A LYSO CALORIMETER FOR THE SUPERB FACTORY

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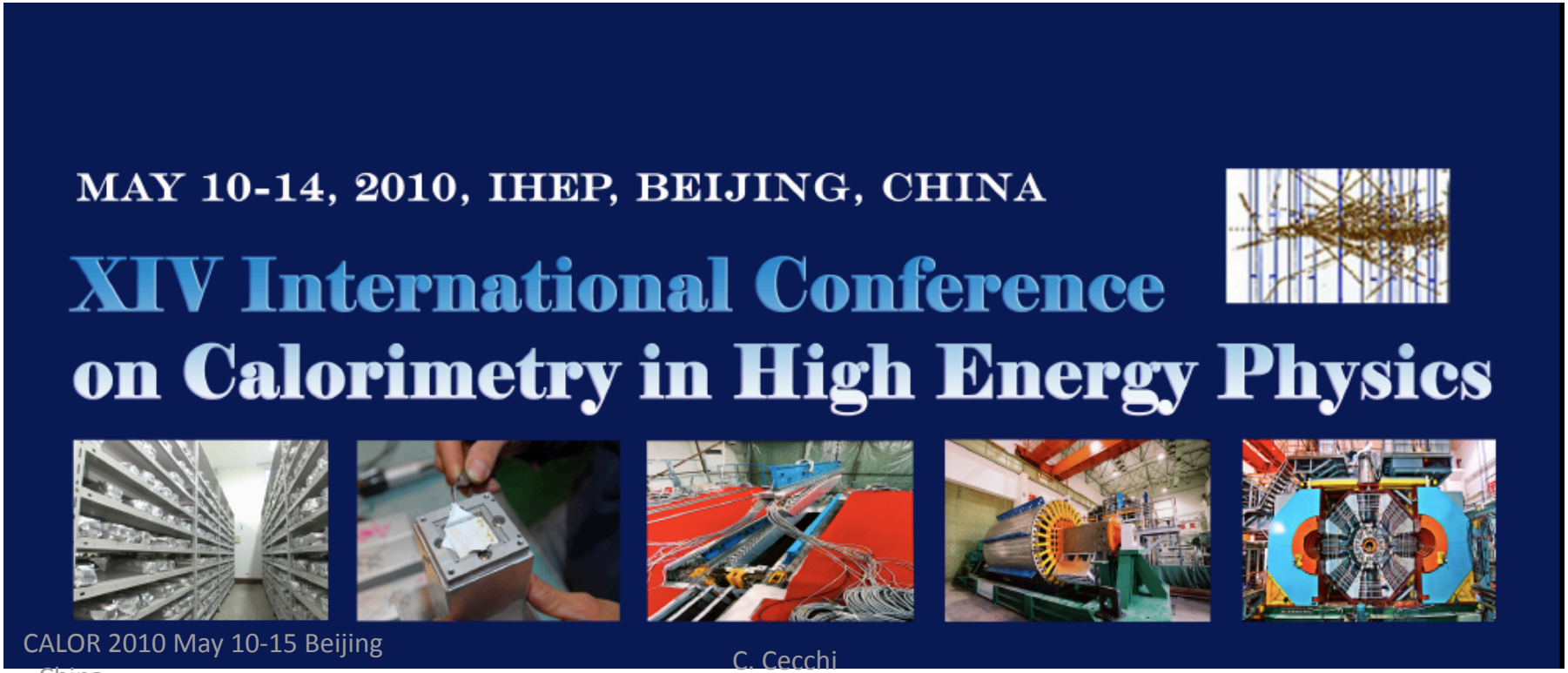


The SuperB factory

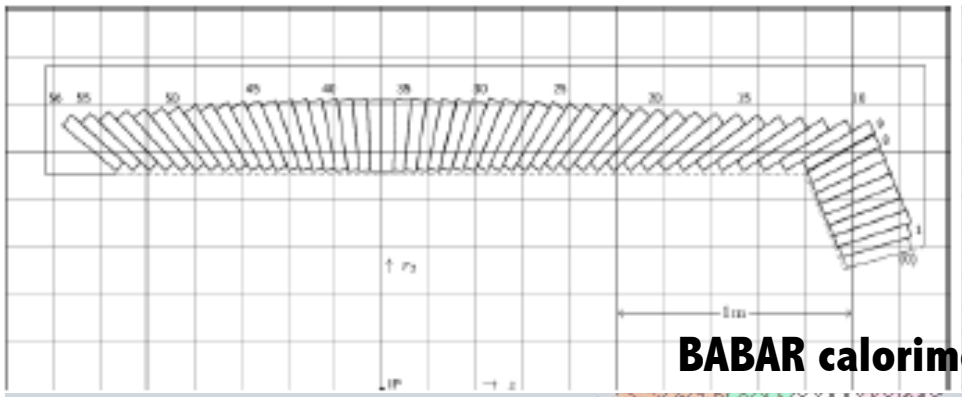
Flavor physics at the SuperB factory, after BaBar/Belle, would be a complement to LHC to study New Physics beyond the Standard Model in the b, c and τ sector.

