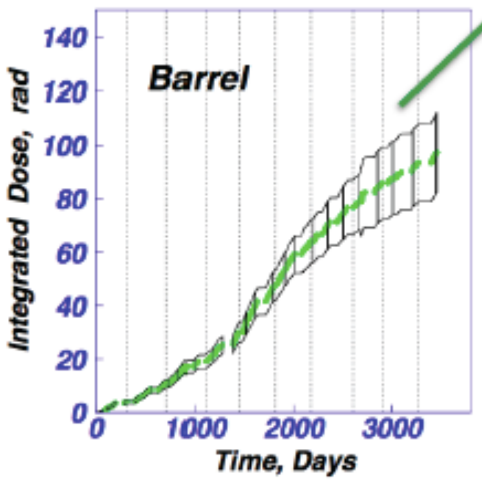
  → need to replace crystals more exposed to radiation damage (forward region)

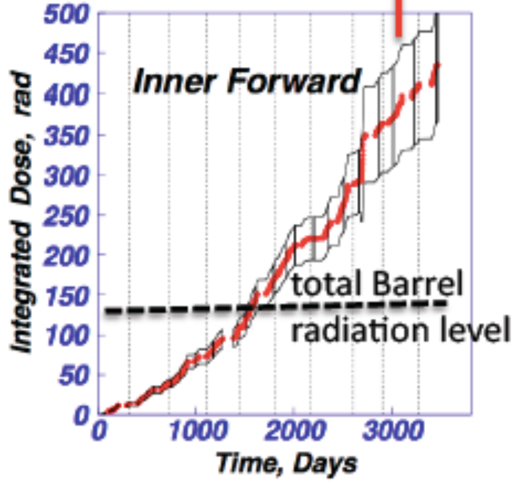
In total, 8736 CsI(Tl) crystals (6624 in Barrel, 1152 in Fwd. Endcap and 960 in Bwd. Endcap)

Covering 12<θ<155° in Lab. frame.

Inner radius = 1250mm.

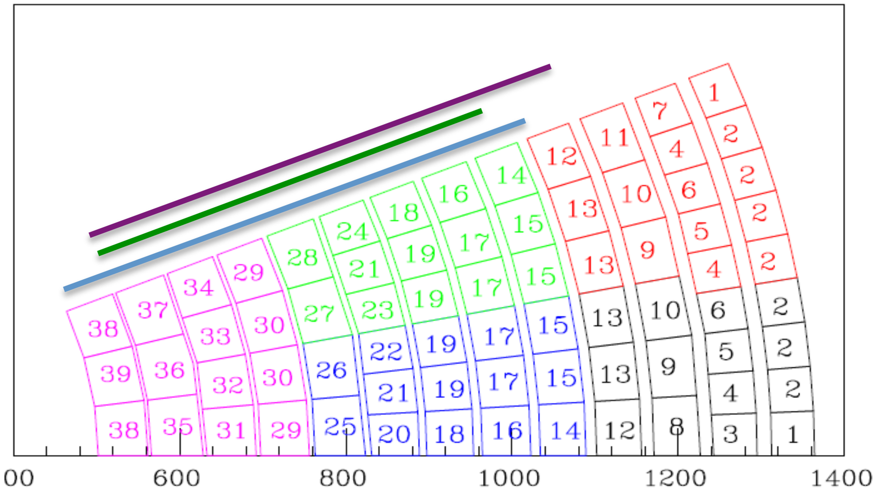




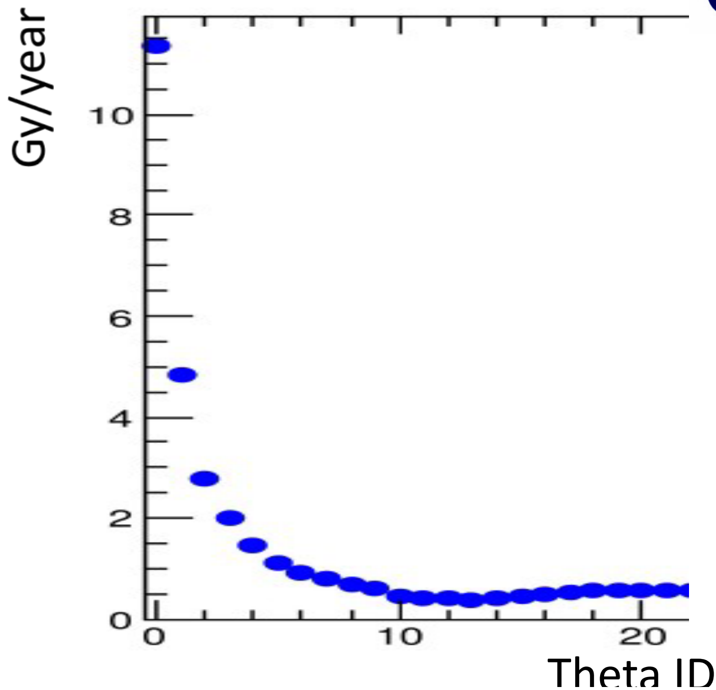


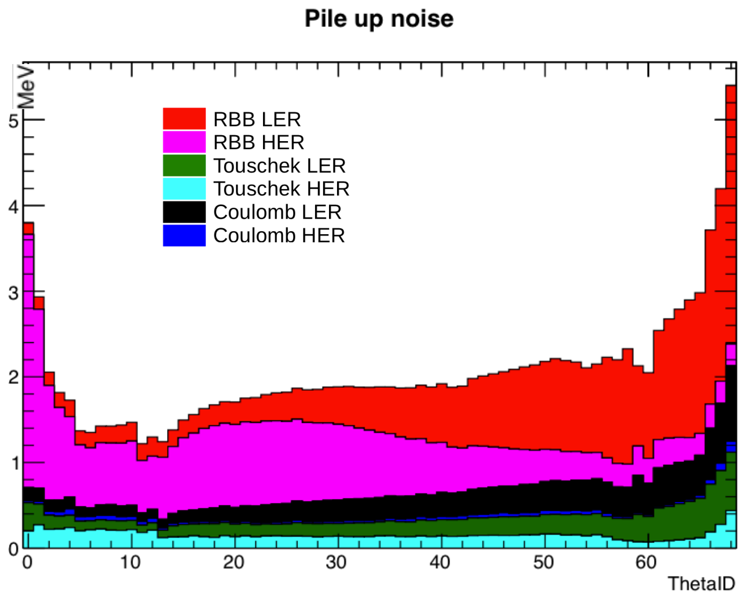
Full Belle experiment data taking period

