R&D on ECL FWD calorimeter:
breve riassunto degli anni trascorsi insieme dagli amici del gruppo ECL

Outlook

- Il problema del FWD ECL ad alta luminosità

→ pile-up
  - ENE
  - Risoluzione
  - Sorgente
- Performance
- Filtri + WLS
- Test beam
- Futuro e conclusioni

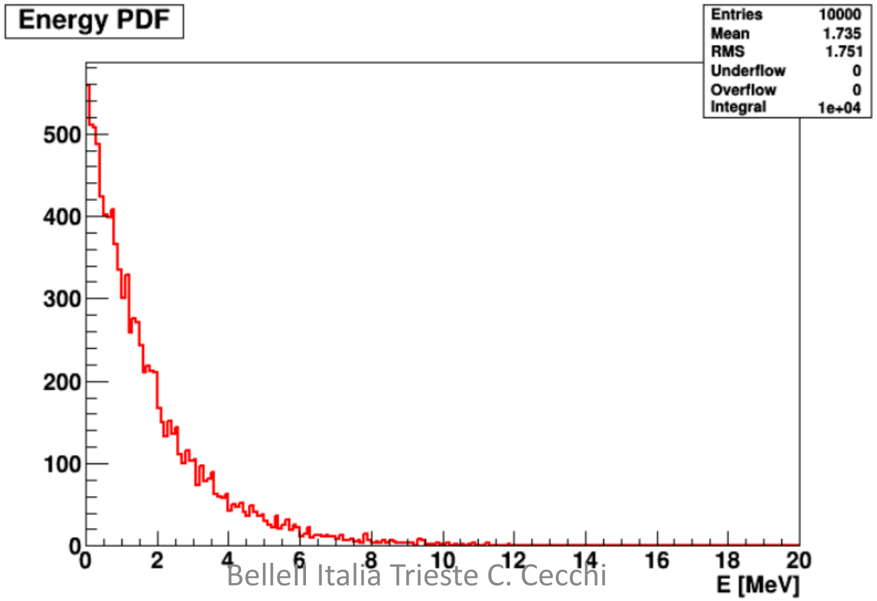
Studio del pile-up

- Simulazione pile-up con cosmici su cristalli CsI(Tl) e CsI puro
- Simulazione a partire da BG campagna ufficiale

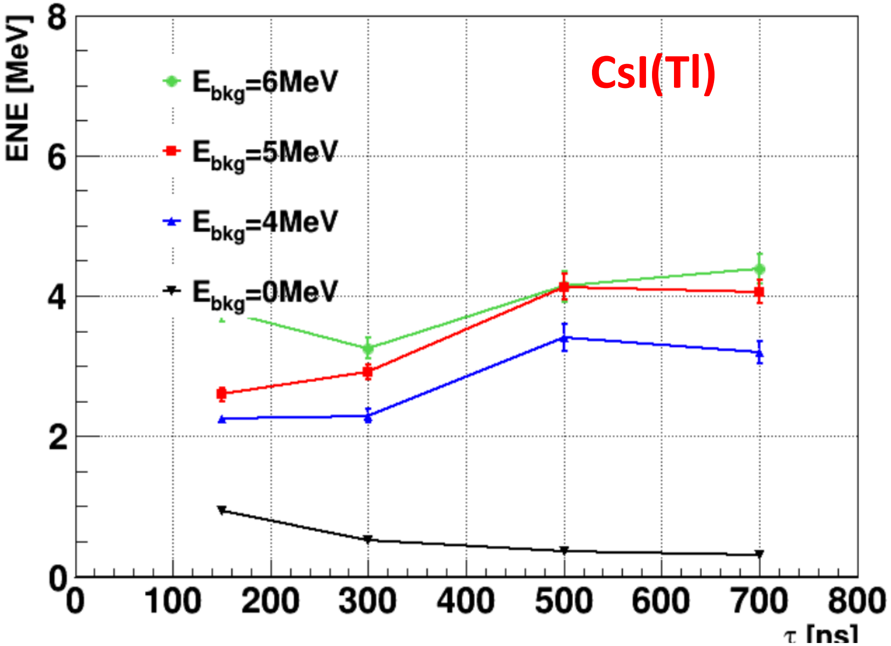
Simulazione

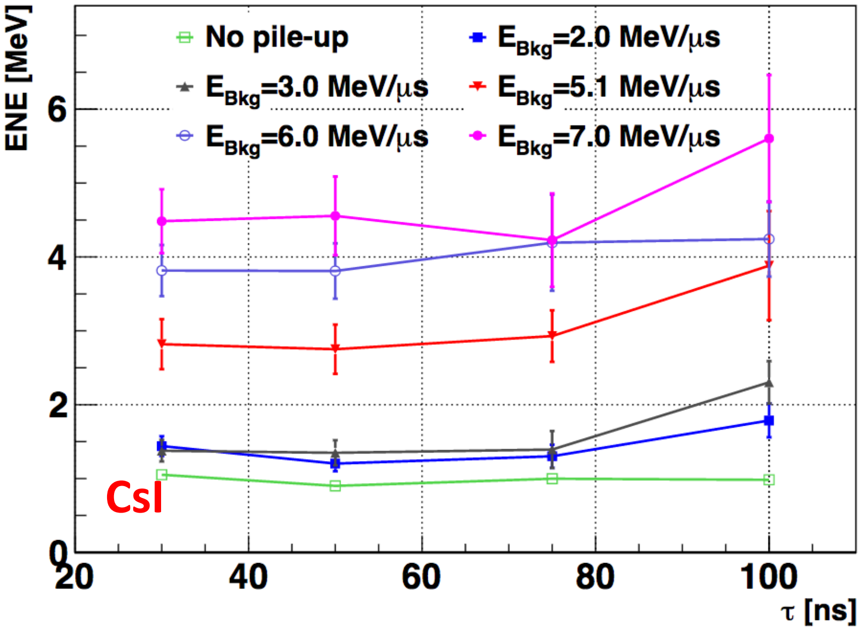
- L’ampiezza dell’evento precedente (con MPV corrispondente a 40 MeV) viene riscalata per ottenere l’energia dell’hit di fondo

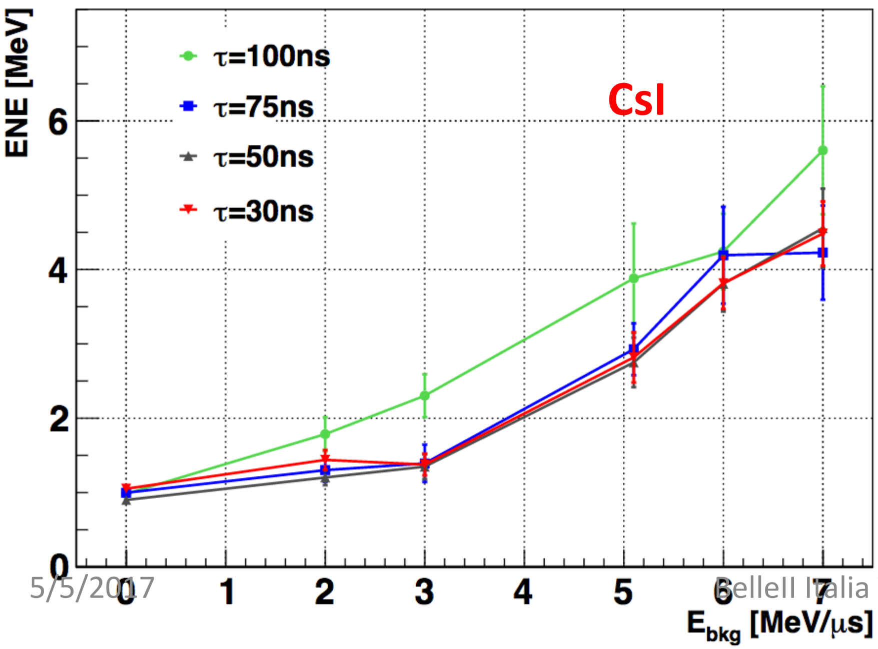
- Per gli hit di di fondo uso una distribuzione energetica esponenziale con media λ = **$E_{average}$/nhit =5.1MeV/3hits** per µsec (i numeri ottenuti da Benjamin per il cristallo 80, con taglio E>0.5MeV). La distribuzione temporale è assunta piatta tra -2 e 10 µsec. In questa configurazione quindi aggiungo in media 5.1 x 12 = **61 MeV** in 3x12 = **36 hits**, per ogni evento
- Ho fatto anche i casi **$E_{average}$/nhit=4MeV/2.5hits** e **6MeV/3.5hits** (~ stessa **λ**)



Equivalent Noise Energy (ENE)



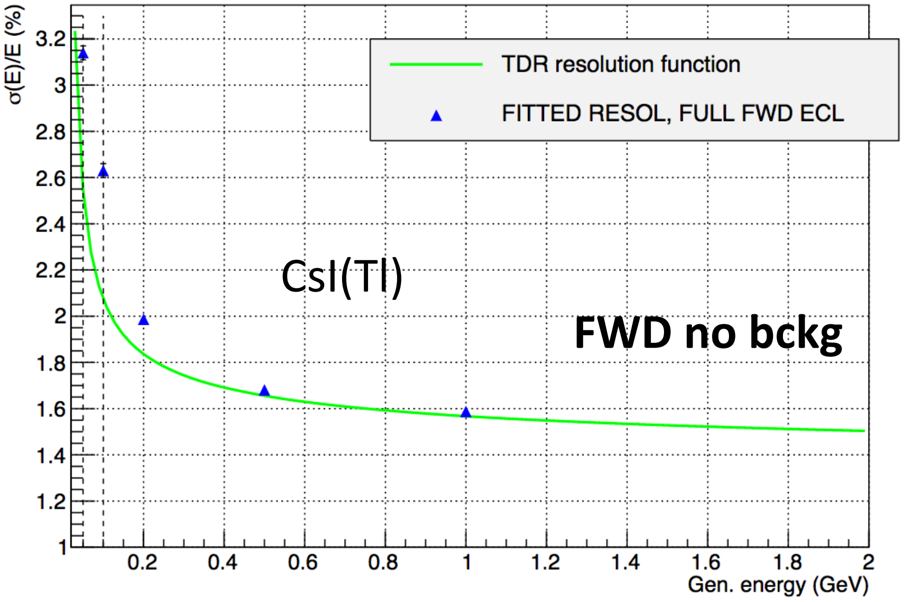




ENE circa 3 MeV in presenza di pile-up.