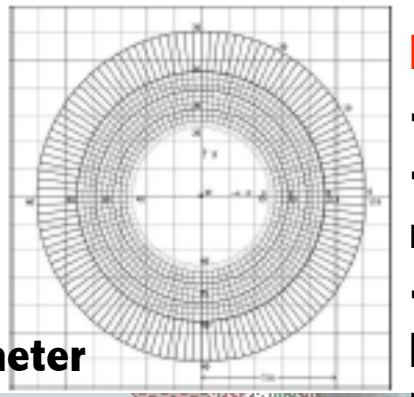
The SuperB factory will run at a luminosity of $10^{36}cm^{-2}s^{-1}$ to collect an integrated luminosity of 50-75ab^{-1}.

The machine is an asymmetric e+e- collider employing the new "crab waist" colliding scheme, with very low emittance. Longitudinally polarized beam at 80% can be obtained.
Luminosity related bckg in the forward region will be high and is one of key study ongoing in the "collaboration".

CDR detector for the SuperB is based on BaBar with re-optimization
TDR phase has been approved for two years

ELECTROMAGNETIC CALORIMETER





BABAR calorimeter

BARREL: OK

- no radiation damage
- can support SuperB rates
- shielding against bckg (radiative Bhabha's) is crucial

NEW FORWARD EMC is needed **(subject of this talk)** :

- radiation damage
- not good for high rates at SuperB
  - finer granularity
  - faster crystals, shorter decay time
  - good Light Yield

Intensive R&D effort in Italy (Perugia, Roma) and Caltech is ongoing for the design, development and construction of a **LYSO** calorimeter.

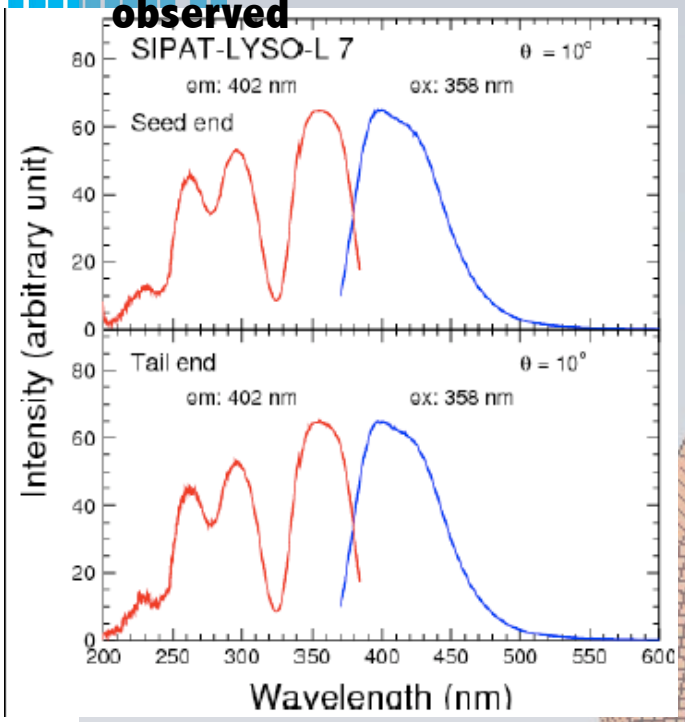
There is a proposal for a **Backward EMC** (not present in BaBar) made of Pb and scintillator.