Upgrade of the FWD ECL



a) From 0 to 8
b) From 1 to 8
c) From 1 to 9





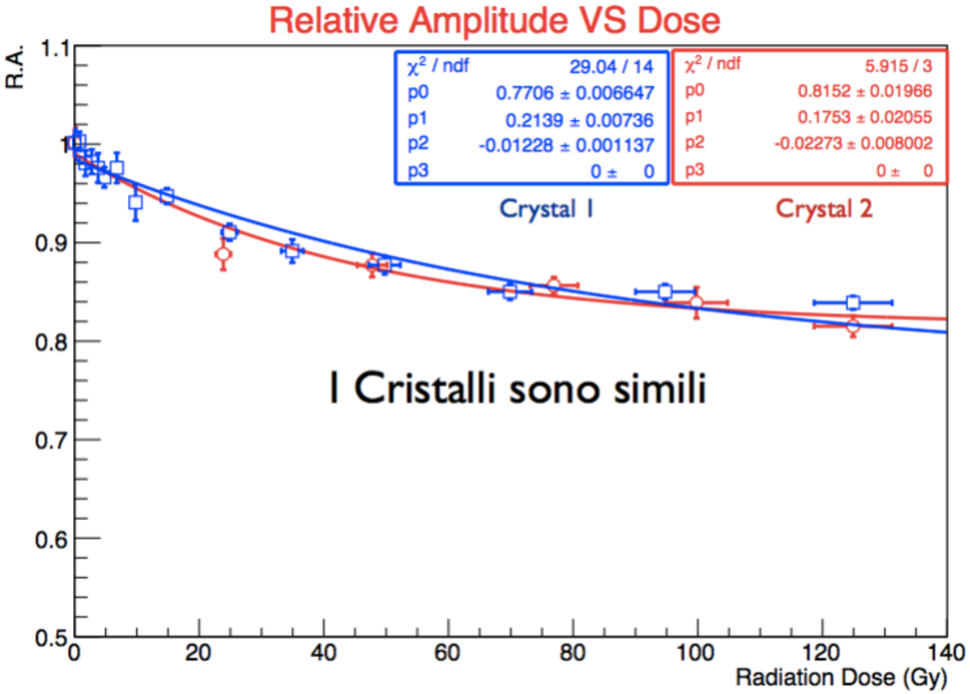
Replace CsI(Tl) with pure CsI crystals

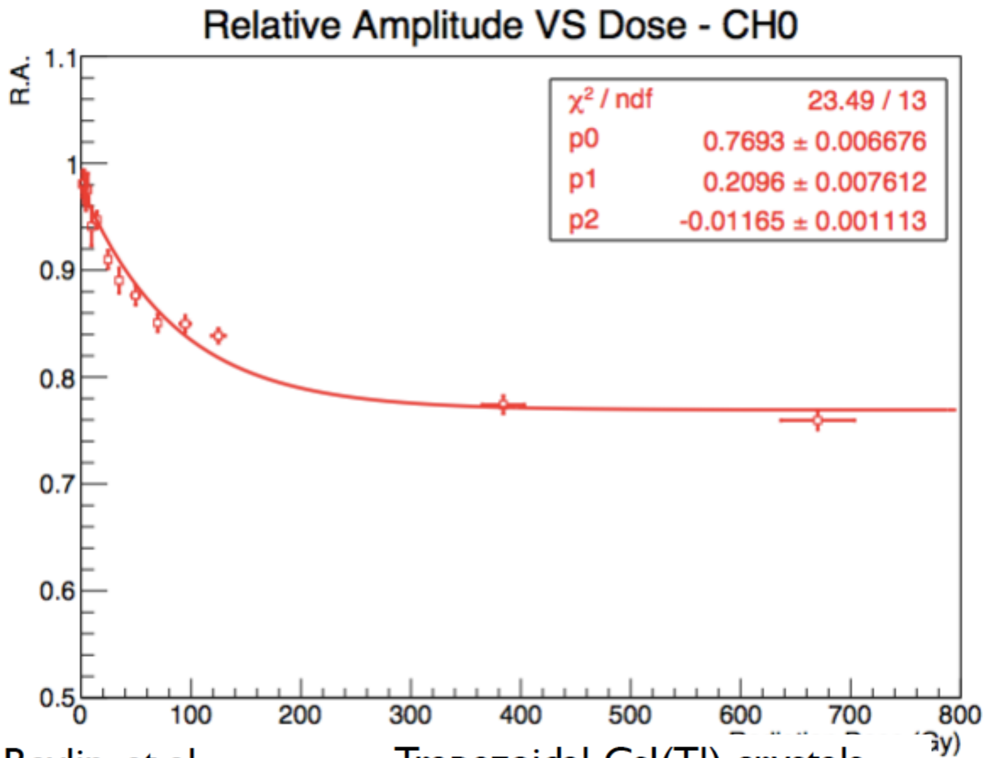
- Same Molière radius → no change in mechanics
- Fast crystals → good for pile-up
- Low light yield (near UV emission 315 nm) → requires a careful study of the photosensor

11/06/2015

ECL FWD status CsI(Tl)

Perugia INFN Istituto Nazionale di Fisica Nucleare

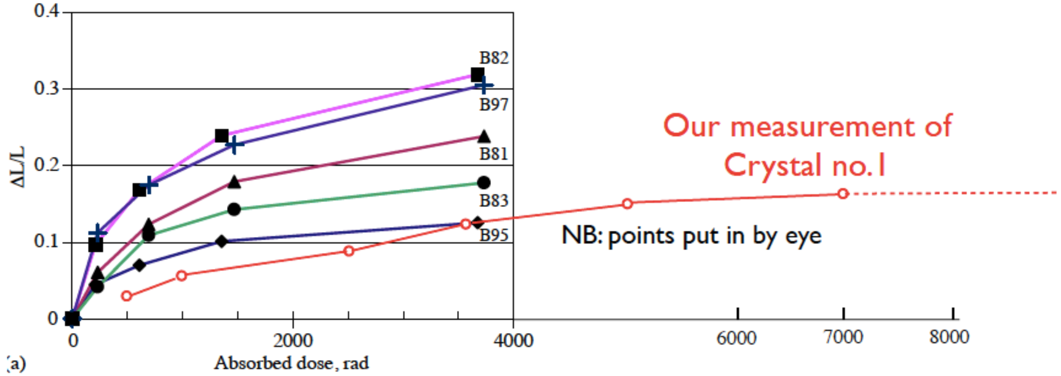




450 rad/year expected in the fwd (steady state operation, injection could be the same)

Which is the effect on resolution?

