FWD ECL resolution studies with pure CsI option

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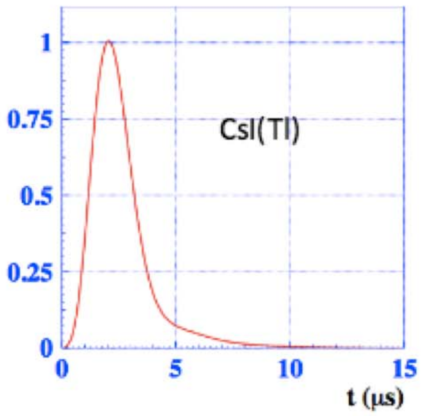
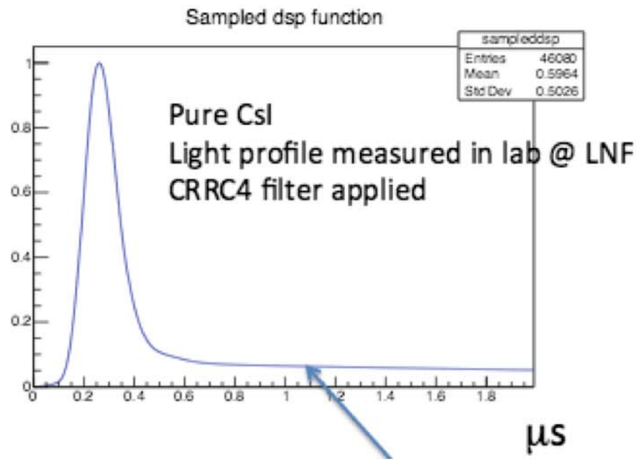
for the ECL group

Resolution in FWD ECL: implementation of pure CsI option

- Digitization algorithm implemented for pure CsI option in forward ECL region
  - as similar as possible to the official one, implemented for full CsI(Tl) fwd ECL
  - accounts for difference in CsI signal shape wrt CsI(Tl) one





- Configurable parameters:

Parameter	CsI(Tl)	Pure CsI
Electronic noise	Correlated noise matrix	Same. Currenly implemented a single parameter in the module → diagonal matrix
Photostatistics	No	fluctuate LY for each pulse (to be refined)
WF fit with covariance matrix	Yes	Yes, with calibration tools committed in svn
Rings with Pure CsI	n.a.	[first ring, last ring]

Breaking down effects

Aim of the study (I)

- Generate single photons at **100 MeV**, in the [13.0°, 30.0°] theta range
  - 2k events per (various) configs.
  - 13 pure CsI rings (FULL FWD ECL)

- Evaluate the impact on resolution of
  - material budget in front of FWD ECL: ECL vs FULL DETECTOR
  - machine bkg: BGx0.0 vs BGx1.0
  - Equivalent Noise Energy: 0 MeV, 0.7 MeV, 1.3 MeV
  - photostatistic: no fluctuation, 20% fluctuation @1 MeV, 40% fluctuation @ 1 MeV

Remarks on photostatistic and Equivalent Noise Energy

- This study was performed before:
  - lab measurements of the light yield (~ 12 ph-e/MeV per APD) : 24 ph-e/MeV expected; this is a preliminary result as discussed by Giuseppe
  - study on test beam data from which we estimate ENE=1.9 MeV with 2APDs

- Stochastic term of the resolution function: $Stat = 100\% \cdot \sqrt{\dfrac{F}{S[ph.e/MeV] \cdot N_{APD} \cdot 1000}}$
- With excess noise factor F=2 (raw estimation, from Epifanov's talk at Oct15 B2GM)
  - σ(E)/sqrt(E) = 20% @ 1 MeV → ~ 50 ph-e/MeV (Epifanov measurement: ~ 52 ph-e/MeV)
  - σ(E)/sqrt(E) = 40% @ 1 MeV → 12.5 ph-e/MeV
- In a study presented at Feb B2GM we used F=1 and stochastic resolution term = 20% → 25 ph-e/MeV (close to lab light yield measurement)

Impact of the material, with and without bkg

BGx	ENE (MeV)	ph. stat. (Nphe/MeV)	Geom	σ(e)/E (%)
0	0.7	50	full	4.39 ± 0.12
0	0.7	50	ecl only	4.33 ± 0.12
1	0.7	50	full	4.79 ± 0.26
1	0.7	50	ecl only	4.75 ± 0.23

- Default values for ENE (0.7 MeV) and Nphe/MeV (50) underestimate and overestimate lab measurements; impact of material budget uncorrelated to that