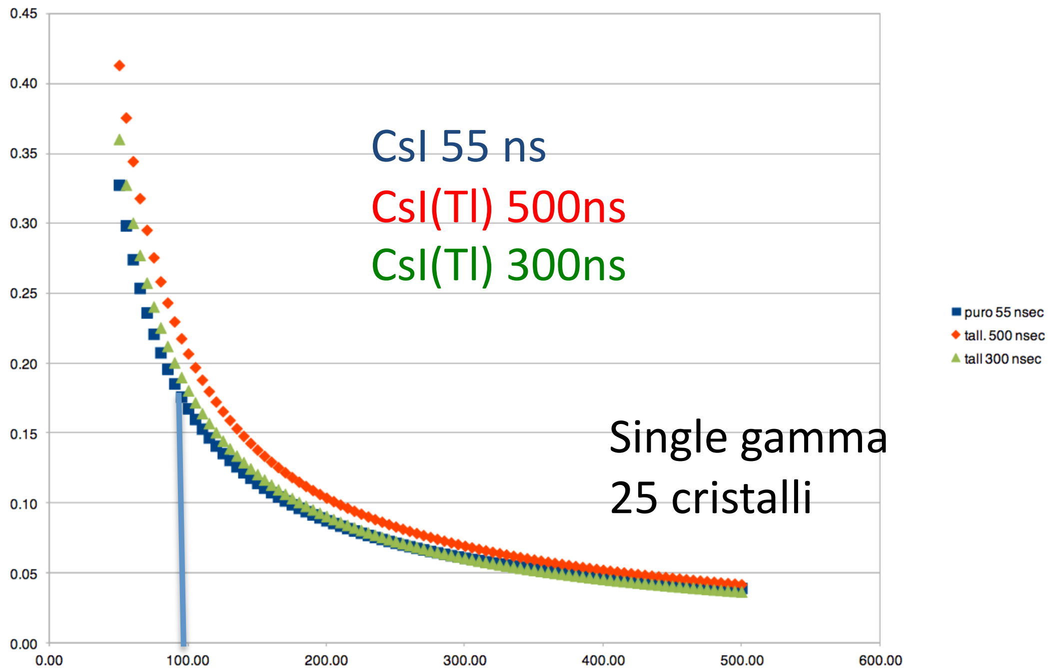
(Dipende da finestra di acquisizione e shaping time)

Risoluzione



CsI(Tl)

FWD no bckg



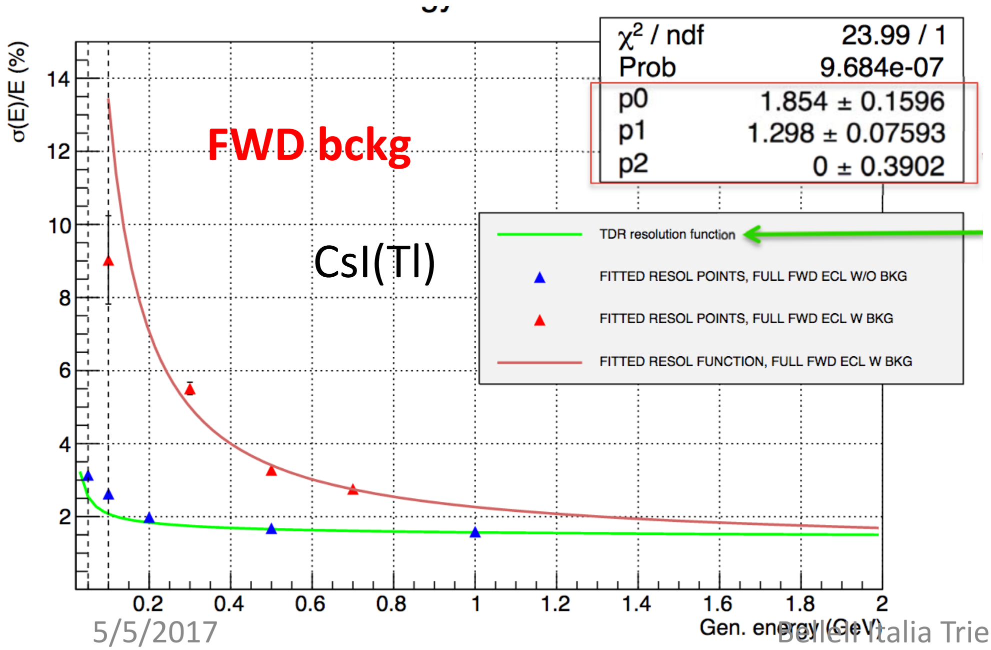
CsI 55 ns

CsI(Tl) 500ns

CsI(Tl) 300ns

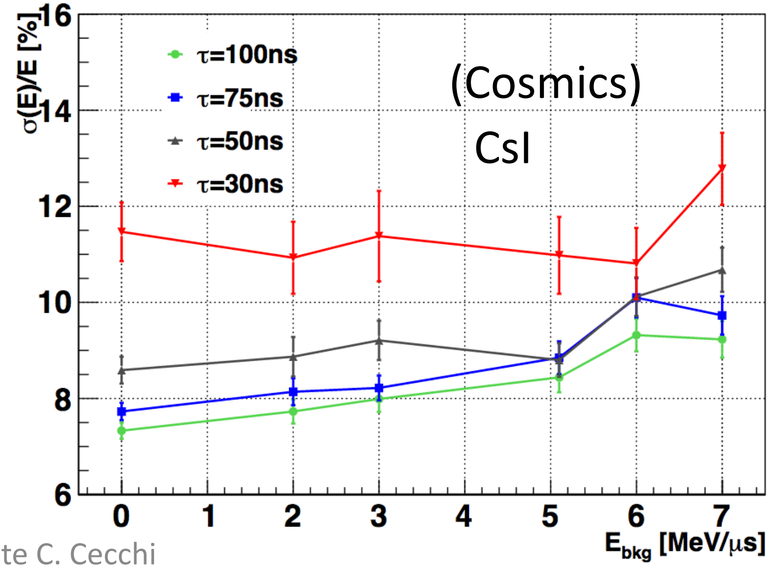
Single gamma

25 cristalli



FWD bckg

CsI(Tl)



(Cosmics)

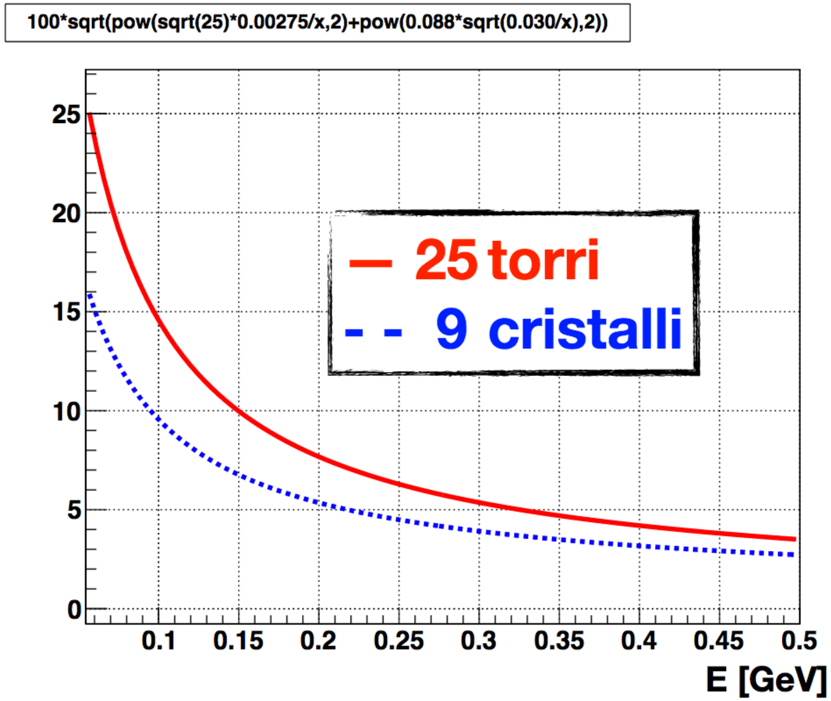
CsI

Risoluzione

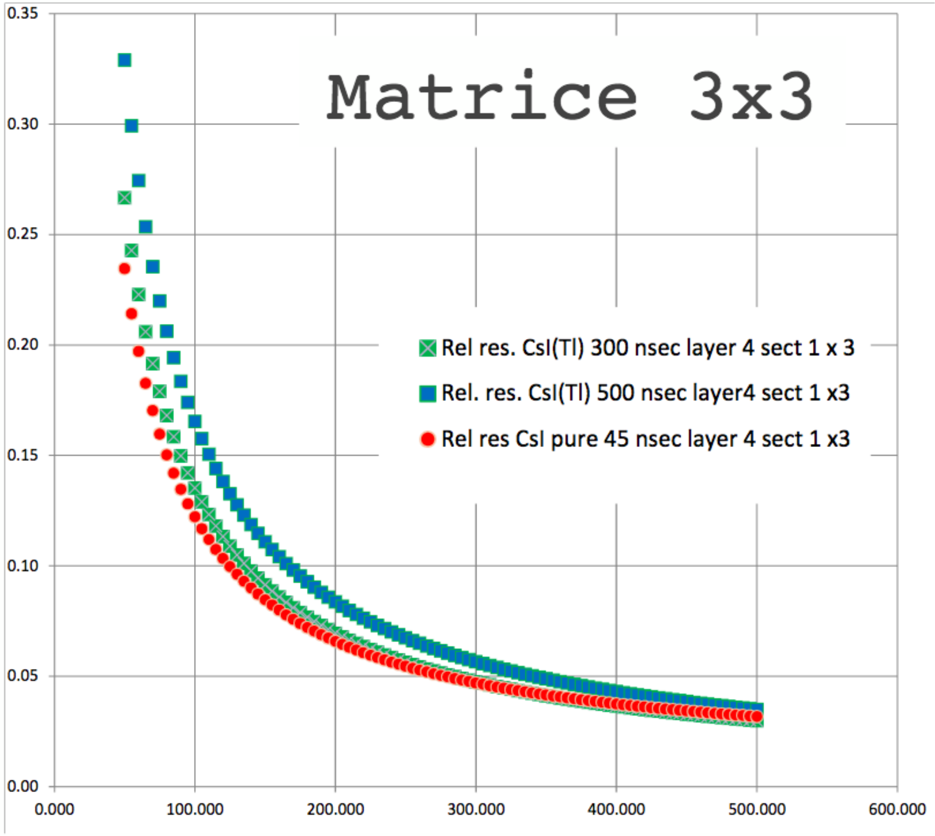
$\sigma(E)/E = \sqrt{25} \times \mathbf{ENE}/E \oplus \mathrm{reso}_{\mathrm{cosmici}} \times \sqrt{(0.030/E)}$