D.M.Beylin, et al. Trapezoidal CsI(Tl) crystals



Nuclear Instruments and Methods in Physics Research A 541 (2005) 501–515

11/06/2015

ECL FWD status PiN diodes

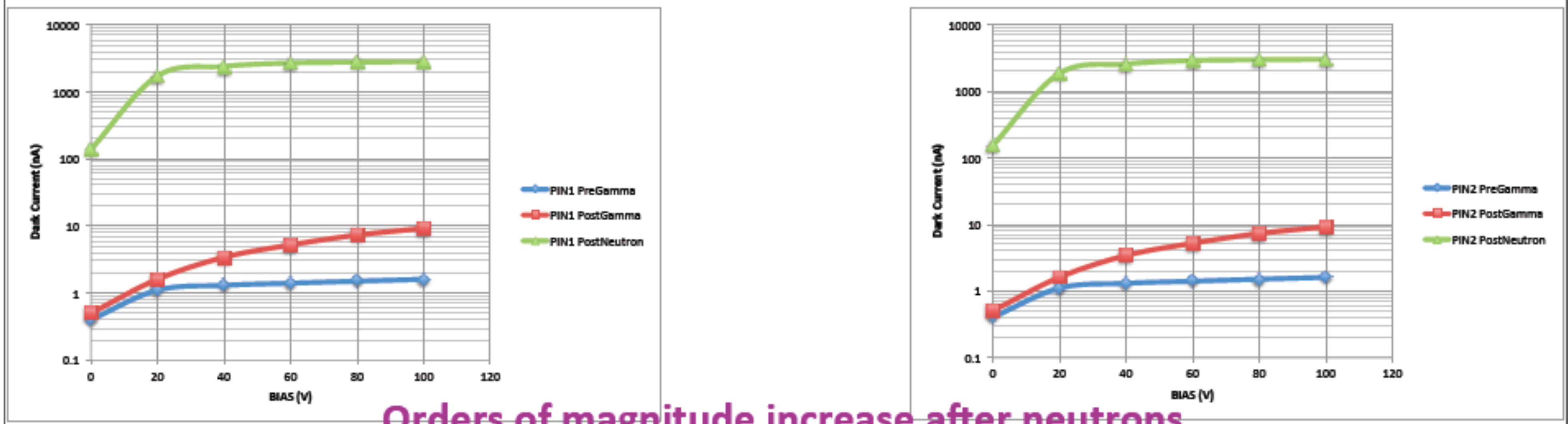
Photons 250 Gy

Neutrons 10^12 n/cm^2

Dark current

PiN diode: 1.4 nA → 1.3 μA

HAMAMATSU PIN S2744-08



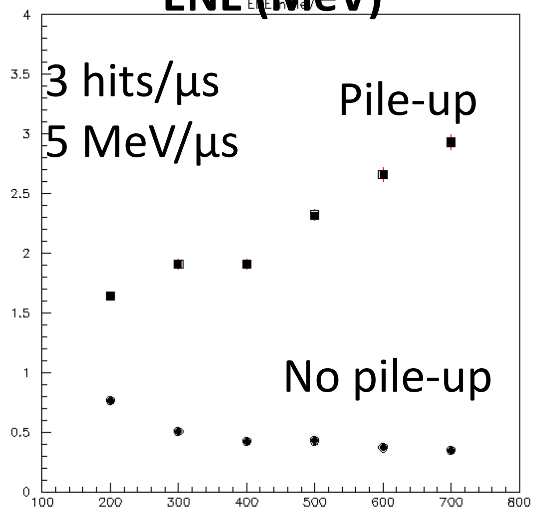
Orders of magnitude increase after neutrons

Photodetectors recover to a stable dark current value after 1 month annealing at RT

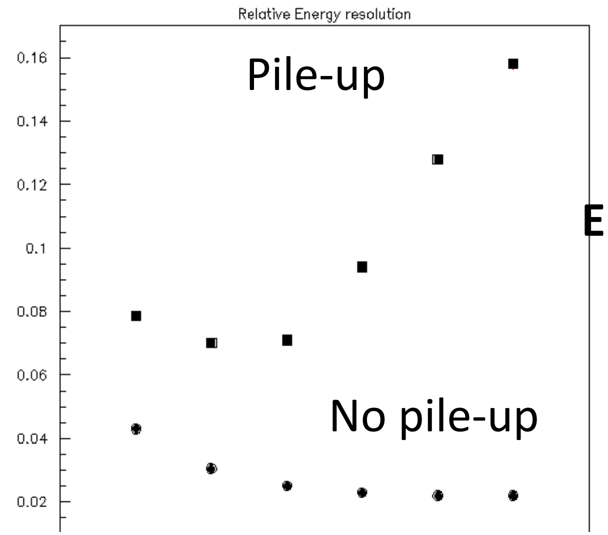
- **After Charge Sensitive Preamplifier (CSP)**
  - **ENE : NoIrr. ~630KeV → Irr. ~4.9MeV**
- **After Shaping (SHP)**
  - **ENE : NoIrr. ~220KeV → Irr. ~1.14MeV**

Simulation: signal + pile-up CsI(Tl)

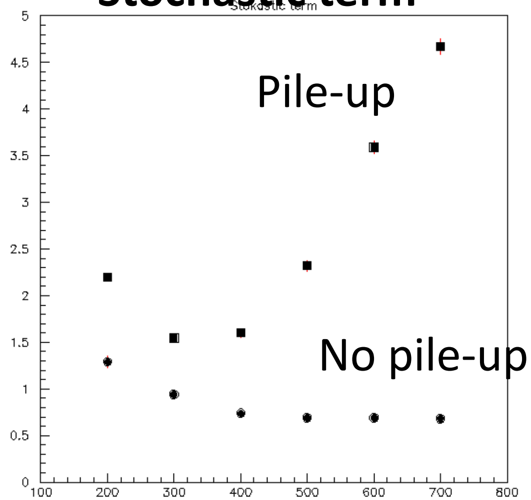
ENE (MeV)



Energy resolution



Stochastic term



For example: 100 Mev at the nominal shaping time (500 ns)

$$\sigma_E = \sqrt{2^2 + 2^2 + .7^2 \times \frac{E}{40.}} = 3.0MeV_{@100MeV}$$

ENE Stoch. term

- Pile-up has an important effect on performance
- @100 MeV about 3% resolution
- comparison with pure CsI: ENE=0, stoch. term 3%

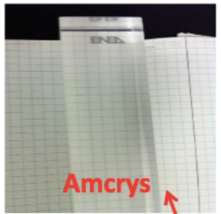
→ 4.5 MeV@100MeV

- **study the effects on physics channels**

R&D: Pure CsI Rad Hard

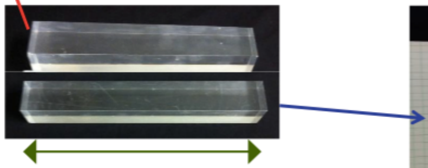
Crystal Amcrys 002 (Amcrys, Ukraine):

trapezoidal shape ~ 7.5 x 6.5 cm^2 cross section



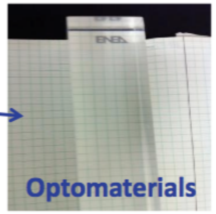
Optomaterials 402 (Optomaterials, Italy)

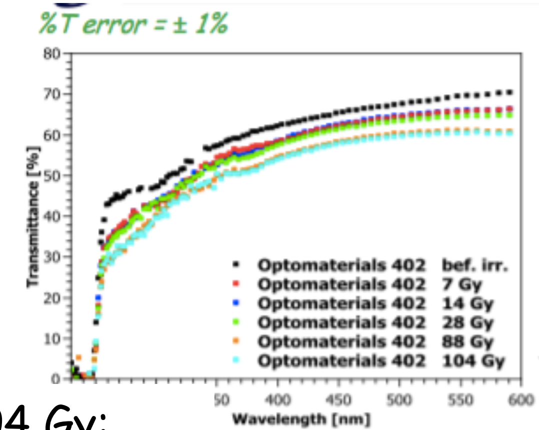
5 x 5 cm^2 cross section



30 cm.