- Relative change in resolution:
  - without bkg: (1.4 ± 4.0)%
  - with bkg: (0.8 ± 7.3)%

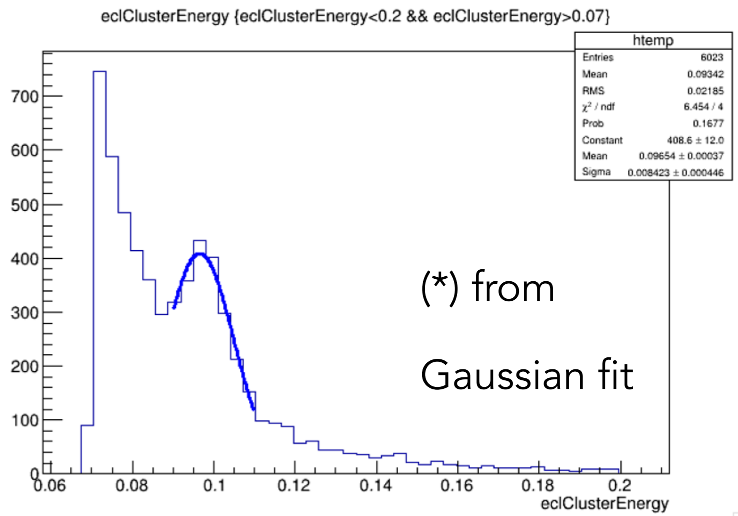
➟ Negligible effect of material budget on resolution

Impact of machine bkg

bg	ENE (MeV)	ph. stat. (Nphe/ MeV)	Geom	**σ(E)/E (%)**
0	0.7	50	full	4.39 ± 0.12
1	0.7	50	full	4.79 ± 0.26
3	0.7	50	full	~ 8%(*)

- Relative change in resolution:
    - BGx0.0 to BGx1.0: (9.1 ± 4.0)%
    - BGx0.0 to BGx3.0: ~ 80%

➟ Large impact of machine background on resolution as expected



(*) from Gaussian fit

Impact of ENE with and without bkg

bg	ENE (MeV)	ph. stat. (Nphe/ MeV)	Geom	σ(E)/E (%)
0	0	no fluct	full	3.56 ± 0.11
0	0.7	no fluct	full	3.89 ± 0.14
0	1.3	no fluct	full	3.94 ± 0.14
1	0	no fluct	full	4.04 ± 0.25
1	0.7	no fluct	full	4.88 ± 0.30
1	1.3	no fluct	full	4.83 ± 0.26

- Relative change in resolution:
  - without bkg:
    - ENE=0 MeV → ENE=0.7 MeV : (9.2 ± 5.2)%
    - ENE=0.7 MeV → ENE=1.3 MeV : (1.3 ± 5.0)%
  - with bkg:
    - ENE=0 MeV → ENE=0.7 MeV : (20.7 ± 9.9)%
    - ENE=0.7 MeV → ENE=1.3 MeV : (-1.0 ± 7.0)%

→

- ENE has an impact on resolution, above all in BGx1.0 config;
- ENE from lab measurement is 1.9 MeV; from ENE = 0.7 MeV to ENE = 1.3 MeV no big changes in resolution, no large effects expected from 1.3 MeV to 1.9 MeV (to be checked)

Impact of photostat fluctuation with and without bkg

bg	ENE (MeV)	ph. stat. (Nphe/MeV)	Geom	σ(E)/E (%)
0	0.7	no fluct	full	3.89 ± 0.14
0	0.7	50	full	4.39 ± 0.12
0	0.7	25	ecl only	4.50 ± 0.12 (*)
0	0.7	12.5	full	4.95 ± 0.26
1	0.7	no fluct	full	4.88 ± 0.30
1	0.7	50	full	4.79 ± 0.26
1	0.7	25	ecl only	4.82 ± 0.18 (*)
1	0.7	12.5	full	5.85 ± 0.25

- Relative change in resolution:
  - without bkg:
    - no fluct. → fluct, 50 ph.e/MeV : (12.8 ± 5.1)%
    - fluct 50 ph.e/MeV→ fluct 12.5 ph.e/MeV: (12.7 ± 6.7)%
  - with bkg:
    - no fluct. → fluct, 50 ph.e/MeV : (-1.8 ± 8.0)%
    - fluct 50 ph.e/MeV→ fluct 12.5 ph.e/MeV: (22.1 ± 8.4)%

➡ Large impact of photo-statistic fluctuation on resolution

(*obtained from a former study with a slightly different basf2 version release-00-06-00 + ecl package r24470)