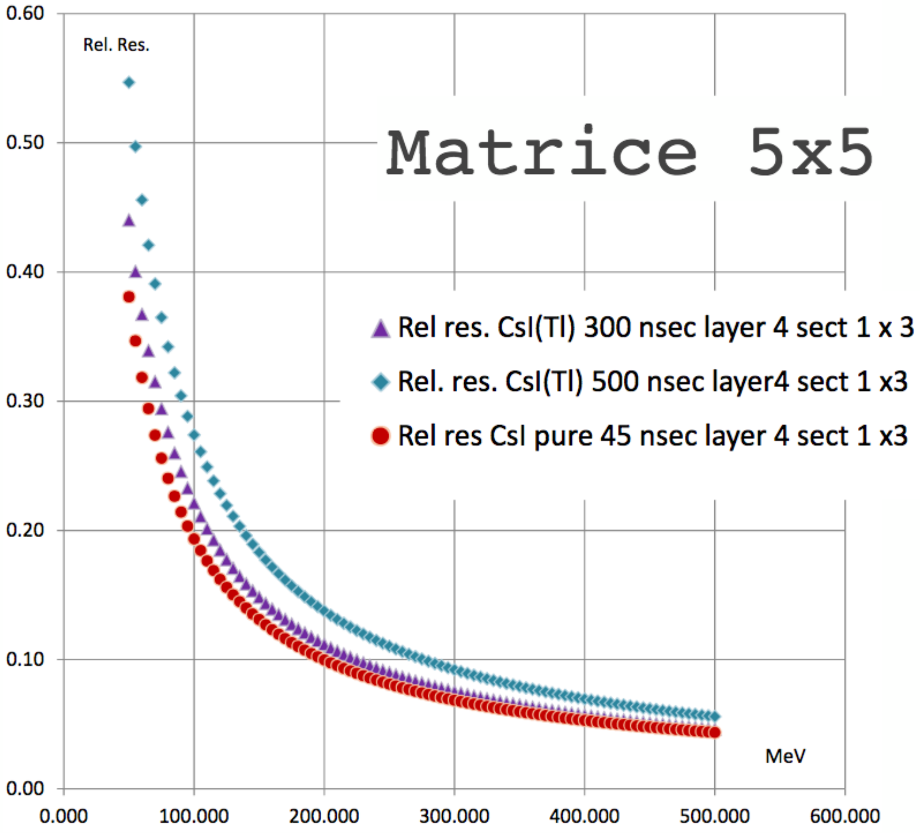
$\sigma(E)/E = \sqrt{9} \times \mathbf{ENE}/E \oplus \mathrm{reso}_{\mathrm{cosmici}} \times \sqrt{(0.030/E)}$

@ E_{bkg}=5.1MeV/μs, τ=50ns:
ENE=2.75MeV σ/E=8.8%



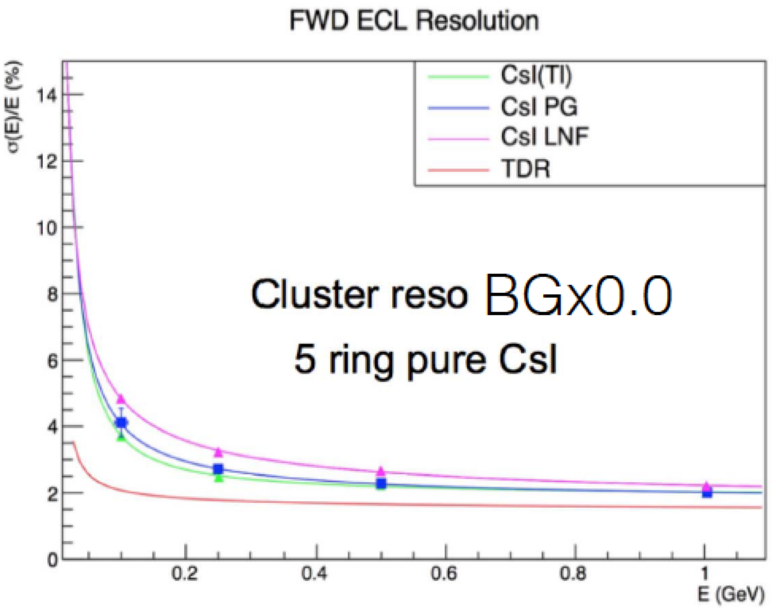
Risoluzione

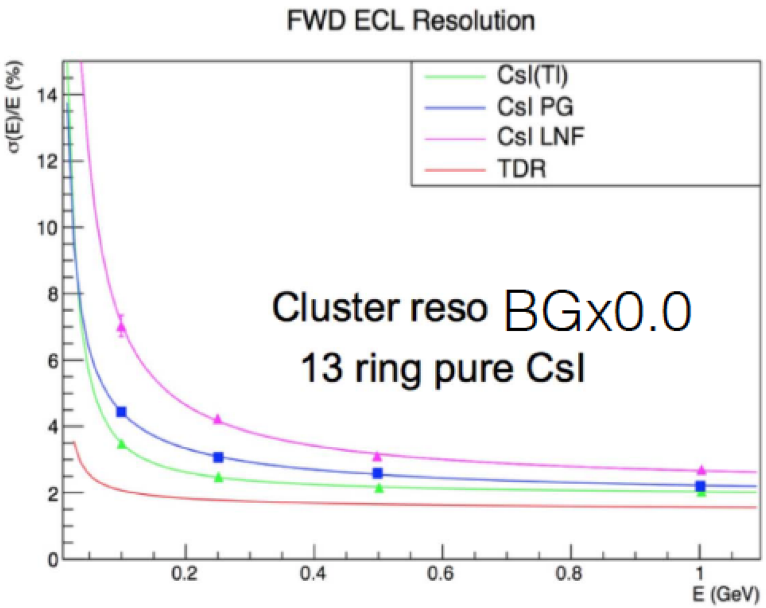


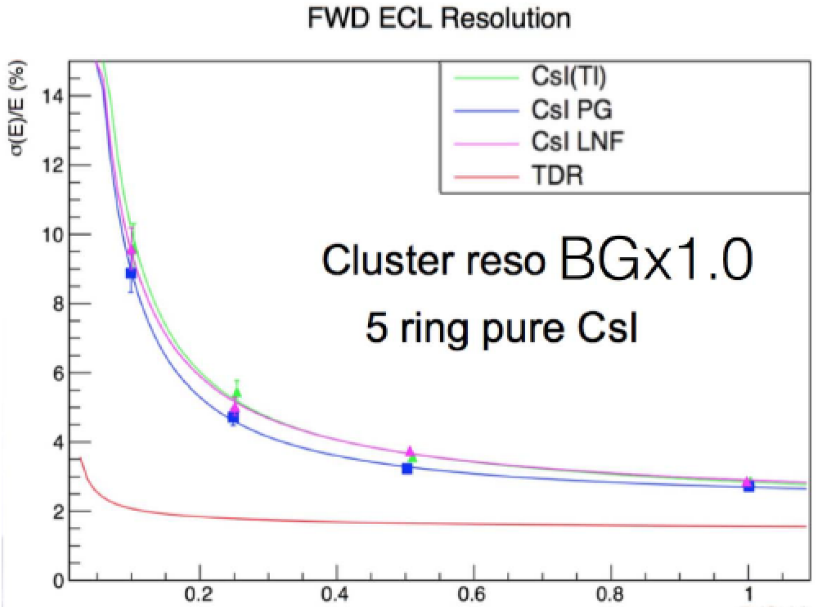


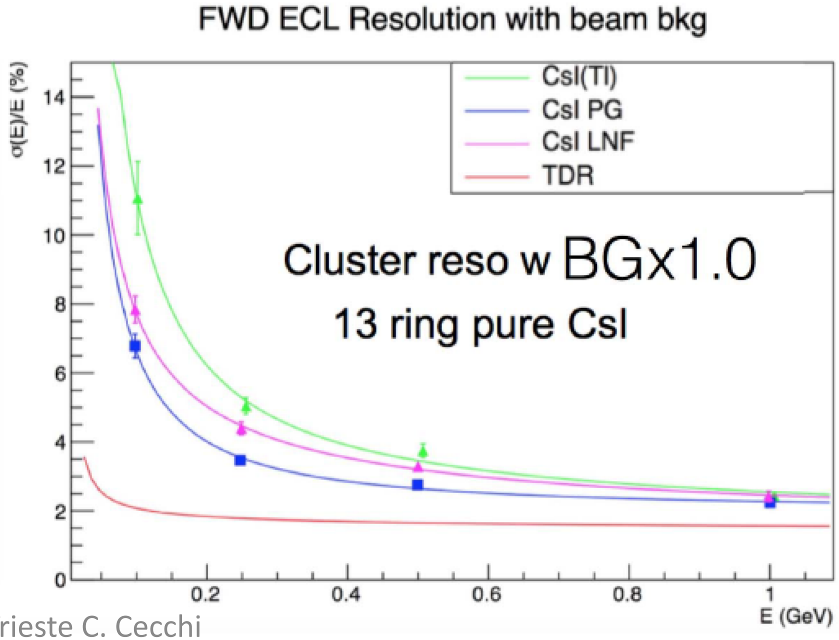
Safety factor x 3

Resolution


FWD ECL Resolution
σ(E)/E (%)
E (GeV)
0
2
4
6
8
10
12
14
0.2
0.4
0.6
0.8
1
CsI(Tl)
CsI PG
CsI LNF
TDR
Cluster reso BGx0.0
5 ring pure CsI