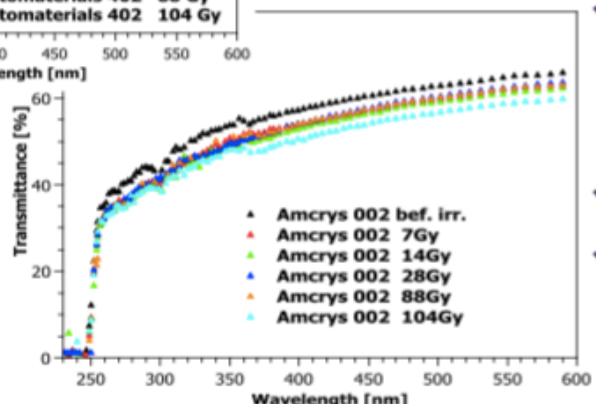
(Belle II ECL standard size)

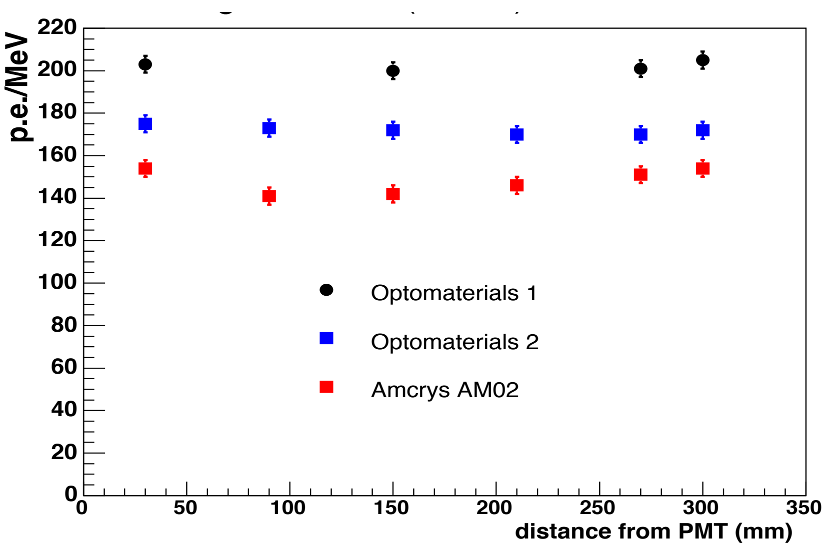


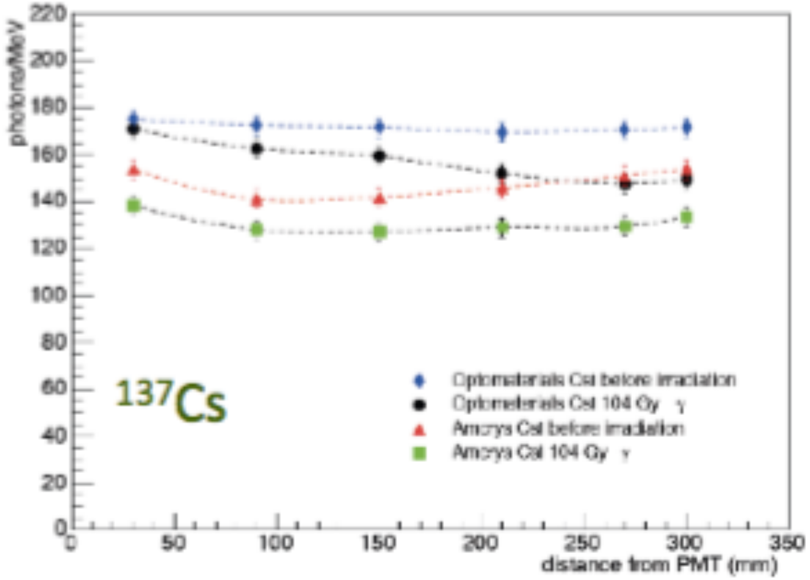


%T

Irradiation at 104 Gy:
- Saturation effect
- Max loss in transmittance 7% at 315nm
- Same behavior for bith crystals

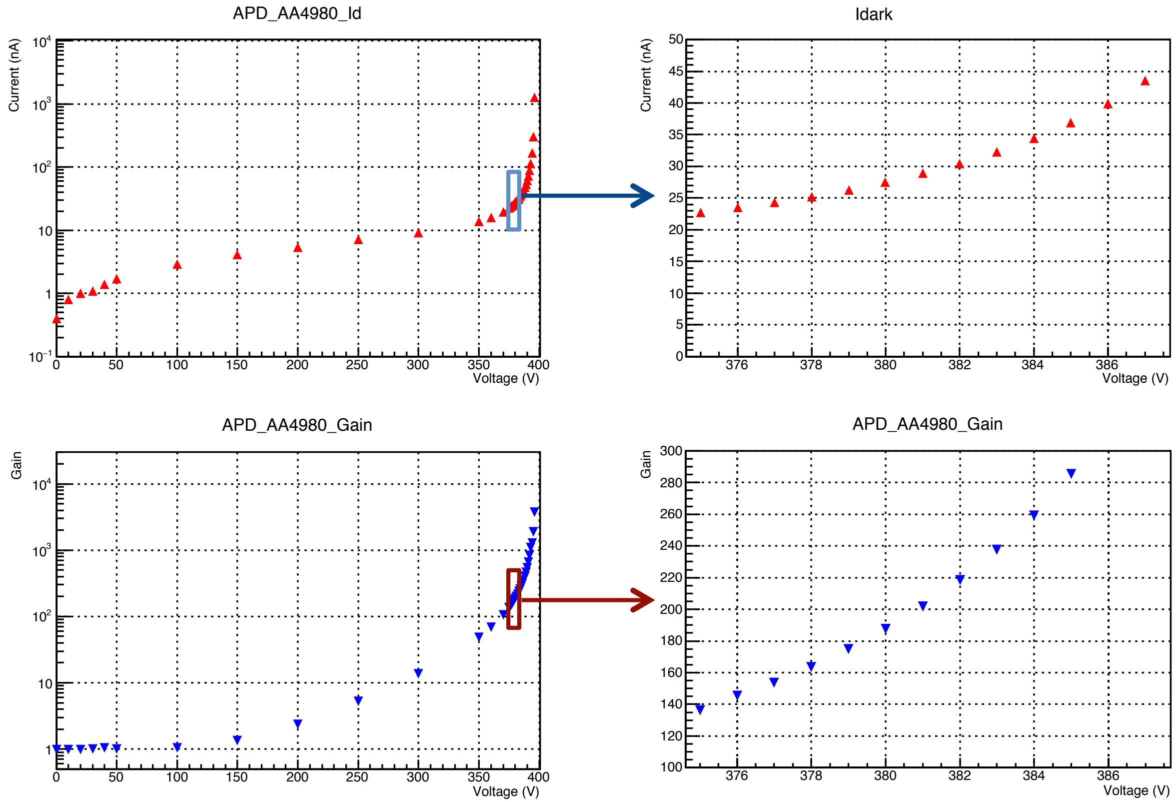






R&D LAAPD: dark current

- Special Large Area APD from Hamamatsu
  - Standard design gain is 50, we use only selected APDs in order to work at G=200 with ΔV>20V
  - Typical I_{dark}~30nA
  - Capicitance 270pF (very high!)
  - QE at 315nm ~ 40%



- 2 APDs for each crystal with separate readout electronics
- Cosmic rays test to optimize the S/N