Summary on break-down effect study

- Resolutions at 100 MeV
  - to be compared with barrel resolution: (12.1 ± 0.25)% (see back-up)

- Most pessimistic config with BGx1.0: ENE = 1.3 MeV (1.9 MeV measured) and Nphe/MeV with 2 APDs= 12.5
  - σ(E)/E (%) = (5.85 ± 0.25)% for ENE = 0.7 MeV
  - no big change from ENE = 0.7 MeV → ENE = 1.3 MeV in BGx1.0

- Most realistic config with BGx1.0: ENE = 1.3 MeV and Nphe/MeV with 2 APDs= 25
  - σ(E)/E (%) = (4.82 ± 0.18) %
  - computed in ECL ONLY config, material doesn't have an effect on resolution

Testing different fwd ECL geometries

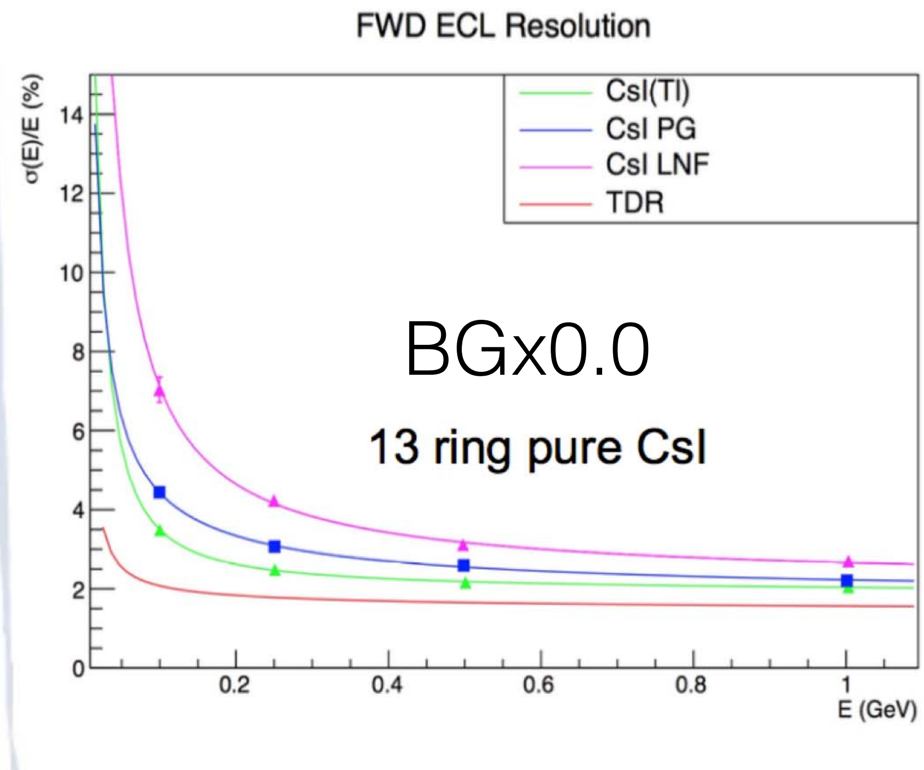
Configurations

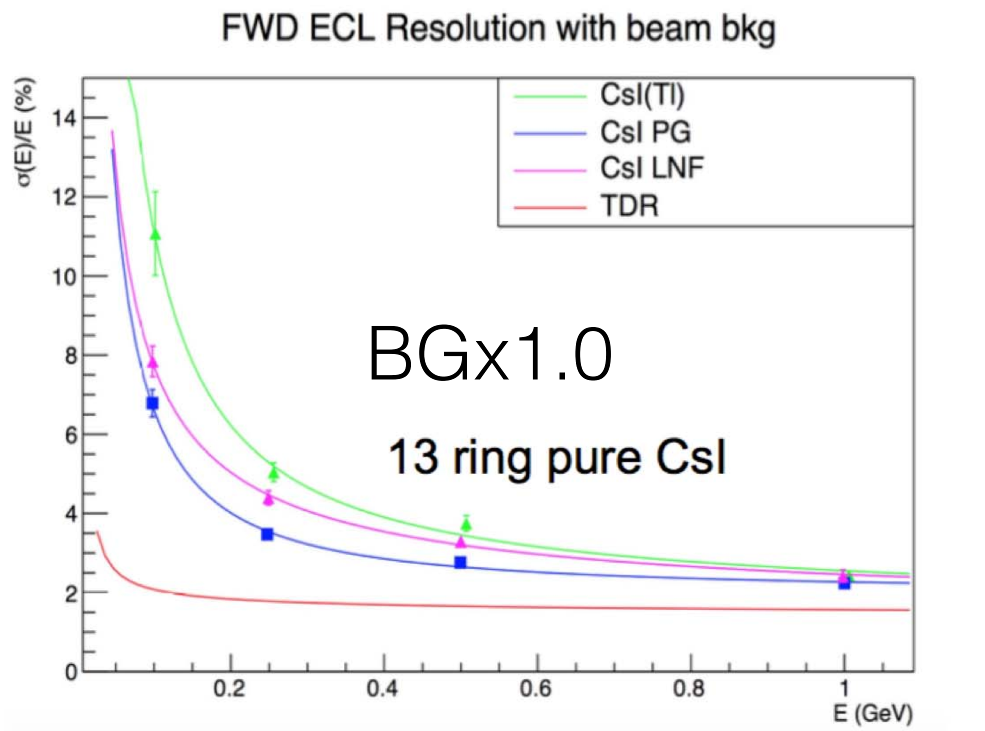
- 2 ENE/phosostatistic configurations studied for CsI option:
  - “Pure CsI LNF version” : ENE = 1.3 MeV, Nphe/MeV=6.26
  - “Pure CsI PG version” : ENE = 0.7 MeV, Nphe/MeV=25