FWD ECL Resolution
σ(E)/E (%)
E (GeV)
0
2
4
6
8
10
12
14
0.2
0.4
0.6
0.8
1
CsI(Tl)
CsI PG
CsI LNF
TDR
Cluster reso BGx0.0
13 ring pure CsI

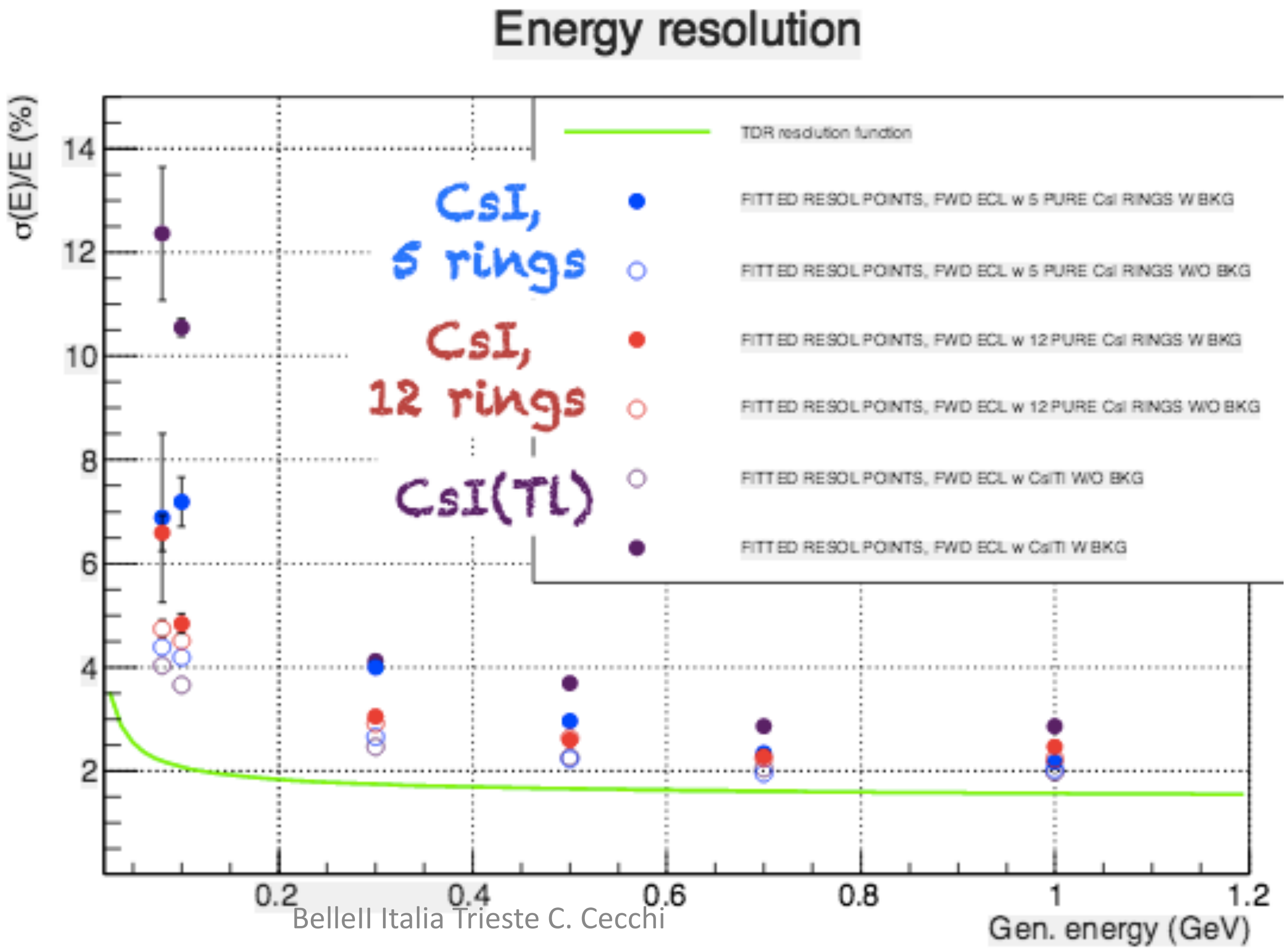

FWD ECL Resolution
σ(E)/E (%)
E (GeV)
0
2
4
6
8
10
12
14
0.2
0.4
0.6
0.8
1
CsI(Tl)
CsI PG
CsI LNF
TDR
Cluster reso BGx1.0
5 ring pure CsI


FWD ECL Resolution with beam bkg
σ(E)/E (%)
E (GeV)
0
2
4
6
8
10
12
14
0.2
0.4
0.6
0.8
1
CsI(Tl)
CsI PG
CsI LNF
TDR
Cluster reso w BGx1.0
13 ring pure CsI

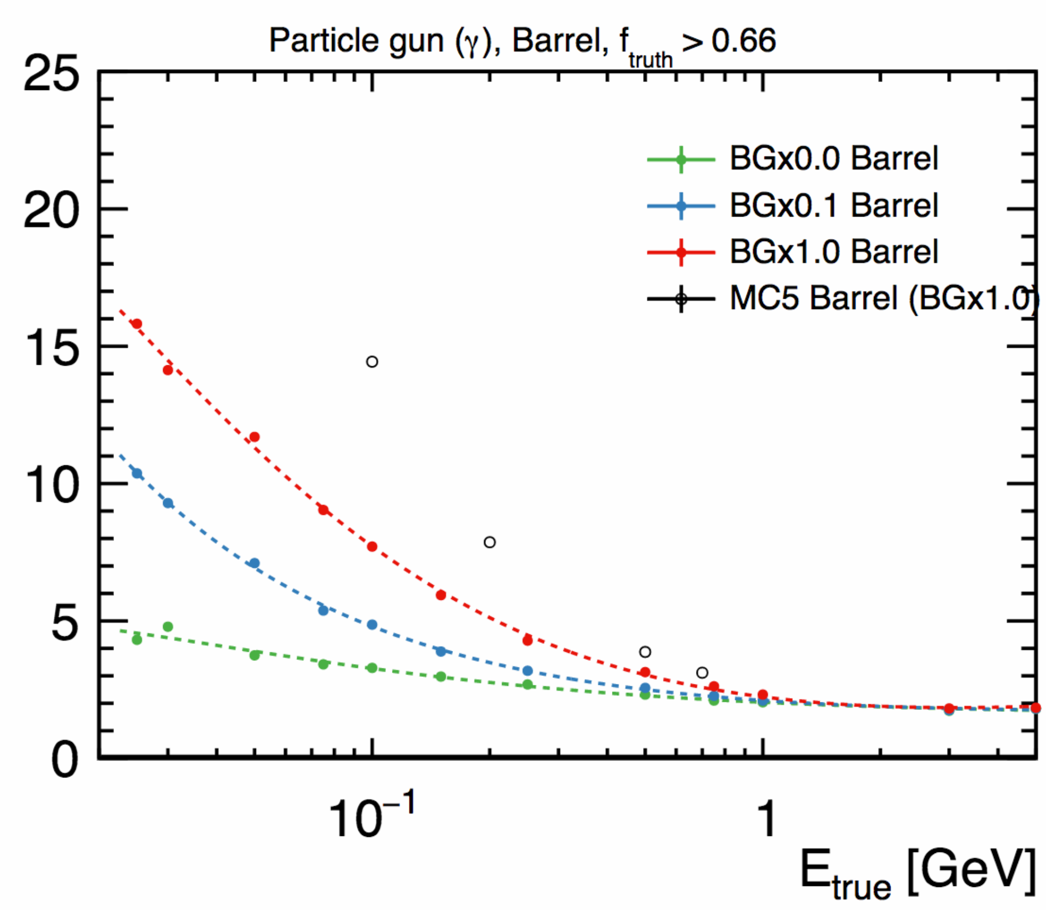
Full simulation of pure CsI

Replacing CsI(Tl) rings with pure CsI

With current reconstruction code and parameter set, resolution with CsI-12 rings + machine bkg at the level of bkg-free performances