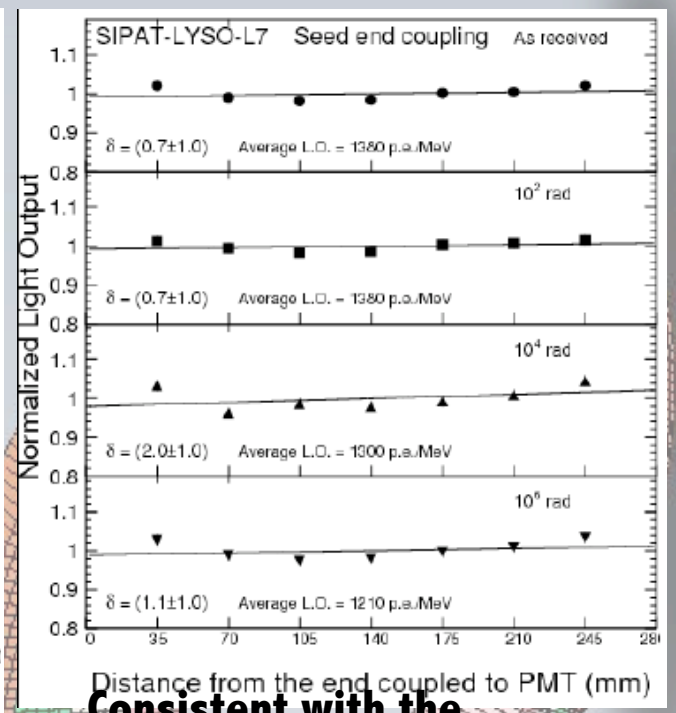
Crystal	NaI(Tl)	CsI(Tl)	CsI	BaF_2	BGO	$PbWO_4$	LSO(Ce)	GSO(Ce)
Density (g/cm^3)	3.67	4.51	4.51	4.89	7.13	8.3	7.40	6.71
Melting Point (°C)	651	621	621	1280	1050	1123	2050	1950
Radiation Length (cm)	2.59	1.85	1.85	2.06	1.12	0.9	1.14	1.37
Molière Radius (cm)	4.8	3.5	3.5	3.4	2.3	2.0	2.3	2.37
Interaction Length (cm)	41.4	37.0	37.0	29.9	21.8	18	21	22
Refractive Index [a]	1.85	1.79	1.95	1.50	2.15	2.2	1.82	1.85
Hygroscopicity	Yes	Slight	Slight	No	No	No	No	No
Luminescence [b] (nm) (at peak)	410	560	420 310	300 220	480	560 420	420	440
Decay Time [b] (ns)	230	1300	35 6	630 0.9	300	50 10	40	60
Light Yield [b,c] (%)	100	45	5.6 2.3	21 2.7	13	0.1 0.6	75	30
d(LY)/dT [b] (%/ °C)	~0	0.3	-0.6	-2 ~0	-1.6	-1.9	-0.3	-0.1
Experiment	Crystal Ball	CLEO *BABAR* Belle BES III	KTeV, E787	TAPS (L*) (GEM)	L3 BELLE PANDA?	CMS ALICE PANDA? (BTeV)	Super*B*?	-

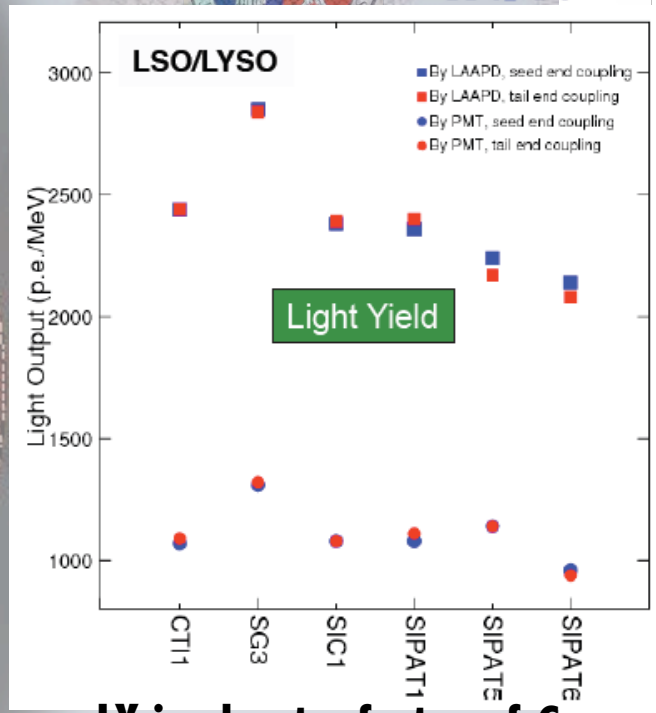
a. at peak of emission; b. up/low row: slow/fast component; c. measured with bi-alkali PMT