- 2 FWD ECL geometries:
  - 13 pure CsI rings (FULL FWD ECL)
  - first 5 rings of pure CsI + 8 outer rings with CsI(Tl)

- Sample:
  - single photons, in the [13.0°, 30.0°] theta range, no material in front of FWD ECL
  - several energy pints generated

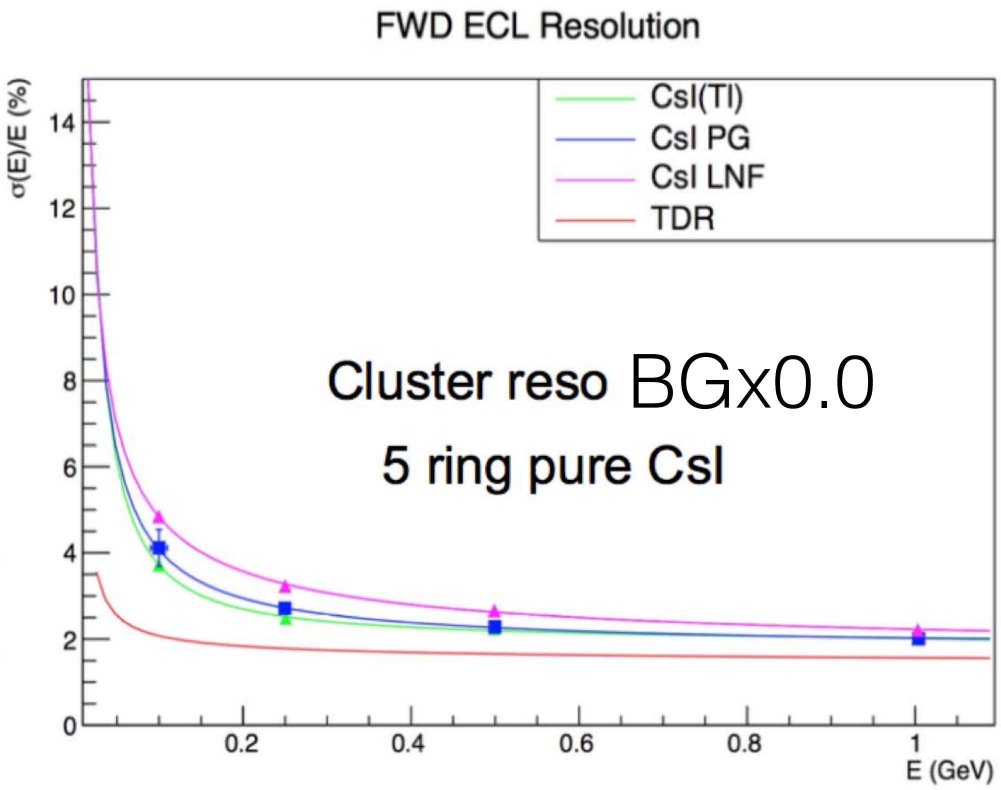
13 rings configuration

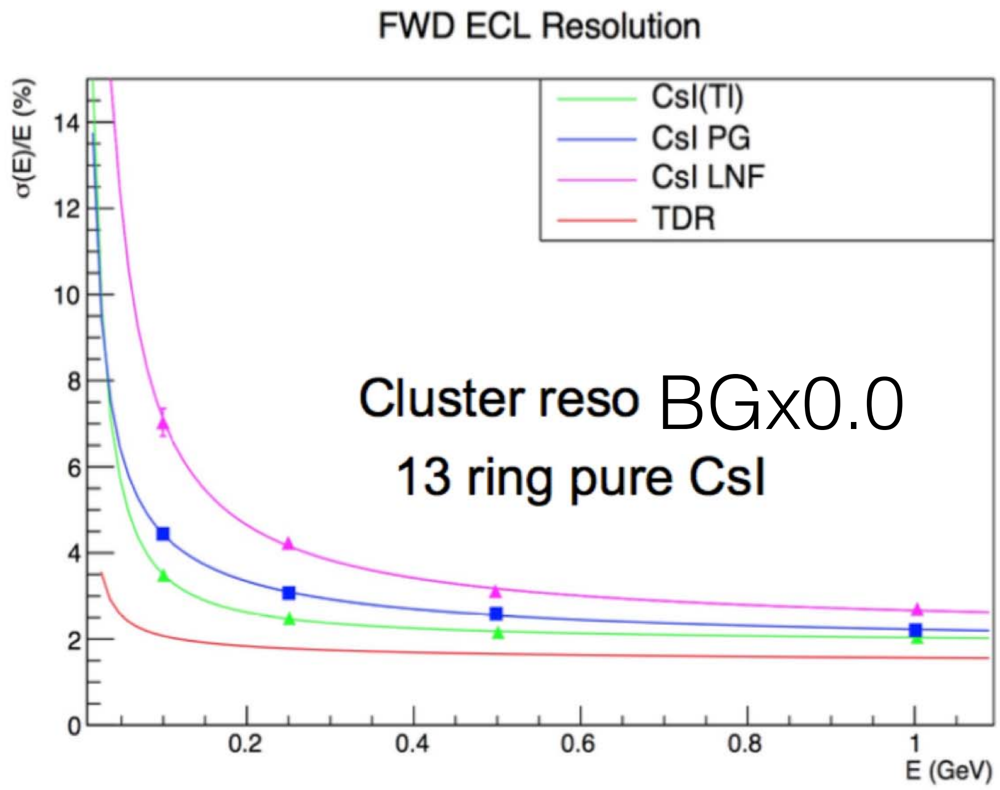




- BGx0.0: CsI(Tl) (higher light yield) better than pure CsI
- BGx1.0: CsI FWD ECL shows better performances

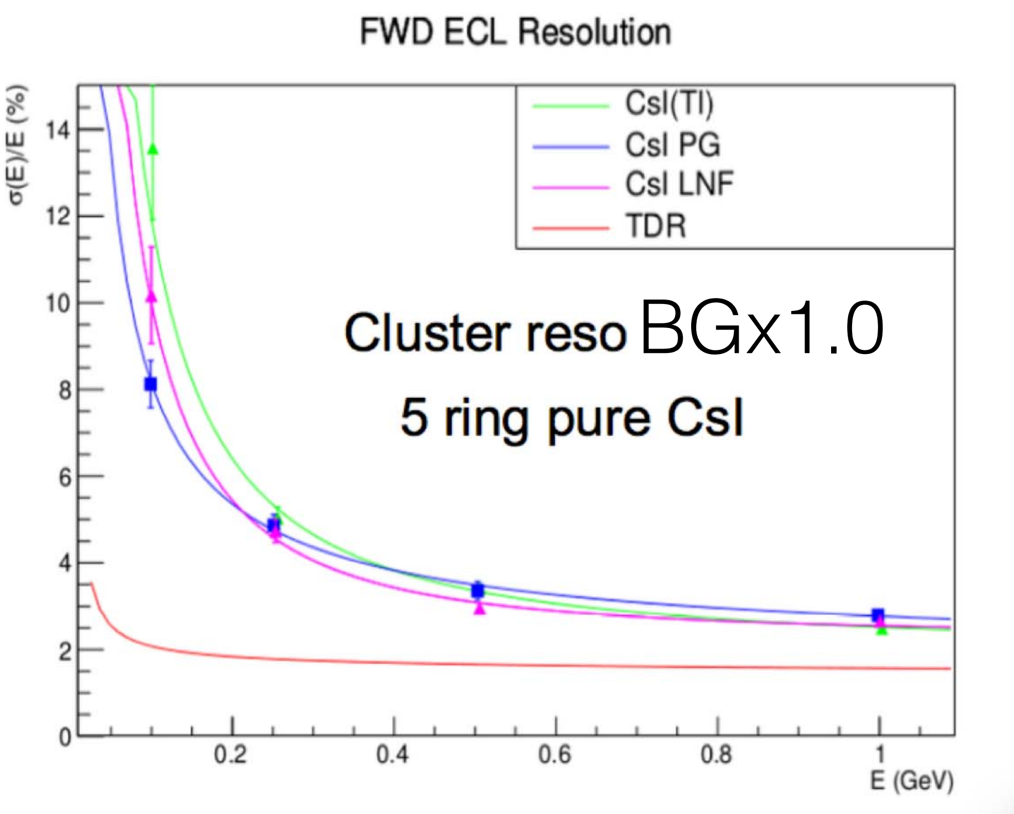
13 vs 5 pure CsI rings (I)