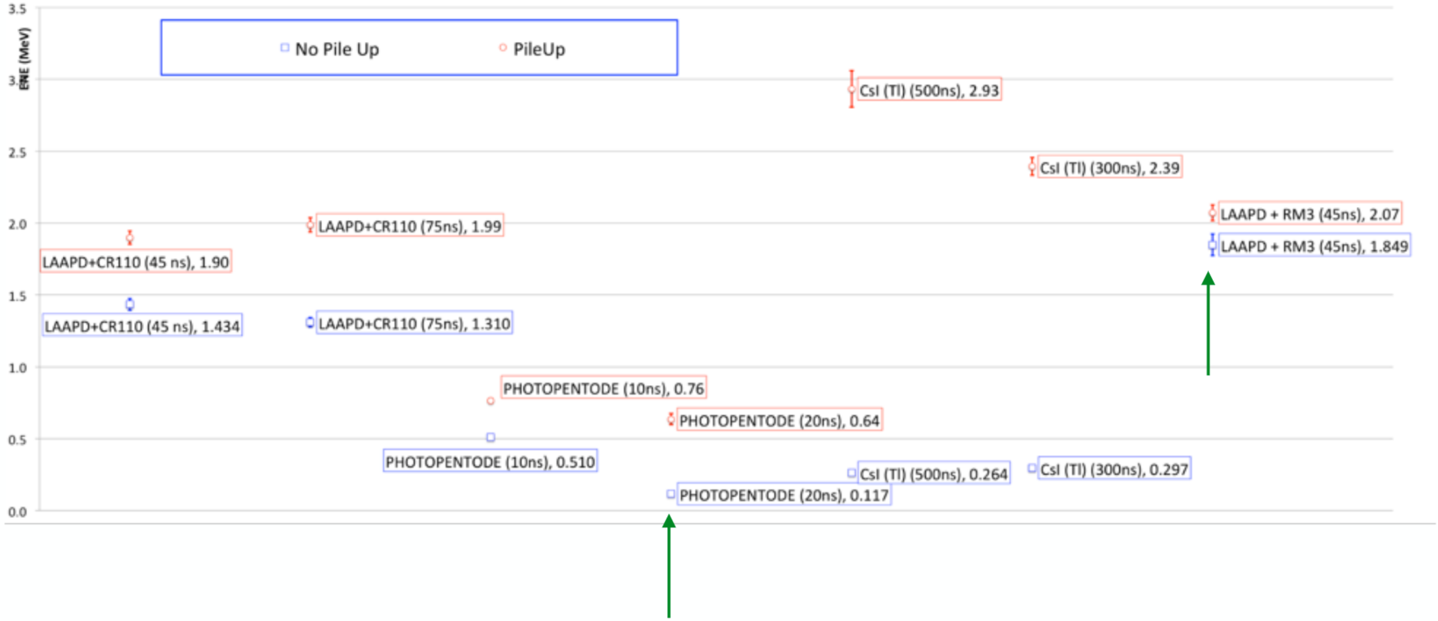


New reconstruction algorithm



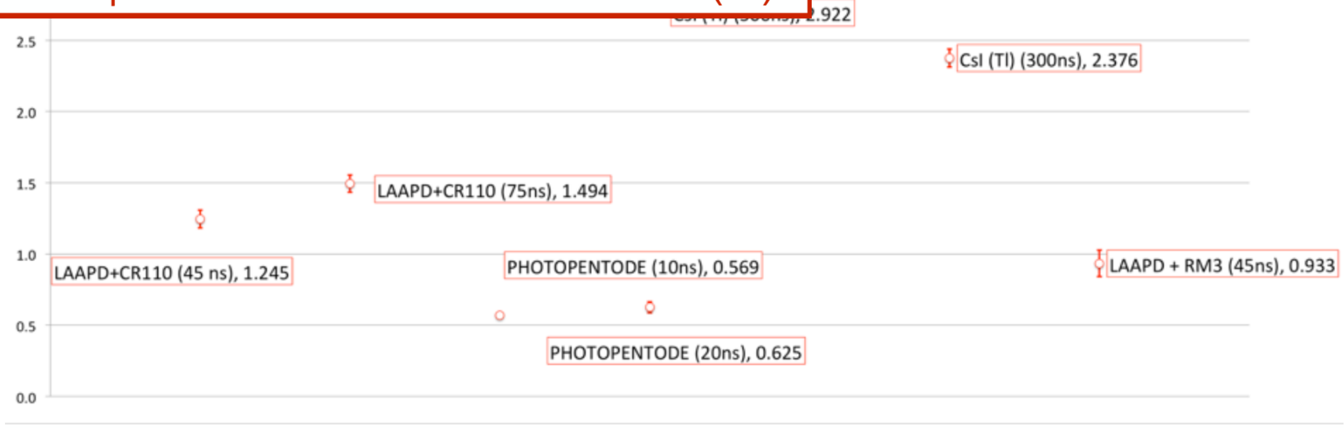
Studio delle performance con CsI puro e algoritmo di ricostruzione ottimizzato → DA FARE

Pile-up con sorgente



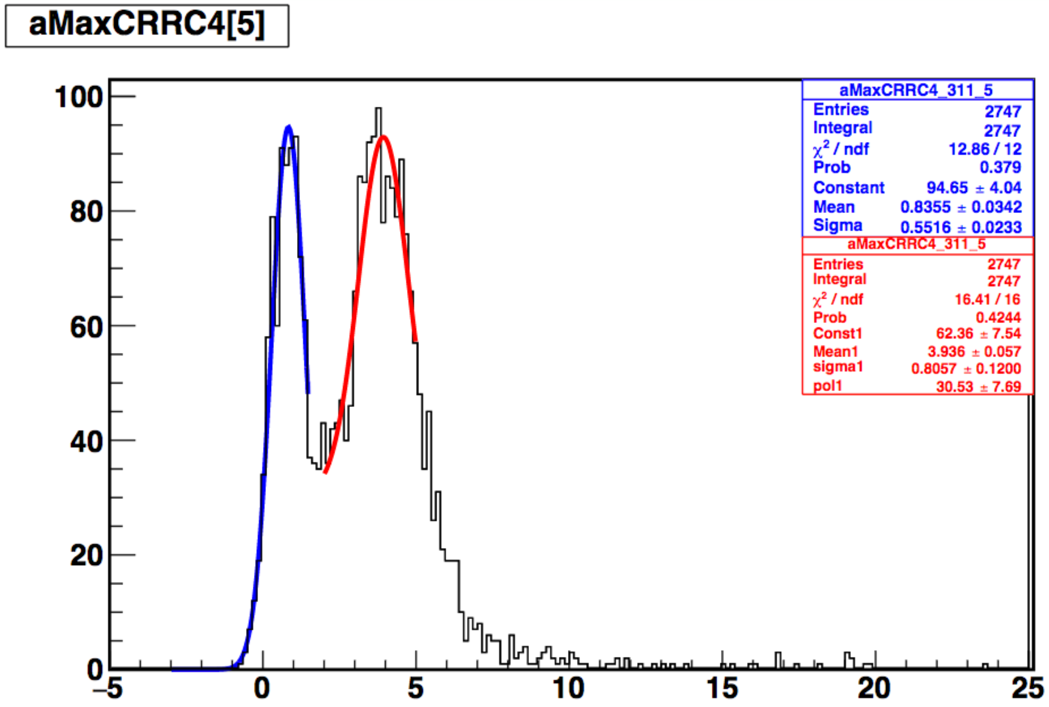
The ENE with pile-up is ~**2 MeV** for pure CsI and ~**3 MeV** for CsI(Tl)

Contributo all’ENE da pile-up



Doped CsI has ~twice the ENE of pure CsI from pile-up, in agreement with the results obtained with the simulations

Misure filtro + sorgente

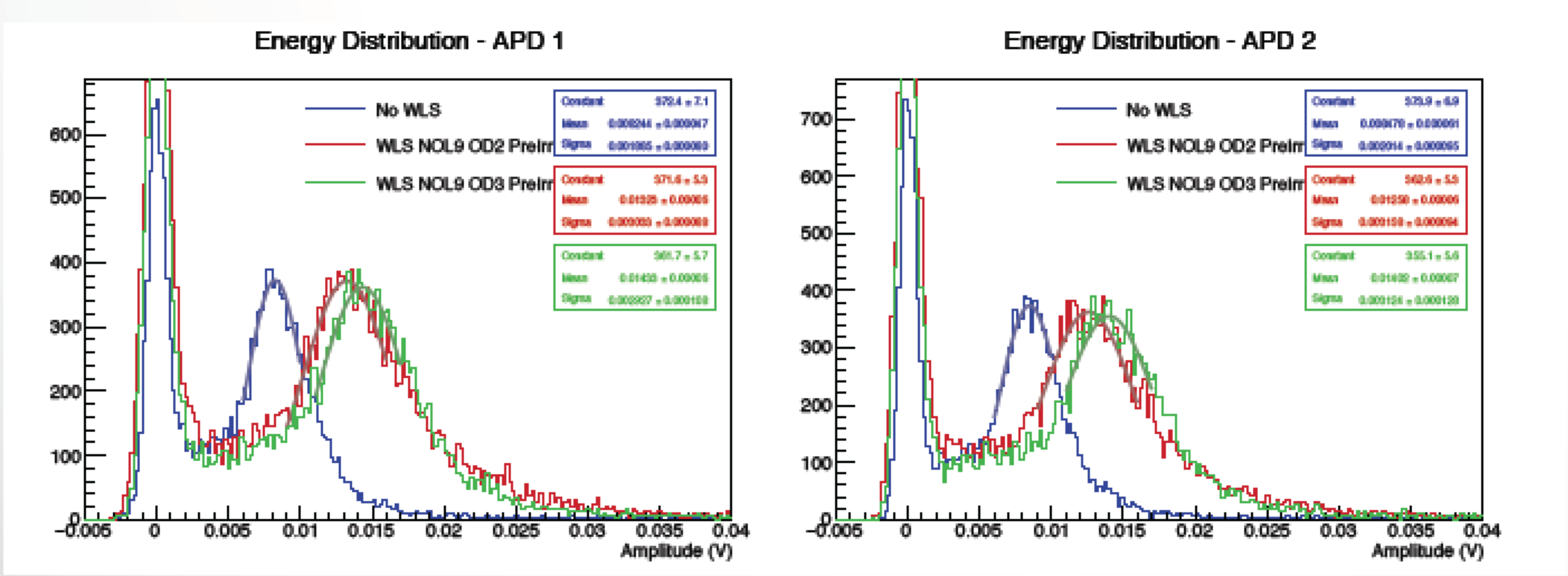


- amplitude = 3.10±0.07 mV ENE = 5.34±0.25 MeV

signal (filter+source)/signal(filter) = 1.06±0.03%
ENE (filter+source) /ENE(filter) = 0.86±0.07

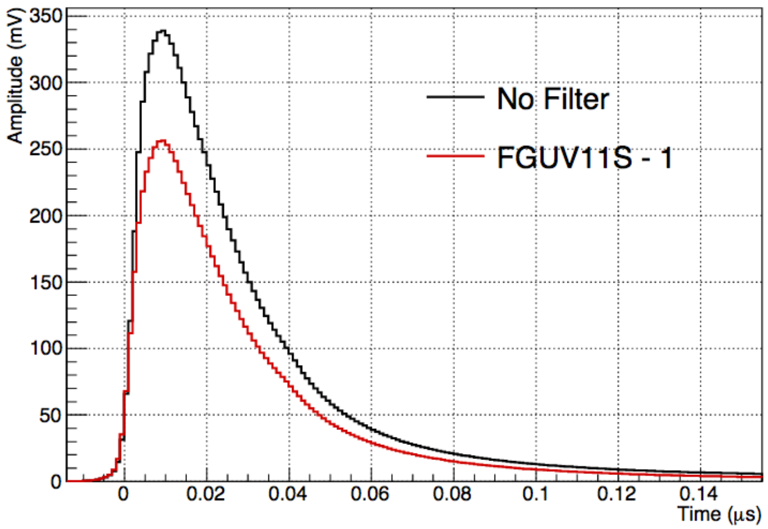
(unchanged)