CRYSTAL STUDY

Tested also after irradiation, no change is observed

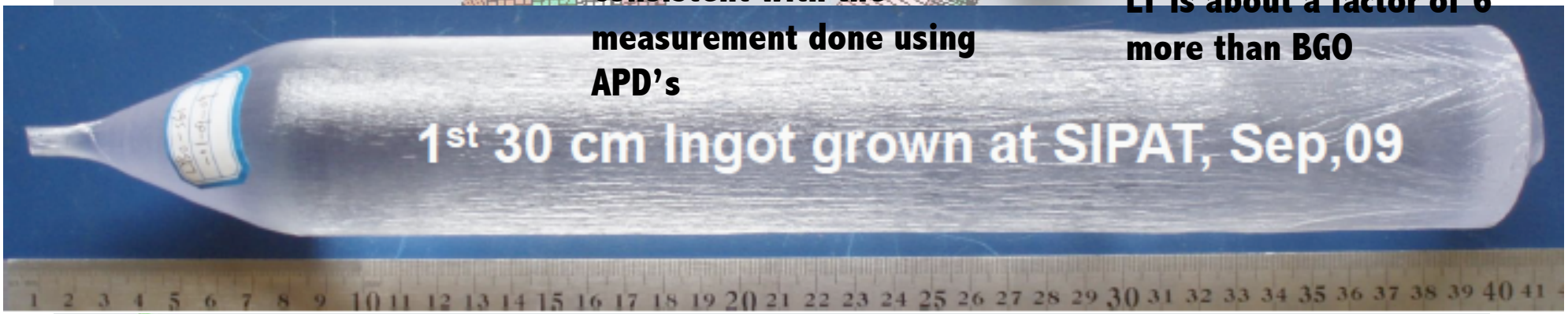






Consistent with the measurement done using APD's

LY is about a factor of 6 more than BGO



More than one producer:

St. Gobain (good quality, very expensive)

SIPAT (quality is growing, approaching preliminary specs)

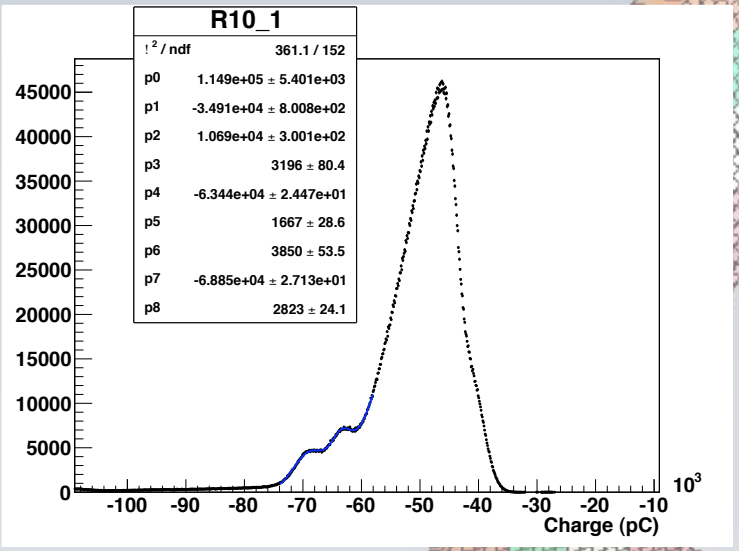
SICCAS (starting to produce LYSO following our requests)

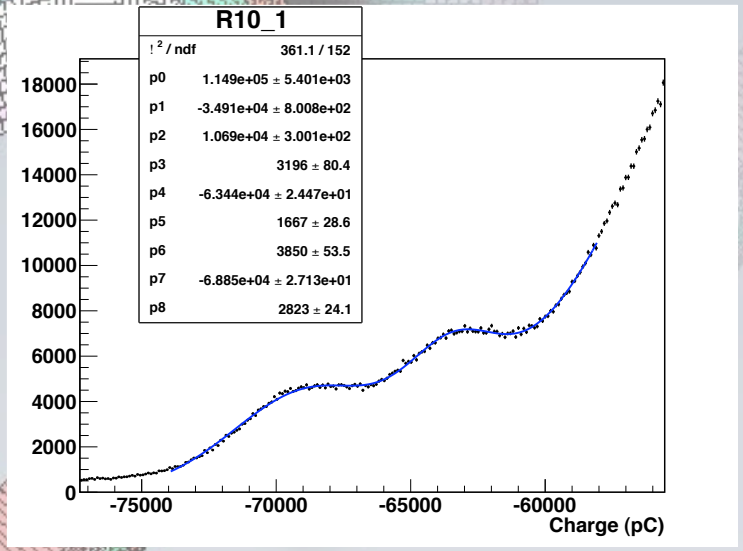
LIYUAN ZHANG talk

CRYSTAL STUDY: St. Gobain production for Test Beam

12 crystals are under test in Italy:

- **Metrology to check dimensions (requested +- 100 μm)**
- **Light yield measurement (using a Co source)**





LY(1.17MeV)=1027 p-e/MeV
LY(1.33MeV)=986 p-e/MeV

Crystals are bare, apply a factor 2.3 with respect to measurement with Tyvek, in agreement with previous measured crystals (1900-2000 p-e/MeV)

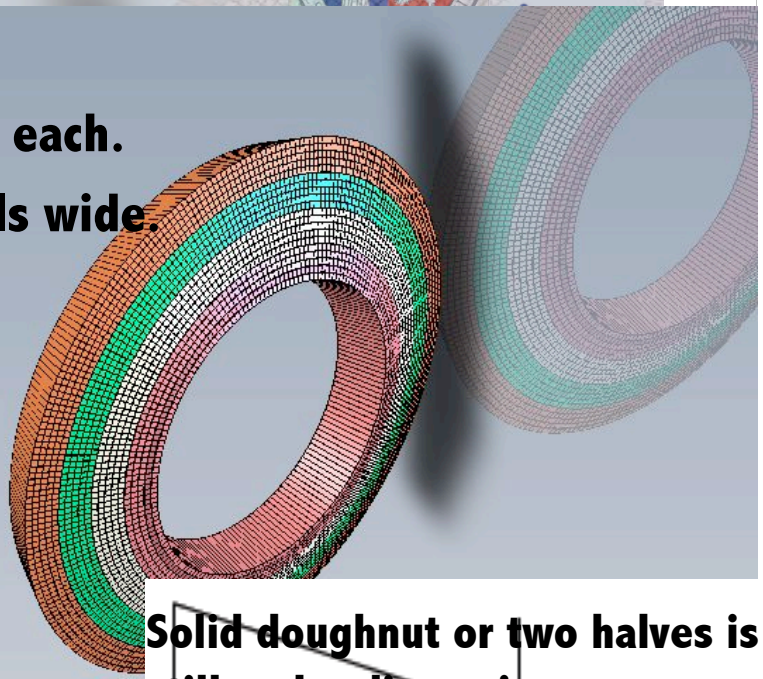
GEOMETRY DESCRIPTION AND MECHANICS

General layout:

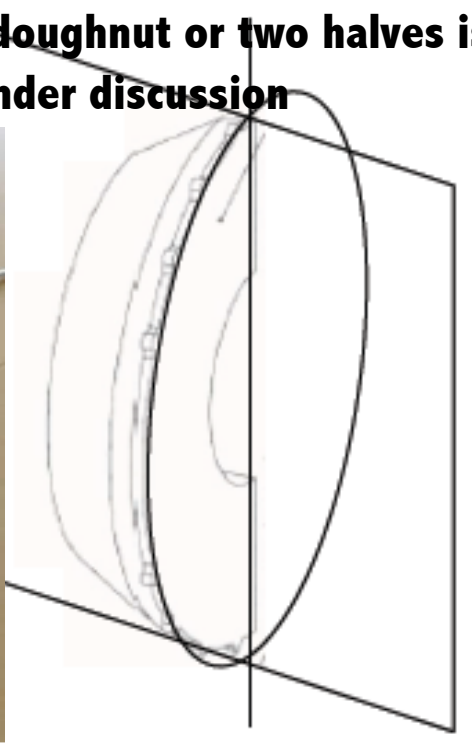
20 rings of crystals arranged in 4 groups of 5 layers each.

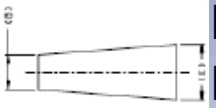
Each group of 5 layers arranged in modules 5 crystals wide.