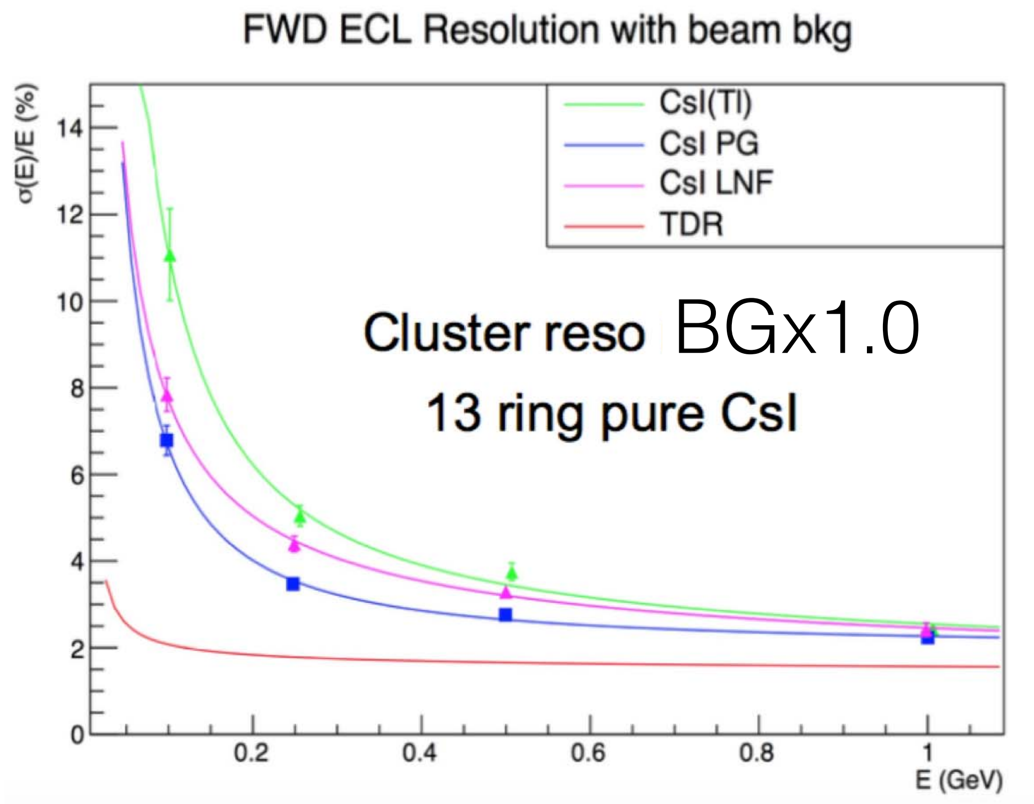




- BGx0.0
- 5-rings configuration better than 13-rings config, as expected

13 vs 5 pure CsI rings (II)





- BGx1.0
- 13-rings configuration better than 5-rings config.
- Benjamin will show studies preliminary on clustering algorithm to test the robustness of this

Conclusions

- Impact of materiale, machine background, electronic noise, and photo-statistic fluctuation on relative energy resolution for 100 MeV-photons reconstructed in pure CsI FWD ECL evaluated:
  - nominal machine background increase resolution of a 10% factor
  - with BGx1.0: switching on ENE and photostatistics effects degrade the resolution of a factor 20% each
- 2 geometries for FWD ECL have been investigated
  - with BGx0.0: CsI(Tl) and 5 rings CsI+8 rings CsI(Tl) perform better than full pure CsI FWD ECL
  - with BGx1.0: full pure CsI FWD ECL seems the best option, studies on clustering ongoing to validate this results
- Another item on out to-do-list: study π^0 reconstruction (e.g. resolution on mass)
- REMARK on ECL code status:
  - most of the reconstruction code and algorithms inherited from Belle, optimization for CsI(Tl) to be implemented for next release. Dedicated studies for CsI option needed ⟶ these results should be considered as PRELIMINARY.