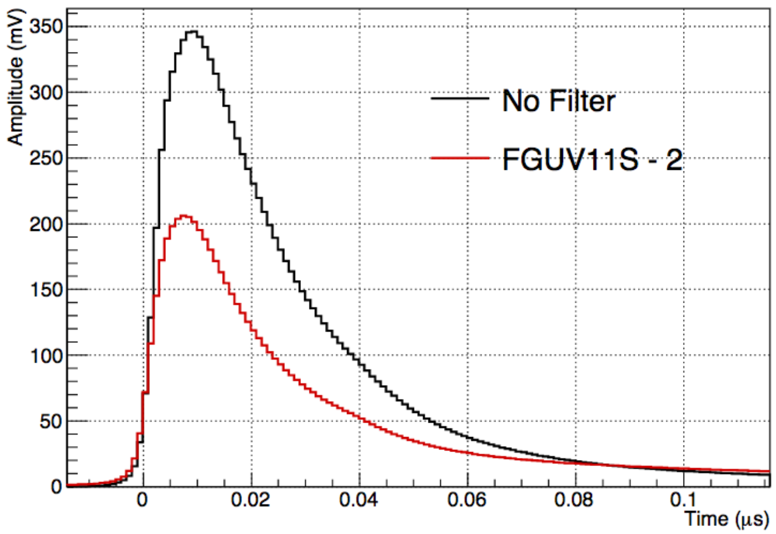
WLS



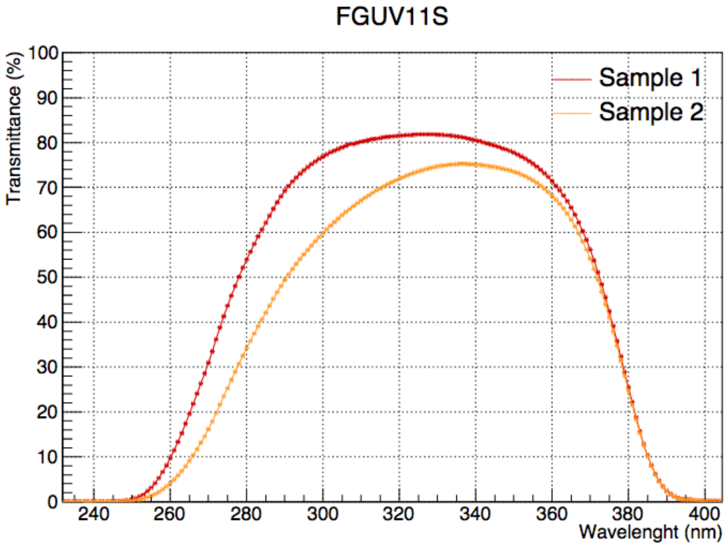
Guadagno circa un fattore 2 nel segnale
Piccole differenze tra i due campioni con densità ottica diversa
Problemi dopo l’utilizzo con grasso ottico a causa della perdita di luminofori
Irraggiati fino a 105 Gy → nessun cambiamento osservato

Filtri

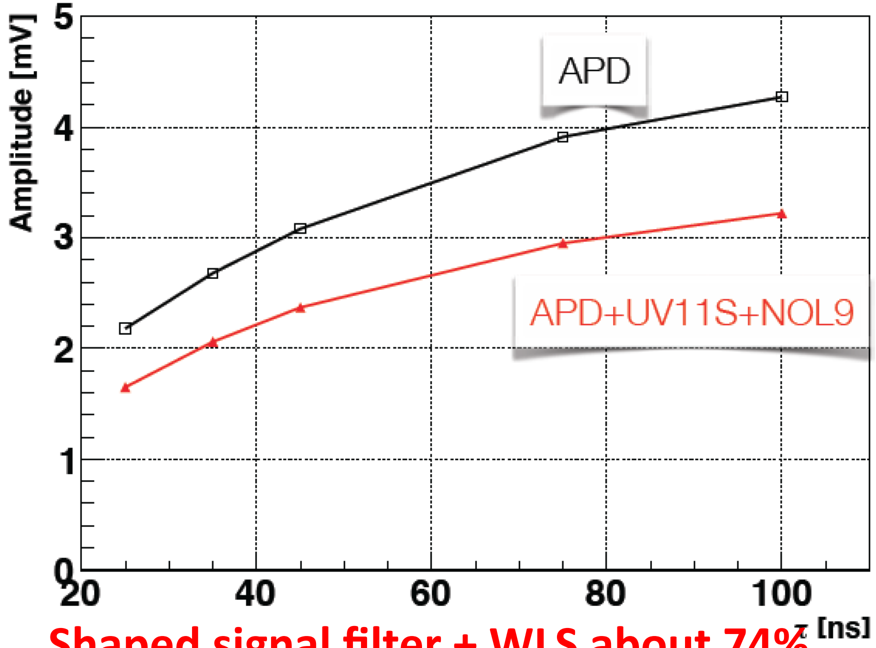




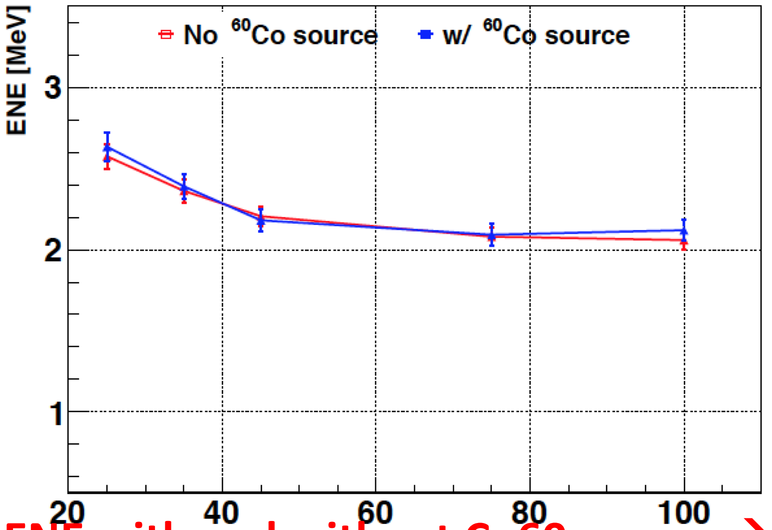
- FGUV11S – Sample 1
    - (340-250)/340=0.27 → **Fast light loss ~ 26%**
- FGUV11S – Sample 2
    - (350-200)/350=0.43 → **Fast light loss ~ 43%**