R&D LAAPD: irradiation

Photons 250 Gy

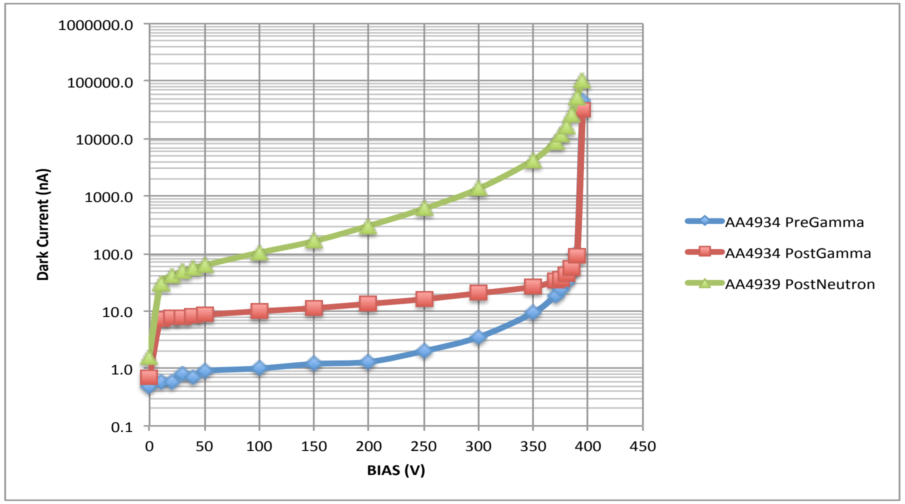
Neutrons 10^12 n/cm^2

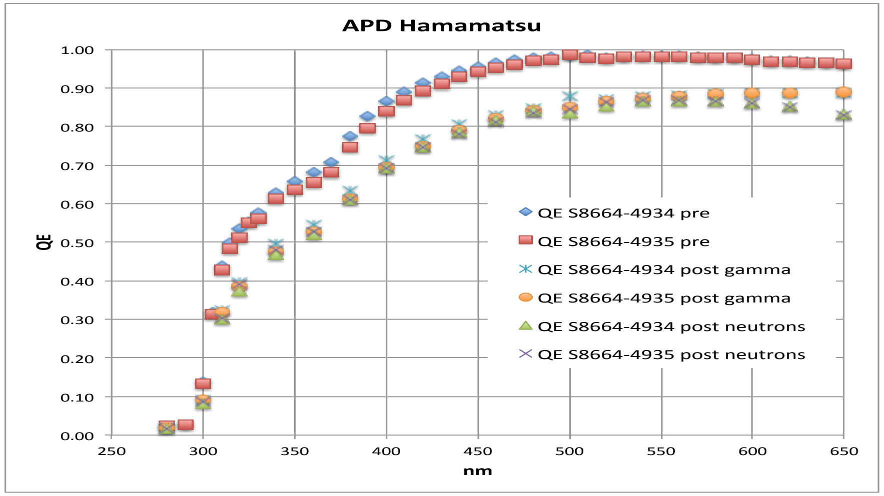
Dark current

PiN diode: 1.4 nA → 1.3 μA

LAAPD: 40 nA → 10 μA

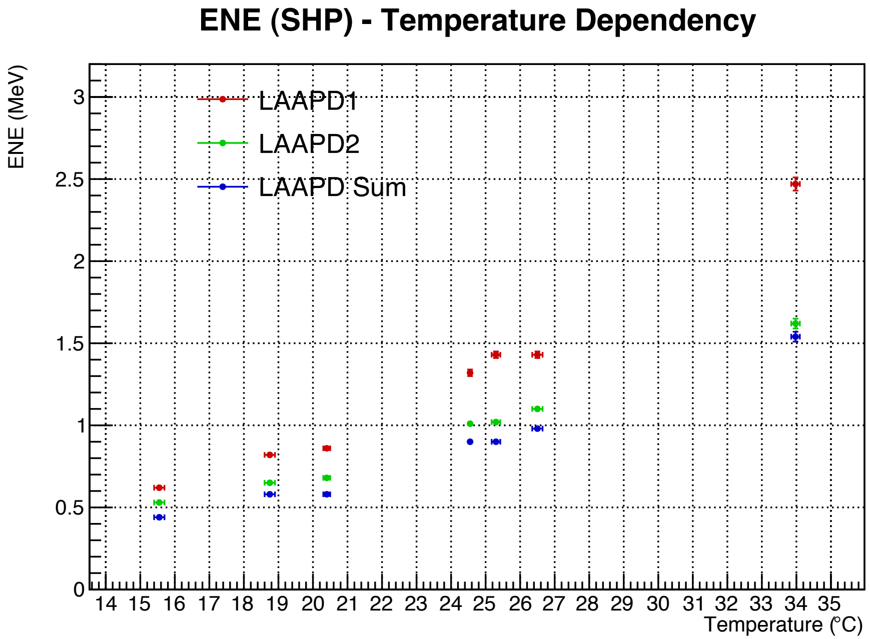
HAMAMATSU LAAPD S8664-1010

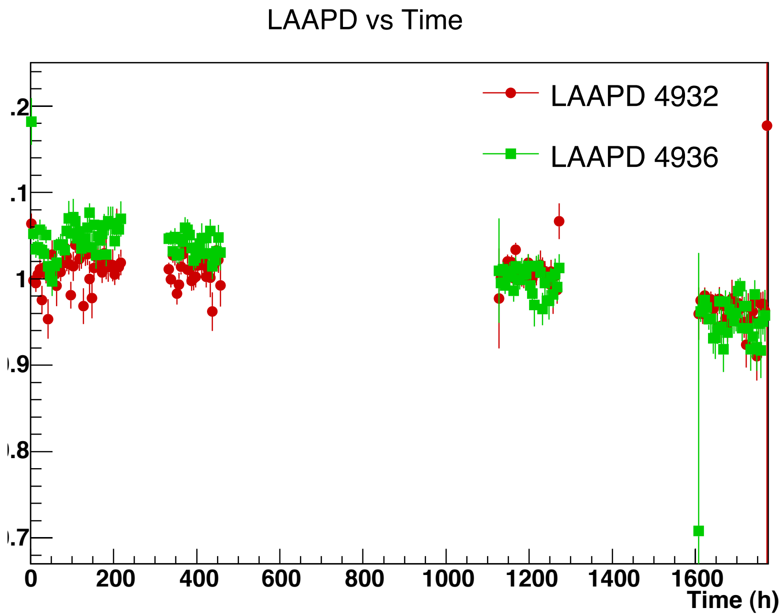




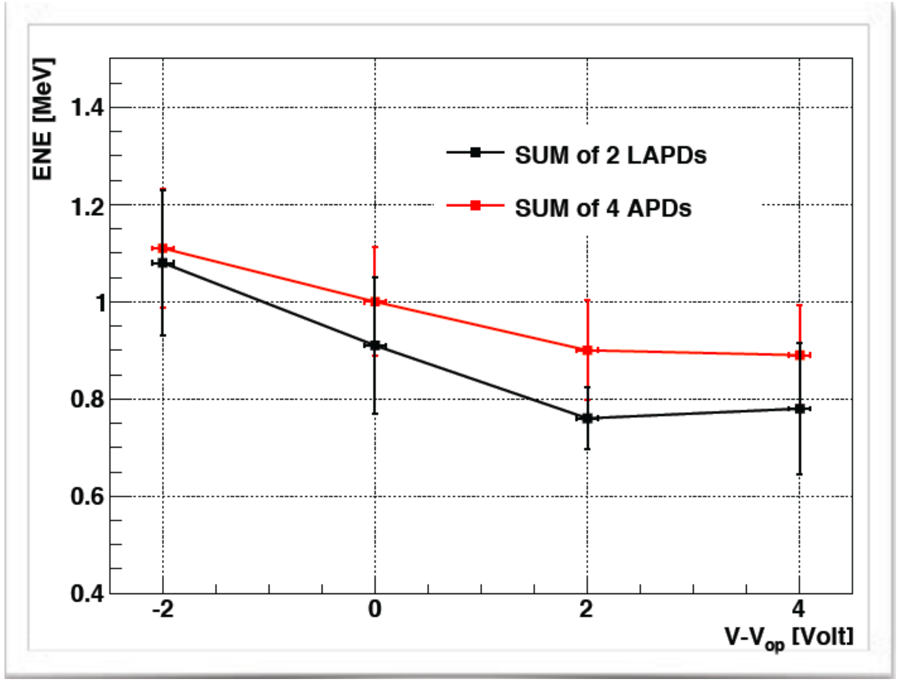
Effect on noise is under study, change in the Q.E. requires a control of the system to calibrate

R&D LAAPD: long term stability





Stability within 1.4% before a drop we suppose caused by the umidity. Nitrogen finished!

