EMC Summary

Frank Porter & Claudia Cecchi

For the EMC group

June 1, 2011

EMC sessions

1. Davide Pinci – BGO option
2. Valerio Bocci – EMC electronics update
3. David Hitlin – LYSO intrinsic resolution
4. Chih-Hsiang Cheng – LYSO/CsI geometries and backgrounds
5. Gerald Eigen – Backward EMC status
6. Matteo Cardinali – Test beam analysis: silicon data
7. Elisa Manoni – Test beam update on data
8. Stefano Germani – Test beam Monte Carlo studies
9. Riccardo Faccini – Test beam studies on shape variables
10. Claudia Cecchi, Frank Porter – Mainz or Frascati test beam in fall

Joint DGWG–Fastsim–EMC session

- Alejandro Perez – Impact of bwd EMC on physics using the Sep2010 fastsim production
- Elisa Manoni – Updated study of HAD recoil $B \to K^* \nu \bar{\nu}$ vs bwd EMC
- Stefano Germani – Impact of fwd PID material on π^0 reconstruction
- Sasha Rakitin – Backward physics impact, $B \to \tau \nu$

Crystal properties

Crystal	LY[1]	X_0 cm	r_M cm	Rad hard	$d(LY)/dT$ %/°C	$\tau_{\rm decay}$ ns	$\lambda_{\rm max}$ nm
NaI(Tl)	1	2.59	4.13	no	-0.2	230	410
LYSO(Ce)	0.83	1.14	2.07	yes	-0.2	40	402
CsI(Tl)	1.65	1.86	3.57	no	0.3	1300	560
CsI	0.036	1.86	3.57	yes	-1.3	35	420
BGO	0.21	1.12	2.23	yes[2]	-0.9	300	480
$PbWO_4$	0.0029	0.89	2.00	no	-2.7	10	420

(Mostly from RPP)
[1]Relative to NaI(Tl), small crystals, corrected for QE, room T
[2]Initial loss of LY, then stable at high doses (10s of Mrad)

What crystal for forward EMC?

LYSO is "ideal", except for price
Lower cost options under investigation

- Possible hybrid solution: Keep outer rings of CsI(Tl), inner rings LYSO
- BGO (maybe recycle L3 crystals?)
- Pure CsI (fast)
- Possible savings on mechanical structure – keep existing CsI frame, replace each crystal with four of higher density (LYSO or BGO), or crystal-for-crystal if pure CsI

Issues

- Effect of backgrounds (Molière radius, τ_{decay})
- Position resolution (Molière radius)
- Energy resolution (Light yield)
- Readout (Light yield)

Radiative Bhabha background, crystals, and shaping

RMS energy (MeV) in 5×5 array from radiative Bhabha background (Pinci)

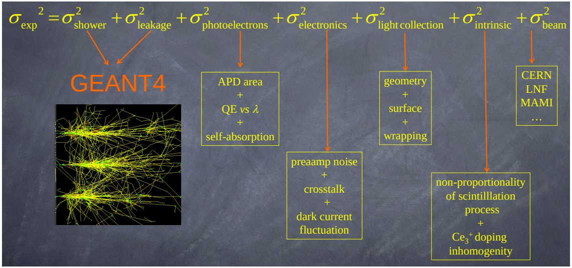
RMS(MeV)	T_{dec}=T_{shaper} =50ns	T_{dec}=300ns T_{shaper}=100	T_{dec}=T_{shaper} =300ns	T_{dec}=1300ns T_{shaper}=600ns	T_{dec}=T_{shaper} =1300 ns
central barrel (CsI geom)	N/A	N/A	N/A	0.5	1.0
worst barrel (CsI geom)	N/A	N/A	N/A	2.7	4.9
external FWD (LYSO geom)	0.1 (no bias) 0.2 (CsI)	0.2 (no bias)	0.3	N/A	N/A
internal FWD (LYSO geom)	0.7 (no bias) 1.4 (CsI)	0.7	1.2	N/A	N/A

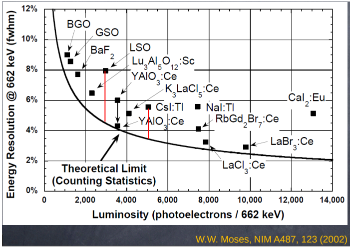
N.B., typically want shaping time = few times decay time

(Cheng) Does the larger CsI crystal size 4.7×4.7 cm^2 perform worse (than 2×2 cm^2) in presence of background?
Fastsim study: Background (last summer) produces $\sim 2/3$ cluster > 20 MeV in each physics event.
No appreciable change in performance wrt backgrounds

Intrinsic resolution

(Hitlin)
Achieved energy resolution is made of several components





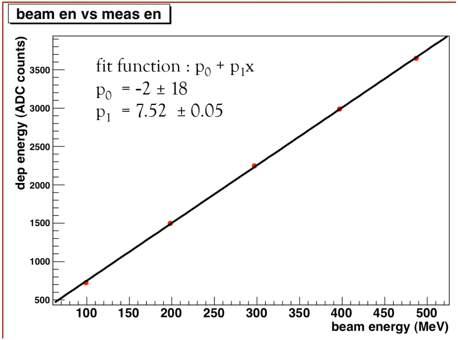
Resolution on ^{137}Cs (662 KeV) for small crystals, PMT readout