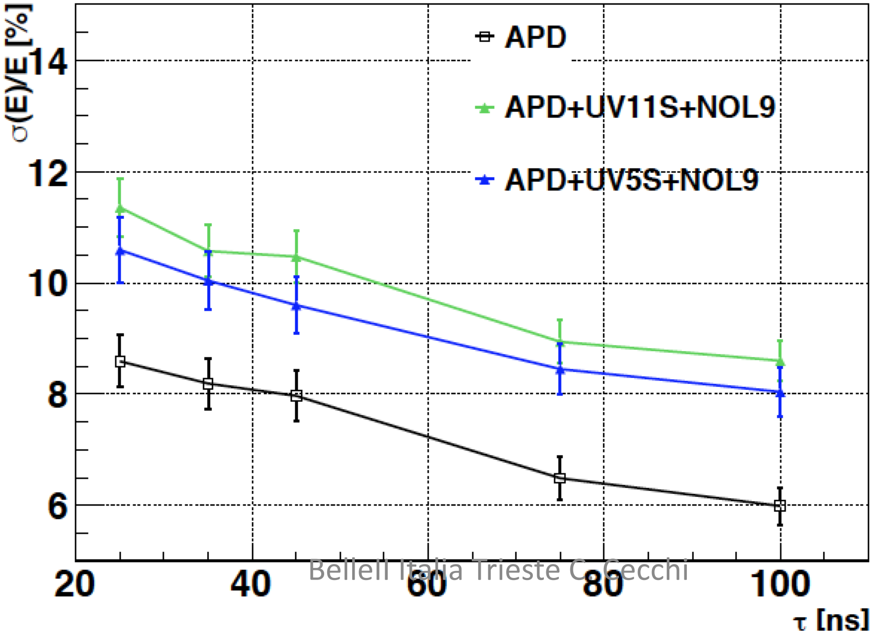
Filtri + WLS



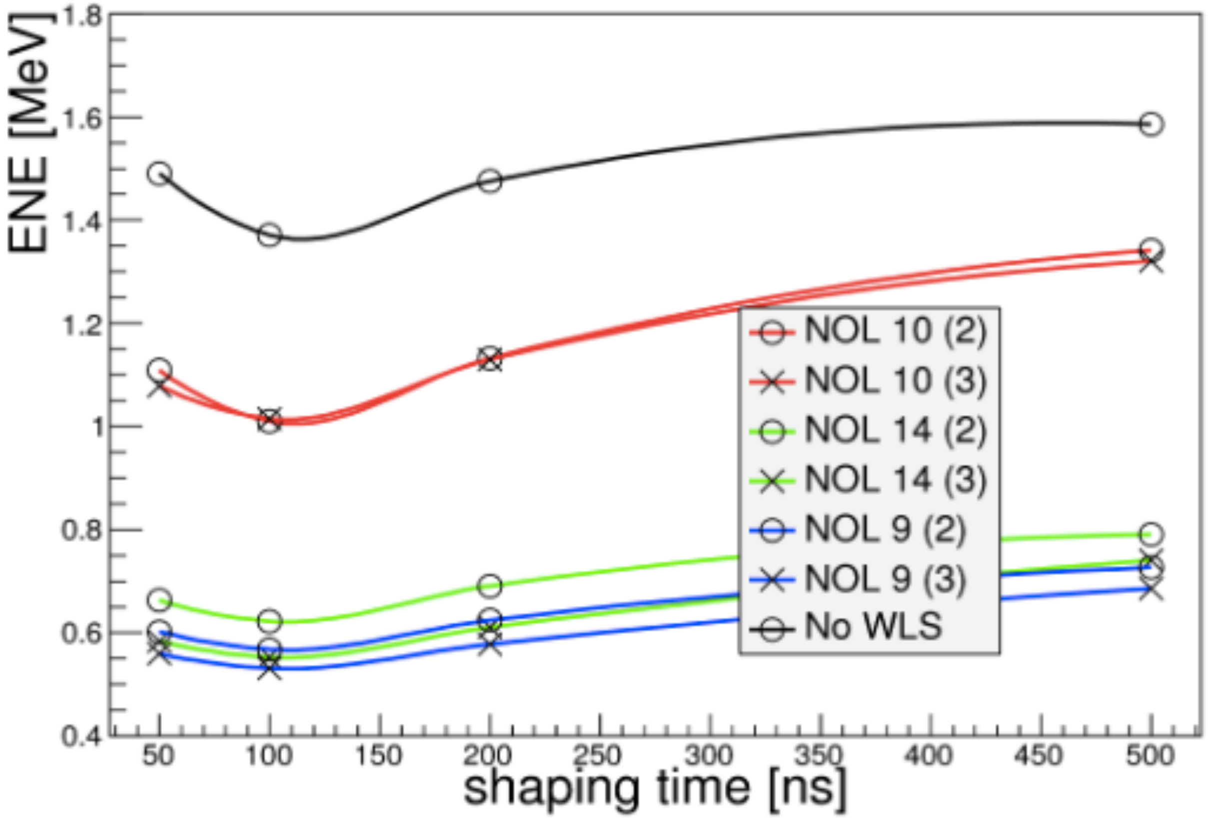
Shaped signal filter + WLS about 74%

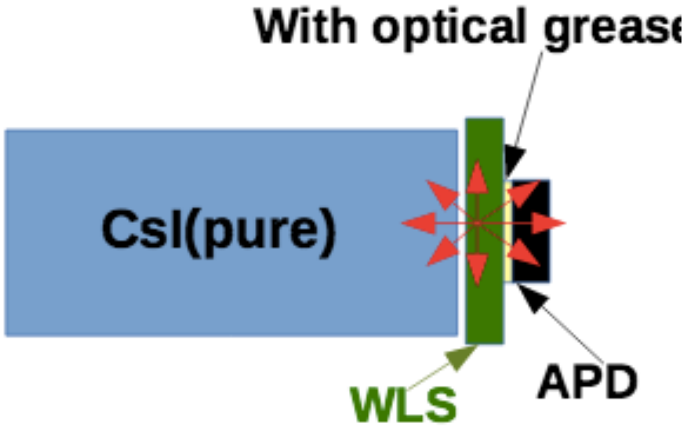


ENE with and without Co60 source → ENE is the same



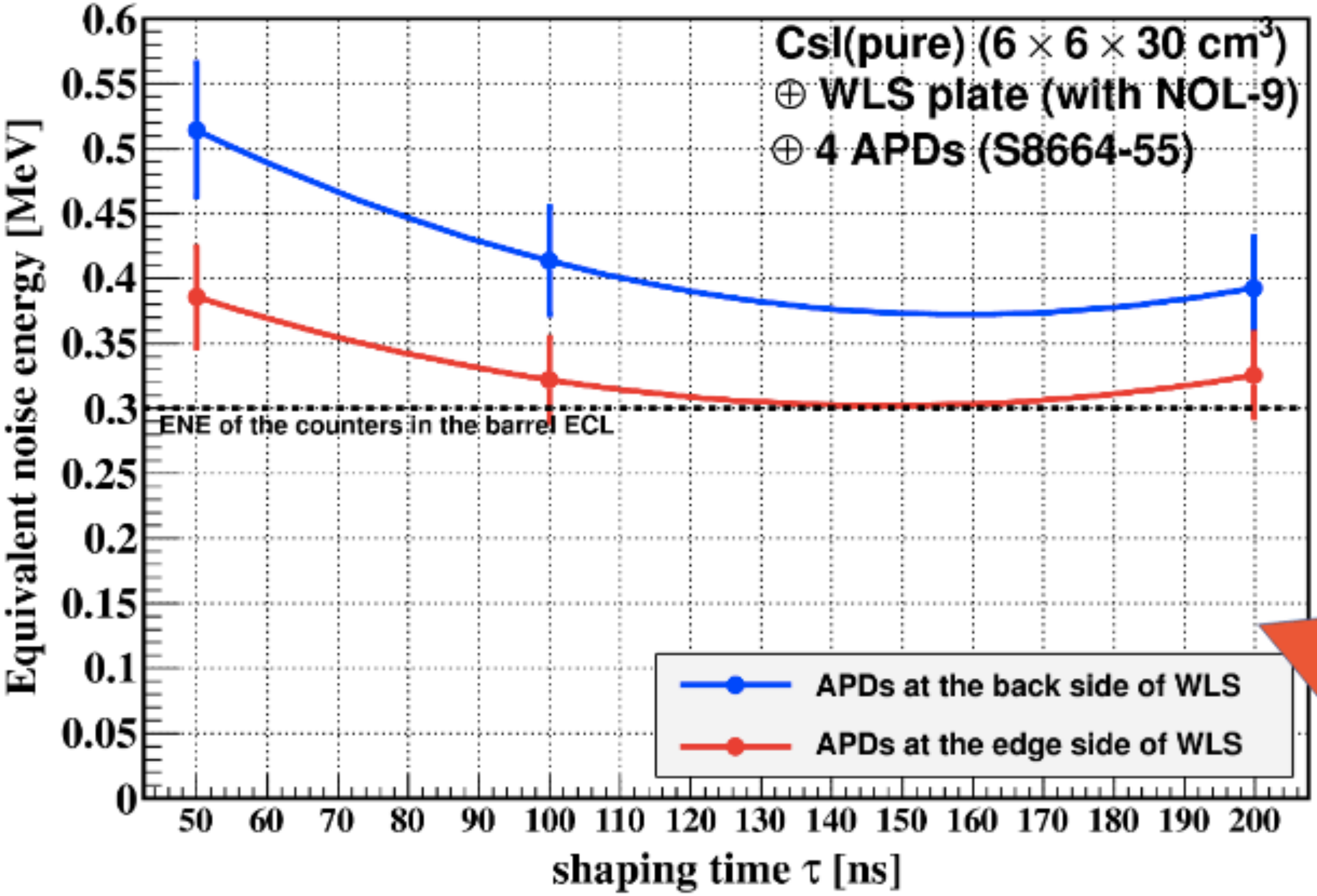
Results with WLS plates

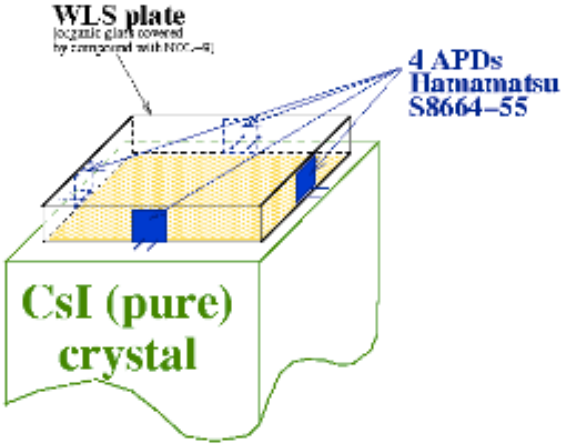


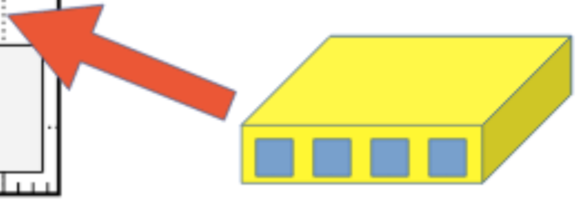


NOL-9 turns out to be the best WLS that provides an enhancement on signal by a factor of about 3.

Attaching APD's on edge side







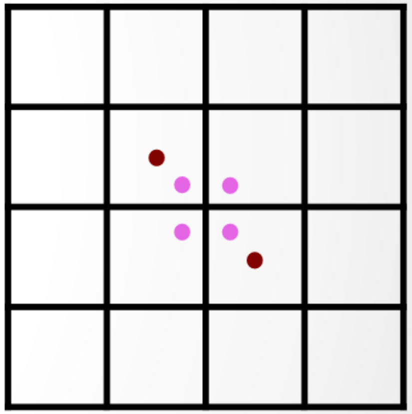
In this measurement, the APD's are attached on one side of the edge due to the limited space of our shield box.

A factor of 1.3 is earned by this configuration.

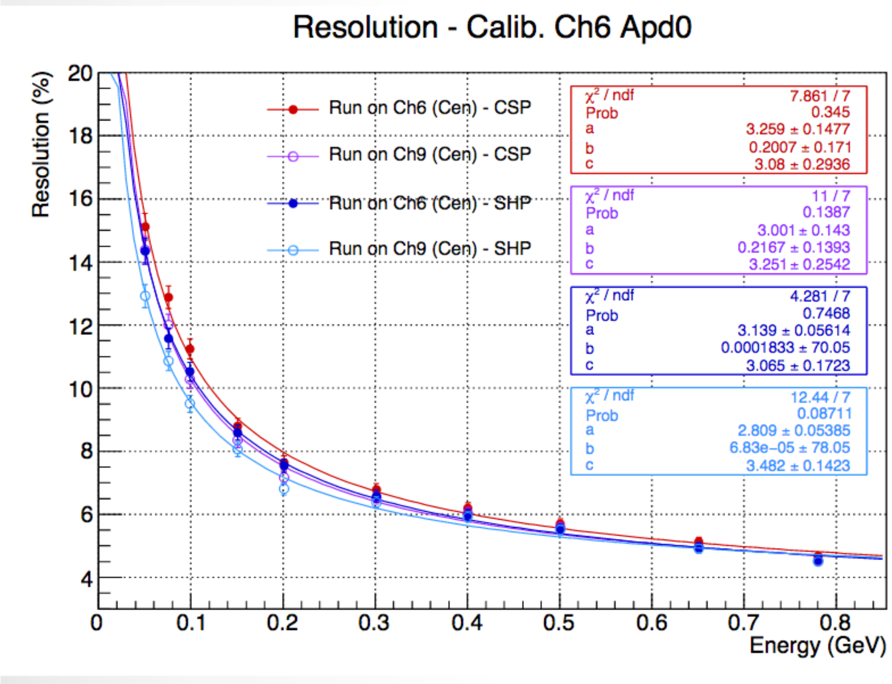
In total, in comparison with the coupling of APD's to the crystal, we earned a factor of 4.