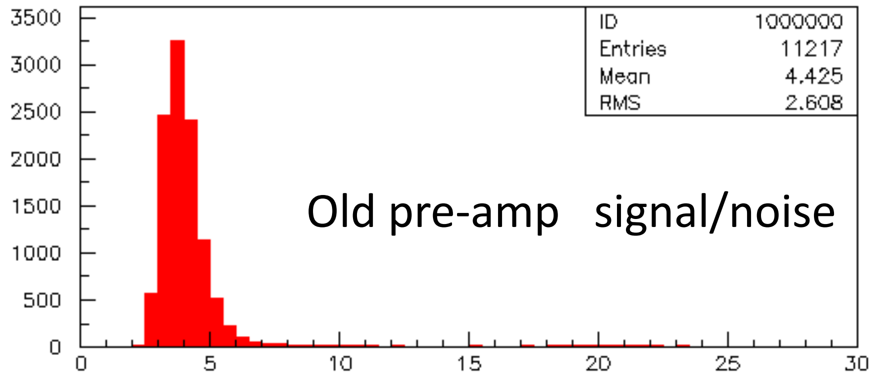


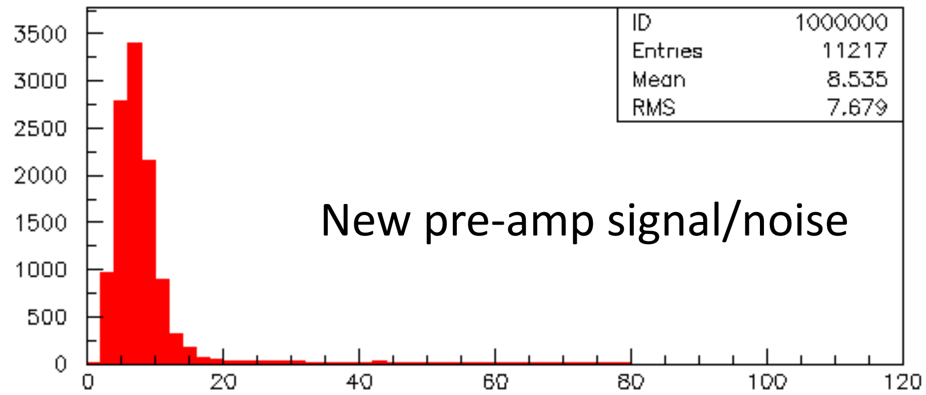
A different producer was tested: smaller devices comparable performance

We have choosen for the beam test to use the LAAPD from HAMAMATSU

Optimization of the preamp

New preamp has been developed at RM3 to enhance S/N for pure CsI crystals





In our setup we gain on S/N a factor 2.6 without shaping. If we had a 12 mV peak (@Test Beam) from cosmic
this would bring our ENE down to 1.5 MeV Single APD no shaping.

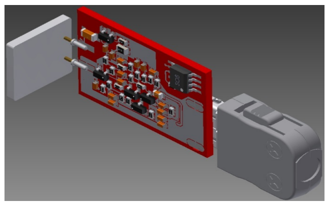
To be compared with final ENE of about 1 MeV after shaping.

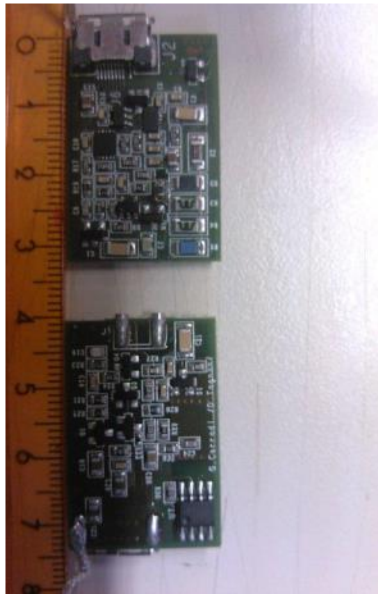
Further improvement can come from WLS now under test → QE of APD's is max @420 nm

Matrix CsI pure prototype

- 4x4 CsI Pure crystals (all produced by Amcrys)
  - Qualification of an Italian producer (Optomaterials) is ongoing
  - First preliminary results shows a very good quality
- Each crystal equipped with 2 Hamamatsu LA-APD
- Each APD is readout with 1 Charge preamplifier
- Single channel HV regulation on frontend board
- 1 temperature sensor (Maxim 1-wire) for each channel

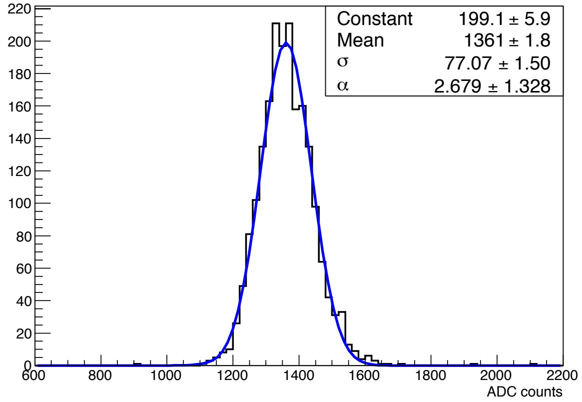
Charge – Preamplifier
Custom discrete amplifier at BJT transistor.
Gain = 1.4V/pC
Power dissipation = 16mW
Single power = 6V to GND
Dynamic Range 2.2V
Tau IN = 40ns



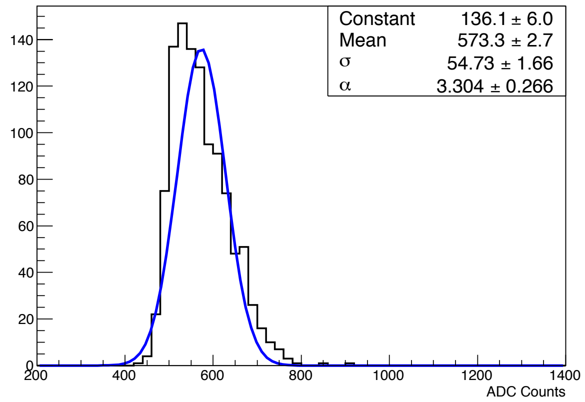


Beam Test results (I)