- Non-linear processes in converting energy deposit to optical photons
- Variations in dopant (e.g., Ce) concentration

LNF beam test, May 2011

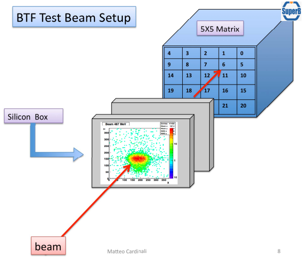
Beam test with electrons, $E = 100 - 500$ MeV
5×5 projective LYSO array in aveolar with CMS APD (5 mm $\times$ 5 mm) on each crystal

Linearity



(Manoni)

LNF beam test, position dependence study

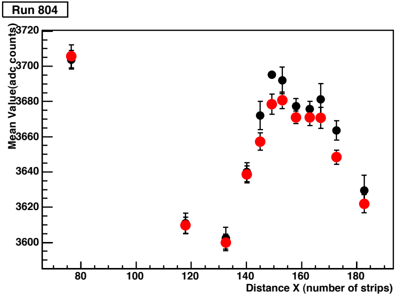


(Cardinali)

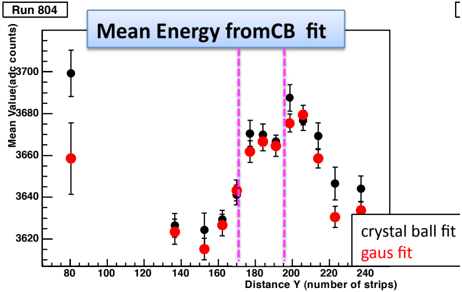
Plots below for 487 MeV

Effect $\sim \pm 1\%$

Crystal width $\sim$ 90 strips



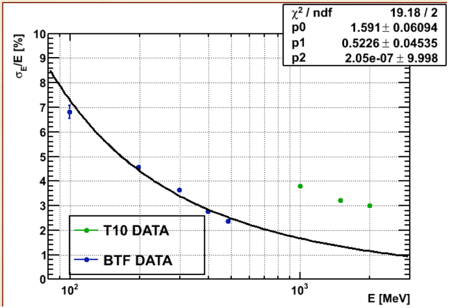
Energy vs x-position



Energy vs y-position

Comparison of CERN, LNF test beam runs

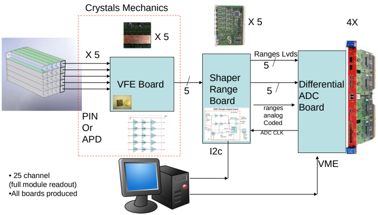
Energy resolution vs Energy



LNF is with selection on Silicon position, CERN data is not
[Effect of Si selection at 500 MeV is 2.9% $\rightarrow$ 2.4%]
(Manoni)

EMC electronics

(Bocci)



Electronics layout

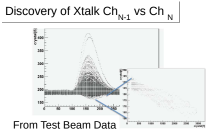
Ch0

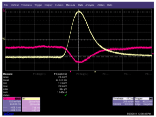
	2.2%	2.0%	1.7%	1.7%
	2.2%	2.0%	2.0%	2.0%
	1.2%	1.2%	1.1%	1.0%
	0.5%	0.5%	0.5%	0.5%
	2.2%	2.0%	2.4%	1.7%

Ch24

Ch3= Ch3(real) + 2.2% of Ch4

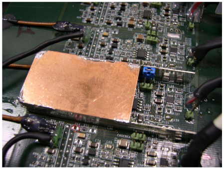
Crosstalk map

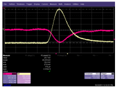


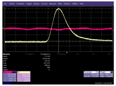


Replicated in LABE

Crosstalk observed



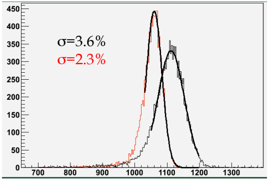




Crosstalk cured

Test beam resolution studies

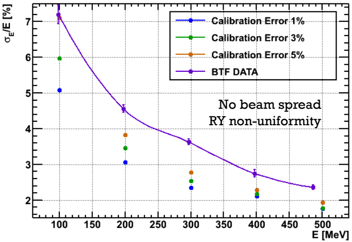
(Faccini)
$E_e = 1$ GeV
Red: MC
Black: CERN test beam data