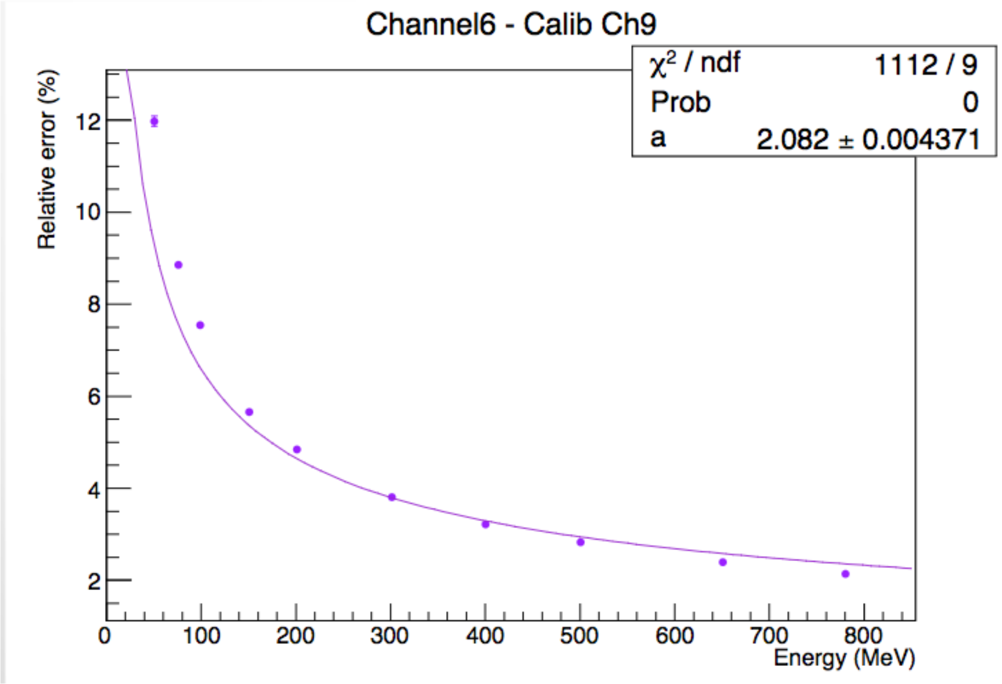
Test Beam

- We acquired 5 different energies for each run
  - Trigger : 5 different tagger in OR
  - The 5 tagger signals used in the trigger are acquired for offline separation of the energies
- Three different trigger configuration:
  - **Calibration: 289MeV – 350MeV – 422MeV – 480MeV – 550MeV**
    - **One run at the center of each crystal**
  - **Low Energy: 50MeV – 76MeV – 99MeV – 151MeV – 201MeV**
    - **1 run at the center of two internal crystals (red dots)**
    - **4 runs at each points which maximize the containment according to MC (pink dots)**
  - **High Energy: 301MeV – 400MeV – 501MeV – 651MeV – 780MeV**
    - **1 run at the center of two internal crystals (red dots)**
    - **4 runs at each points which maximize the containment according to MC (pink dots)**



Test Beam





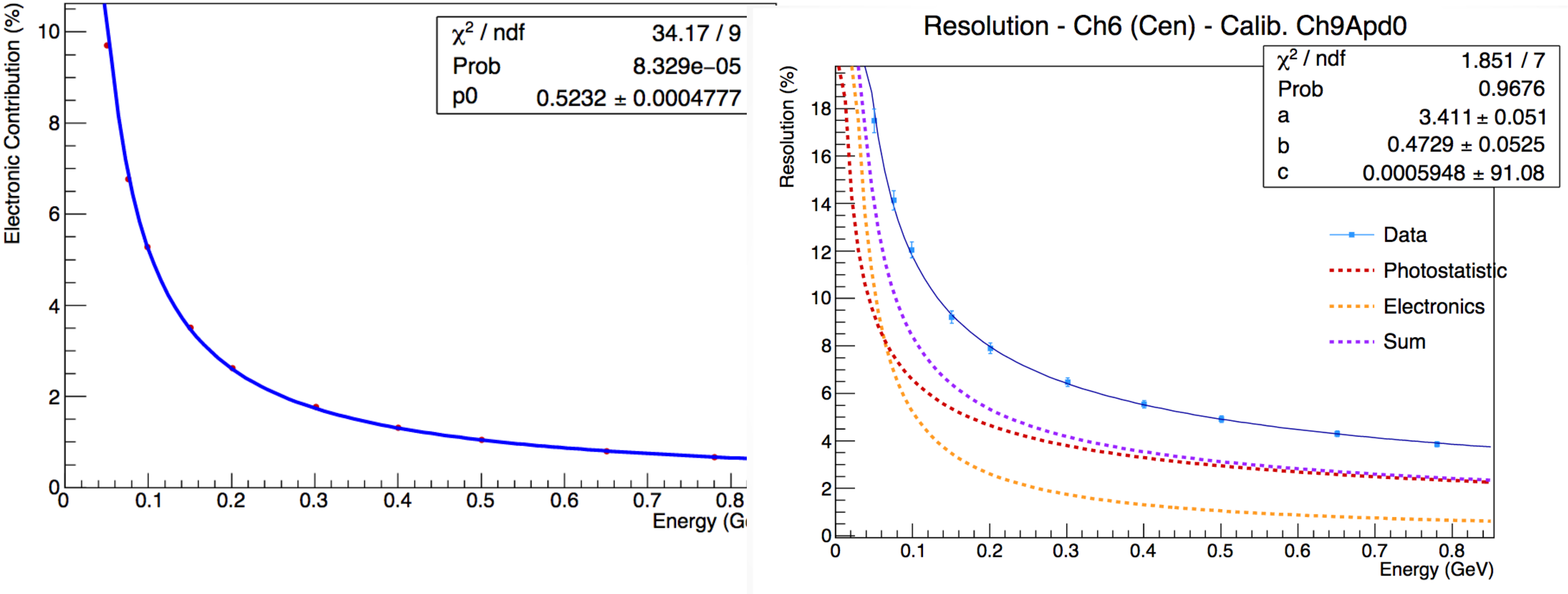
LY = 15 phe/MeV misurato a PG e consistente con altre misure a LNF

→ con questo LY ci aspetteremmo una risoluzione di 2.6% @100 MeV con un excess noise factor di 2.

→ Questa risoluzione corrisponde ad un valore di a nel fit di circa 0.8

Test beam

Noise misurato con i cosmici 2.7 MeV/cristallo → 6 MeV noise (matrix 3X3)



Osservata una non linearità a 200 MeV → ma questo non dovrebbe avere impatto sulla risoluzione.

Test beam

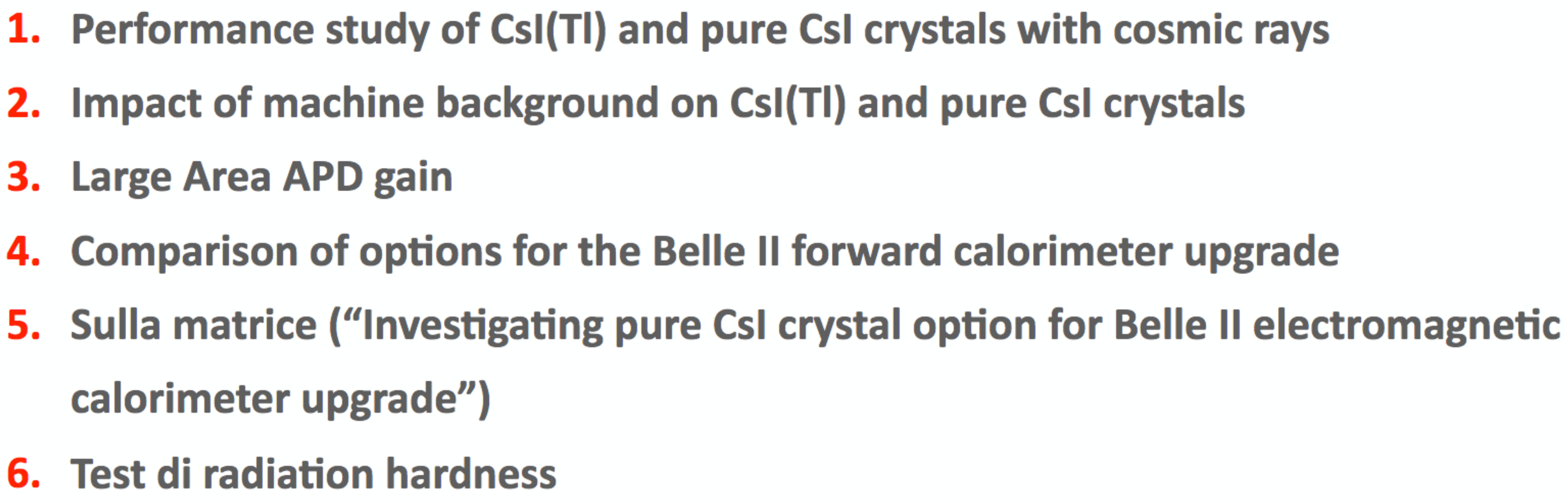
L’analisi è ferma da molto tempo → Mario Merola si è offerto di contribuire con PG.
Stiamo organizzando il lavoro e prevediamo di avere I primi risultati a breve termine.

TEST BEAM@BINP (autunno): I nostri cristalli + 4 APD 5x5mm^2 messi lateralmente e non sulla faccia del cristallo + WLS + FE custom sviluppato da Epifanov (stanno costruendo le board).

Noi forniamo la matrice di CsI + richietsa una partecipazione di qualcuno di noi per collaborare.
Da discutere per I fondi disponibili, IMHO credo che sia importante avere un piede in questo progetto.

Conclusioni

NOTE INTERNE



1. **Performance study of CsI(Tl) and pure CsI crystals with cosmic rays**
2. **Impact of machine background on CsI(Tl) and pure CsI crystals**
3. **Large Area APD gain**
4. **Comparison of options for the Belle II forward calorimeter upgrade**
5. **Sulla matrice ("Investigating pure CsI crystal option for Belle II electromagnetic calorimeter upgrade")**
6. **Test di radiation hardness**

7. FE electronics for the pure CsI readout

- WLS + filtri capire differenze con misure dei Russi
- Test Beam analisi prima priorità
- Test beam@BINP
- Due cristalli nuovi CsI puro trapezoidali da misurare, irraggiare, etc….

- Studio delle performance con simulazione puro CsI + nuovo algoritmo di ricostruzione