450MeV – CSP output

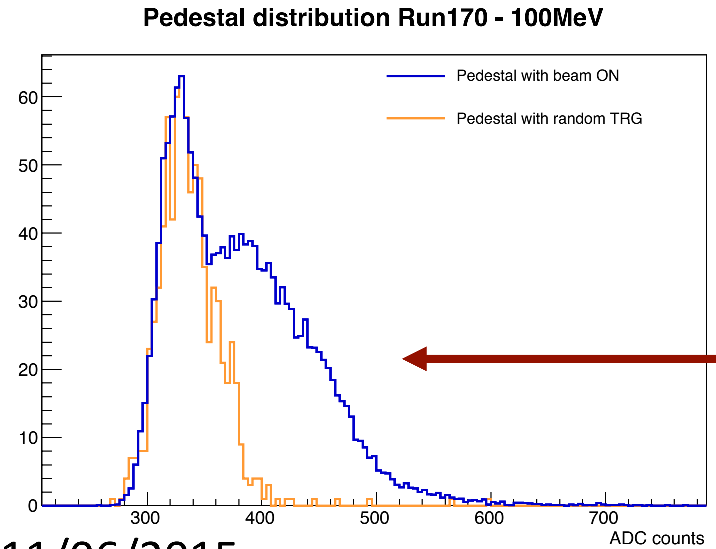


100MeV – CSP output



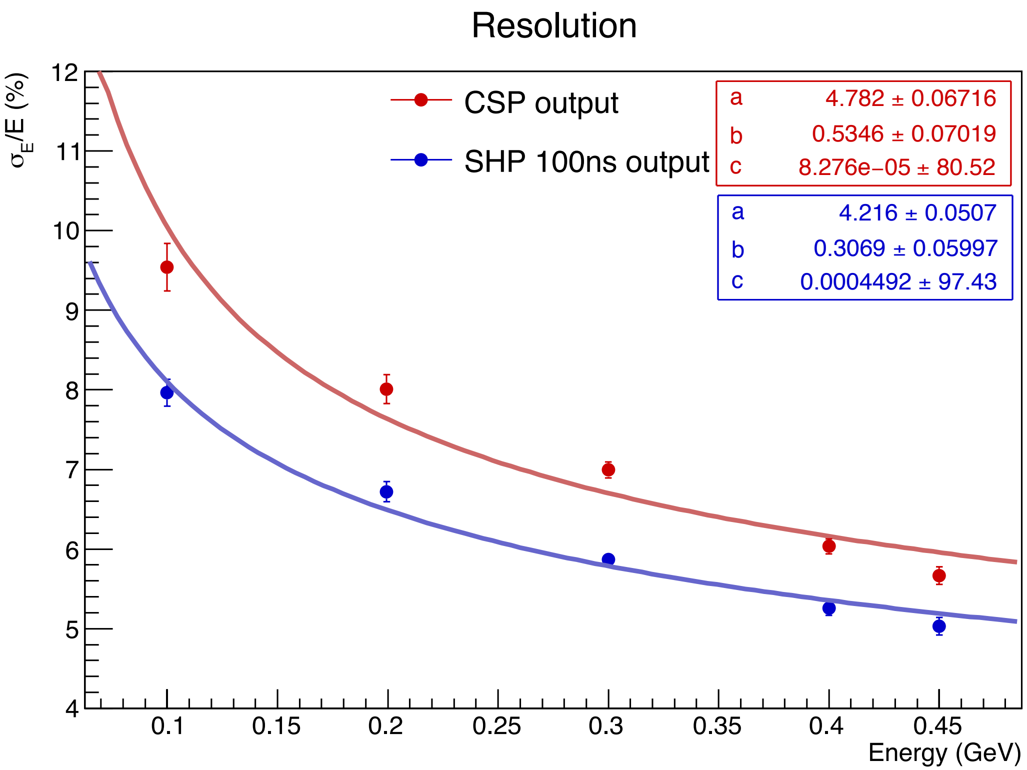
Calibration and temperature correction parameter extracted from cosmic data and applied event-by-event

We found some distortion on energy distribution mainly at low energies



- This is due to pickup noise synchronous to BTF RF trigger
- This is evident when a comparison between pedestal with random trigger and pedestal with BTF RF trigger is performed

Beam Test results (II)

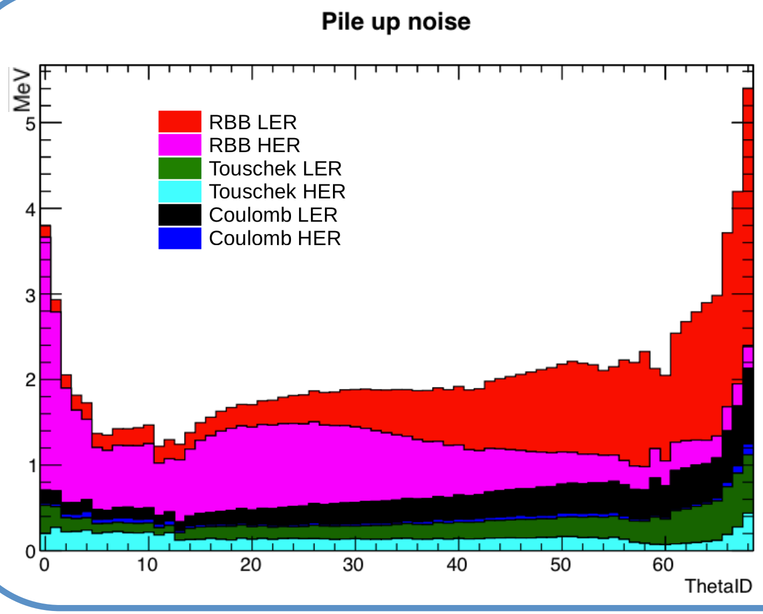


- Resolution compromised by the pickup noise
- Another effect is the beam degradation due to multiple scattering
  - Matrix - Beam pipe distance ~1.7m
  - 8 silicon layer 400μm each
- constant parameter *c* not extracted correctly
  - Probably due to the few energy points

Fit function: $\sigma(E)/E = \frac{a}{\sqrt[4]{E}} \oplus \frac{b}{E} \oplus c$

New Test Beam at Mainz end of July

Backround study



Last results from BelleII MC simulations

Samuel de Jong (UVic)
20th BelleII General Meeting

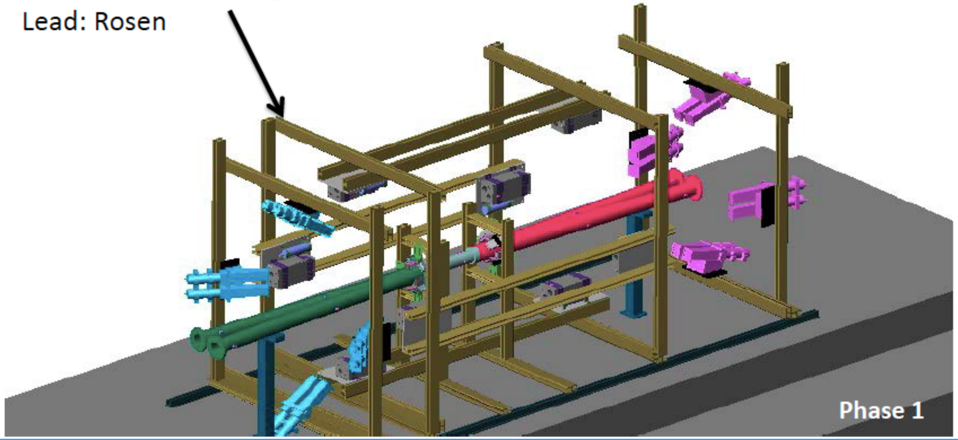
- Pile up greater than 2MeV on fwd and bwd region
  - High background rate expected
  - Study of background is crucial

BEAST: Beam Exorcism for A Stable Belle Experiment

Goals:

1. Protect Belle II: Ensure radiation levels safe before Belle roll-in
2. Measure individual beam background components
3. System tests (beam abort, VXD occupancy, cooling, mask control system)
4. Provide real-time feedback to SuperKEKB

- Hawaii delivering phase 1 mechanical mounting structure
- Lead: Rosen



- Variety of detector systems on fiberglass support structure
- Some detectors (TPCs, He-3 tubes, PIN diodes) can be easily moved manually
- Full 3D CAD exists (Rosen). Also has been incorporated in the Belle II simulation (Jaegle).
- All parts procured, most assembly, to be used for "MiniBEAST" system test January 2015.
- Disassemble and ship to KEK August 2015.