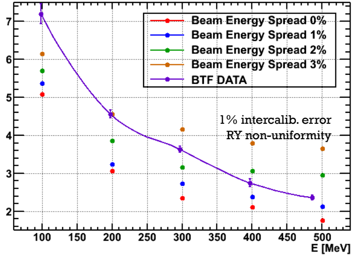
- Crosstalk – Small improvement in agreement at low energy (LNF BT), may be more important at high energy
- Raising threshold to eliminate noisy crystals – Doesn't improve agreement
- Correcting for different lateral shower pattern – Improves agreement slightly (2.3% $\rightarrow$ 2.6%)
- Correcting for tilt – Doesn't improve agreement
- Intercalibration with electrons – Same result as MIPS
- Pedestal fluctuations negligible (Cardinali)

Data–MC comparisons (LNF test beam)

Intercalibration error



Beam energy spread



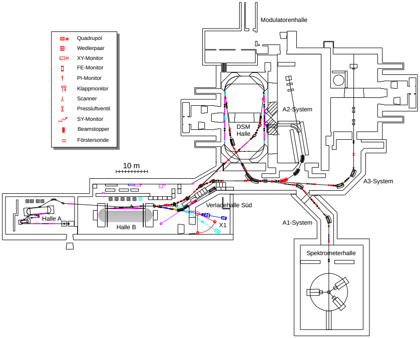
- Even large intercalibration error cannot explain resolution
- Energy-independent beam energy spread cannot explain resolution

(Germani)

Future test beam

Test beam planned in fall

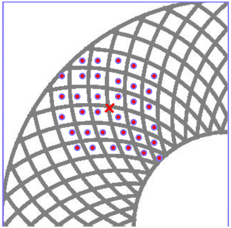
- Improved uniformity
- Sum 2 APDs per crystal
- Electronics crosstalk eliminated
- Possible use of MAMI (Mainz) tagged photon beam
  - E_γ from $\sim$30 MeV to $\sim$1.5 GeV
  - Well-measured γ energy
- LNF beam reserved 3 weeks in October



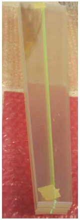
MAMI floorplan

Backward EMC prototype status

Spiral strips

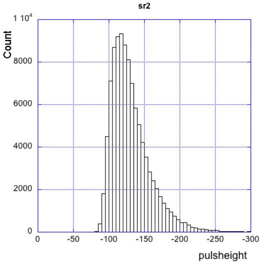


Straight wedges

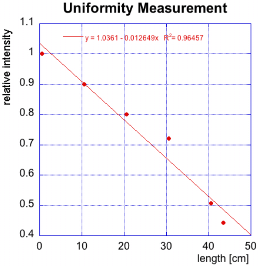


Lead sheets (2.8 mm)

MIP peak = 5.9 p.e.



Uniformity



(Eigen)

Backward EMC status

- Prototype is $6 \times 24 = 144$ readout channels
- Prototype, to be done
  - Strip production still bottleneck (spiral strips)
  - Uniformization procedure (e.g., black dots)
  - Acquire 30 m Y11 fiber
  - Borrow 3 more SPIROC boards
  - Clear fibers and calibraton board from Prague
  - Plastic filler, Diffuse reflector, paint
- Manpower to improve after summer
- Looking for collaborators
- Cost estimate $450k

Physics impact of backward EMC

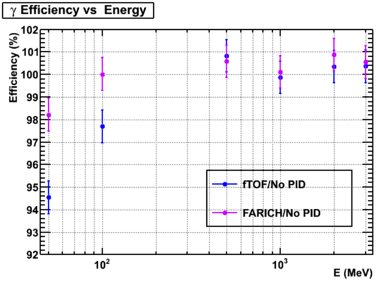
Sept 2010 production bug in backward EMC simulation; validated workaround exists, performance studies have been redone.
Figure-of-merit: $\frac{S}{\sqrt{S+B}}$. Compute

$$\delta \equiv \frac{\left.\frac{S}{\sqrt{S+B}}\right|_{\mathrm{w/BWD}} - \left.\frac{S}{\sqrt{S+B}}\right|_{\mathrm{noBWD}}}{\left.\frac{S}{\sqrt{S+B}}\right|_{\mathrm{noBWD}}}$$

(Perez) $B \to K^*\nu\bar{\nu}$ with semileptonic tag
(Manoni) $B \to K^*\nu\bar{\nu}$ with hadronic tag
Result of both analysis is that backward EMC provides gains (δ-values) of 6-10%, depending on mode.
(Perez), (Rakitin) Separate $B \to \tau\nu$ analyses with semileptonic and hadronic tags
Find $\delta \sim 3-6\%$, depending on mode.

Forward PID impact on π^0 reconstruction

Looked at impact of fTOF and FARICH on photon and π^0 resolution and efficiency.
No significant impacts found except on low energy photon efficiency.



fTOF is $\sim 10\%\ X_0$, next to DCH
FARICH is $\sim 25\%\ X_0$, next to EMC
(Germani)

EMC Conclusions

- Much effort on prototype test beams (FWD and BWD)
- Big question: If we can't afford LYSO, what crystal(s) do we use for forward EMC?
- New results on effect of backward EMC, forward PID
- Many other things to do, not discussed here
- Plenty of room for new collaborators (Please!)