Extra-slides

Remarks on photostatistic error

- photostatistics (% error @ 1 MeV) = 20%
  – computed according to with F=2;

D. Epifanov at last B2GM

$$\frac{\sigma_E}{E} = \frac{1.9\%}{\sqrt[4]{E[GeV]}} \oplus \frac{Stat}{\sqrt{E[GeV]}} \oplus \frac{Elec}{E[GeV]}$$

fluctuation of e/m shower leakage; statistics of photoelectrons; electronic noise

$$Stat = 100\% \cdot \sqrt{\frac{F}{S[ph.e/MeV] \cdot N_{APD} \cdot 1000}}$$

S – sensitivity = 26 ph.e/MeV for S8664-1010
= 6.5 ph.e/MeV for S8664-55
with WLS(NOL-9) = 78 ph.e/MeV for S8664-1010
= 26 ph.e/MeV for S8664-55

N_{APD} – number of APDs per crystal

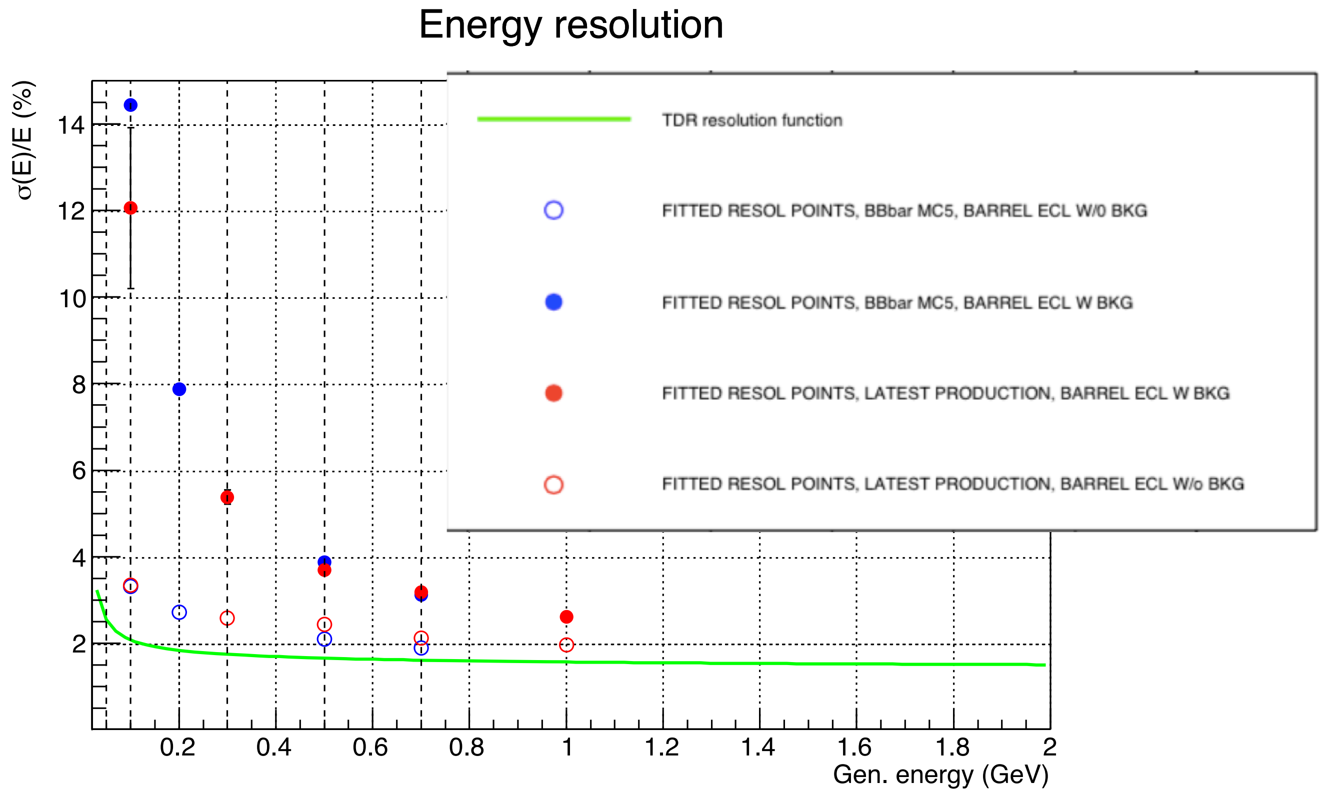
- x-check: F=5 → photostatistics =31%
  F=8→ photostatistics =40%
- resolution @ 100MeV 1xBKG, 12 rings CsI:

F	σ(E)/E%
2	4.84 +/- 0.19
5	4.63 +/- 0.26
8	5.49 +/- 0.21
CsI(Tl) 1XBKG	10.5 +/- 1.3

Resolution in barrel ECL

- Update wrt to resolution extracted with MC5 samples, shown at last B2GM
- What's new:
  - new machine background production (12th campaign)
  - ad-hoc correction to calibrate reconstructed energy
  - [fit with Novosibirsk function, was Crystall-Ball]

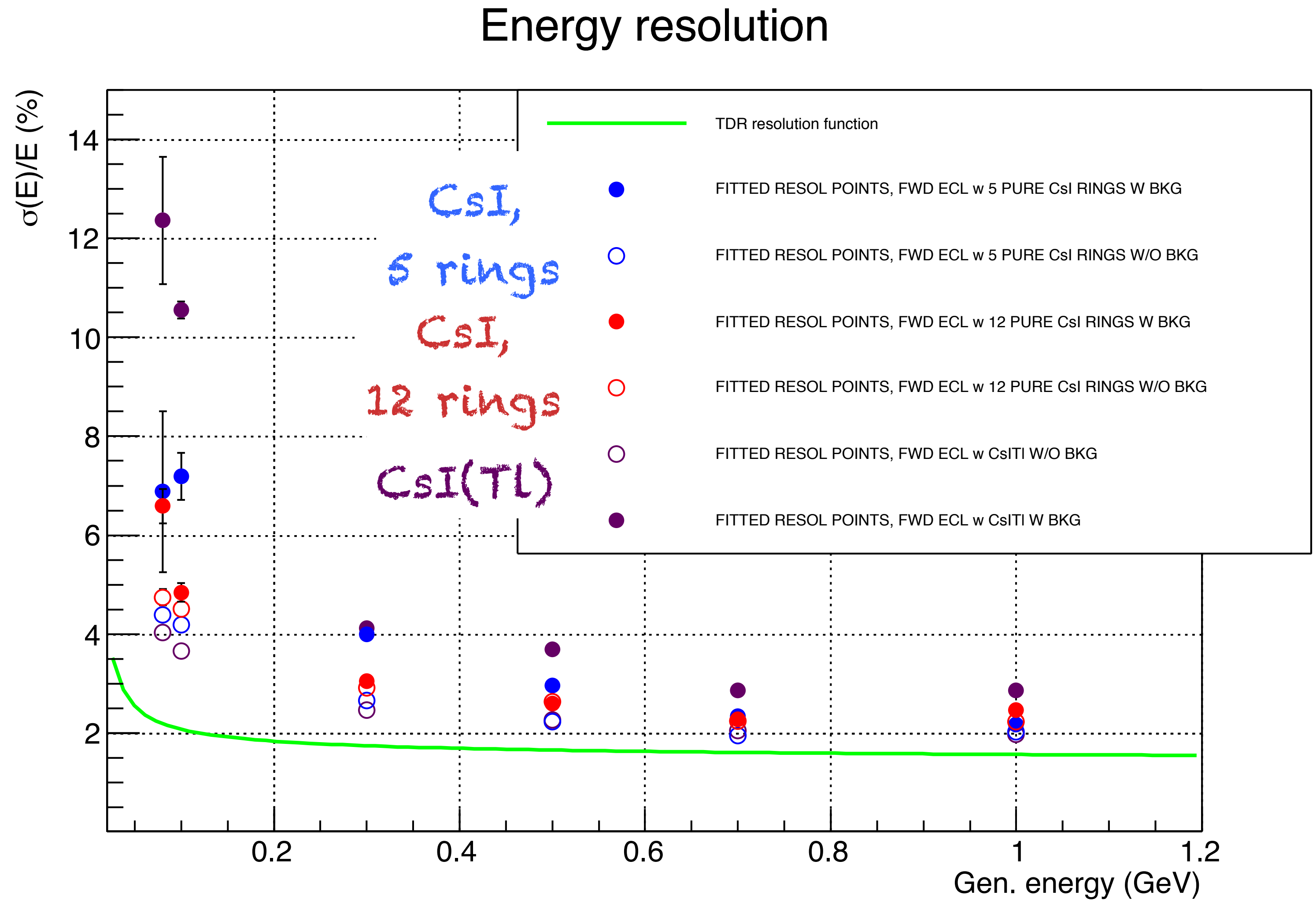
consistency between MC5 and new resolutions



from Feb16 B2GM talk

Resolutions in FWD ECL: summary

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



from Feb16 B2GM talk