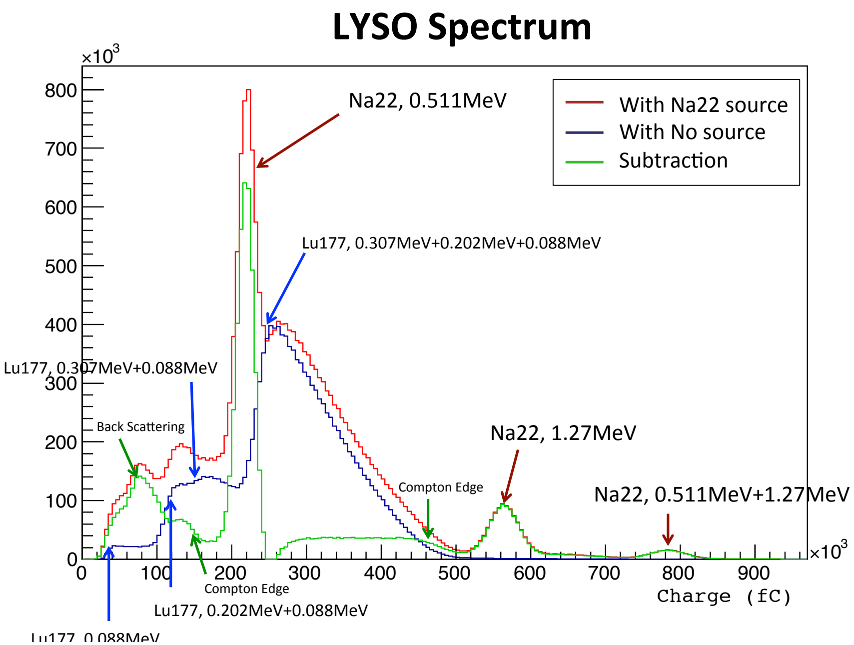
Phase 1 Jan 2016

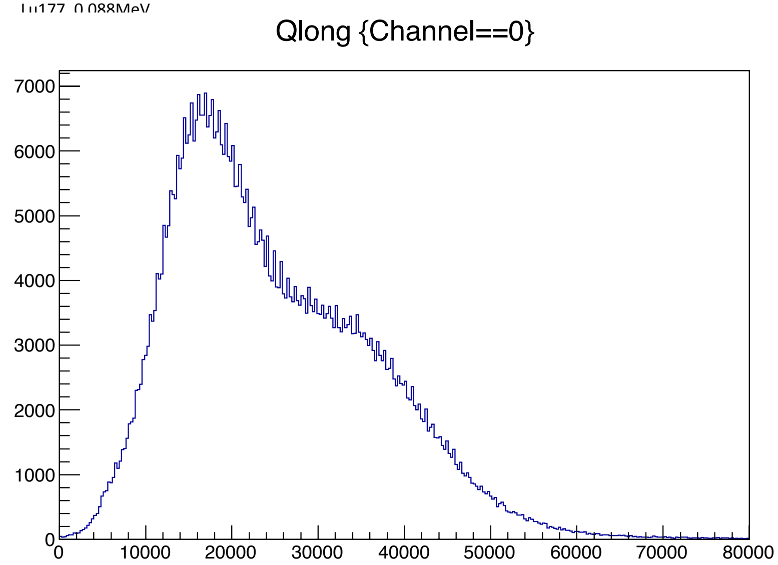
Scrubbing of beam pipe
No collisions, Belle will not roll in
Variety of subsystems on fiberglass support structure

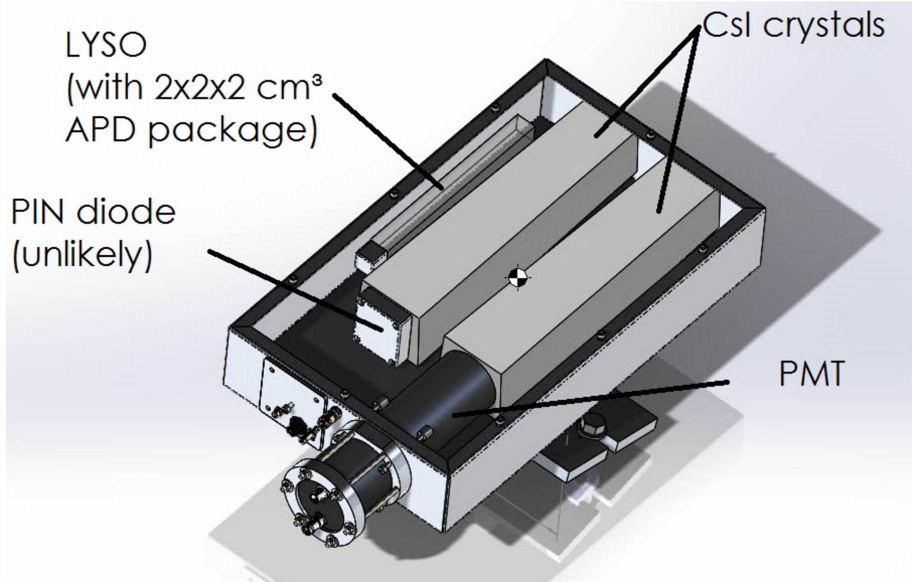
Phase 2 Feb 2017

Belle rolled in
VXD BEAST
He-3 and TPC neutron detectors in VXD dock space

BEAST: first mechanical assembly of detectors + DAQ







- Validate MC predictions of rates in crystals
- Integrate CsI(Tl) system with:
  - Pure CsI crystal read out
    - Faster 1 us → 30 ns light emission can sustain higher rates (but << LY)
    - Allow comparison of performances w.r.t. CsI(Tl) in high rate environment
  - Lyso crystals read out
    - Fast (~40 ns light emission) AND comparable LY w.r.t. CsI(Tl), yielding high resolution at low energy (~MeV)
  - Add counting capability
    - Add scalers to count rates in crystals → Correlation between rate and energy "dN/dt(E)"
  - Monitor conditions
    - Add uSOP based readout of T,RH probes attached to CsI crystals
- Keep system as simple as possible

Schedule of BelleII and upgrade

Task force on ECL upgrade will make final decision February 2016

A partial upgrade (only internal ring) is also under study

Alternative proposal in case of no upgrade are under investigation (understand pile-up mitigation with an ad-hoc FE + shaping)

TDR ECL FWD: I would propose to shift it from January 2016 to July 2016 → by that time R&D will be finished, BEAST will have first result and physics performance studies will be well advanced in order to have a clear view of the ECL FWD upgrade

Conclusions

- Studies on the actual ECL FWD calorimeter have been performed
- R&D on crystals, APD's and FE electronics

  Compare results to optimize the upgrade

- Test beam: final test end of July at Mainz
- BEAST: measurement of the background will give more information on pile-up mitigation
- TDR for ECL FWD upgrade → July 2016 after the decision of the task force on the upgrade