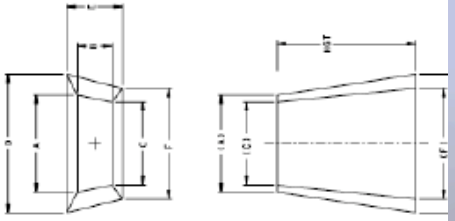
The number of modules in a ring is multiple of 2x3



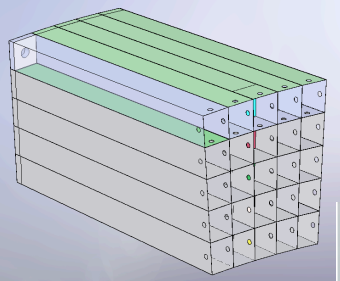
Solid doughnut or two halves is still under discussion

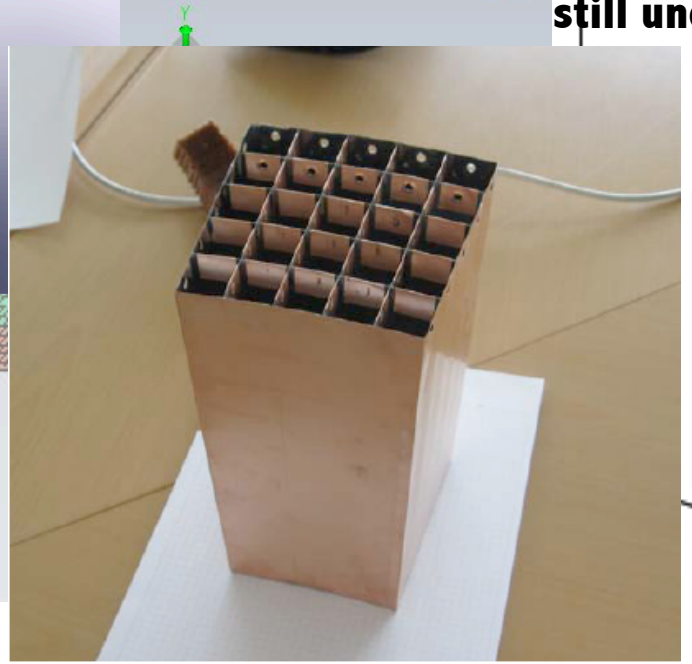






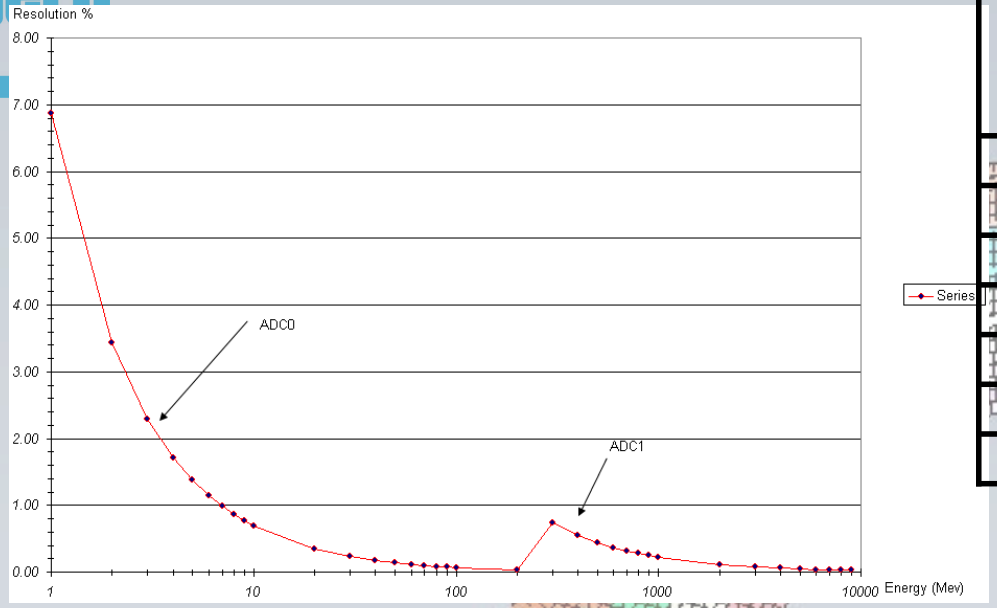
Module prototype for Beam test October 2010





Mechanical structure prototype has been built by RIBA (Faenza, Italy).

VFE: DESIGN CHOICE and TRIGGER



MeV	% Low Range MeV	% High Range MeV	% Range selected/ MeV
1	6.87	219.73	6.87
10	0.69	21.97	0.69
100	0.07	2.20	0.07
200	0.03	1.10	0.03
300	OVF	0.73	0.73
1000	OVF	0.22	0.22
9000	OVF	0.02	0.02

-charge preamplifier + 2 ranges gain (x1, x32)
-12 bit digitalization + 1 bit range
-special range for calibration

- **Towers of 25 crystals for the forward => 4 towers per trigger link**

Σ Σ Σ Σ optical

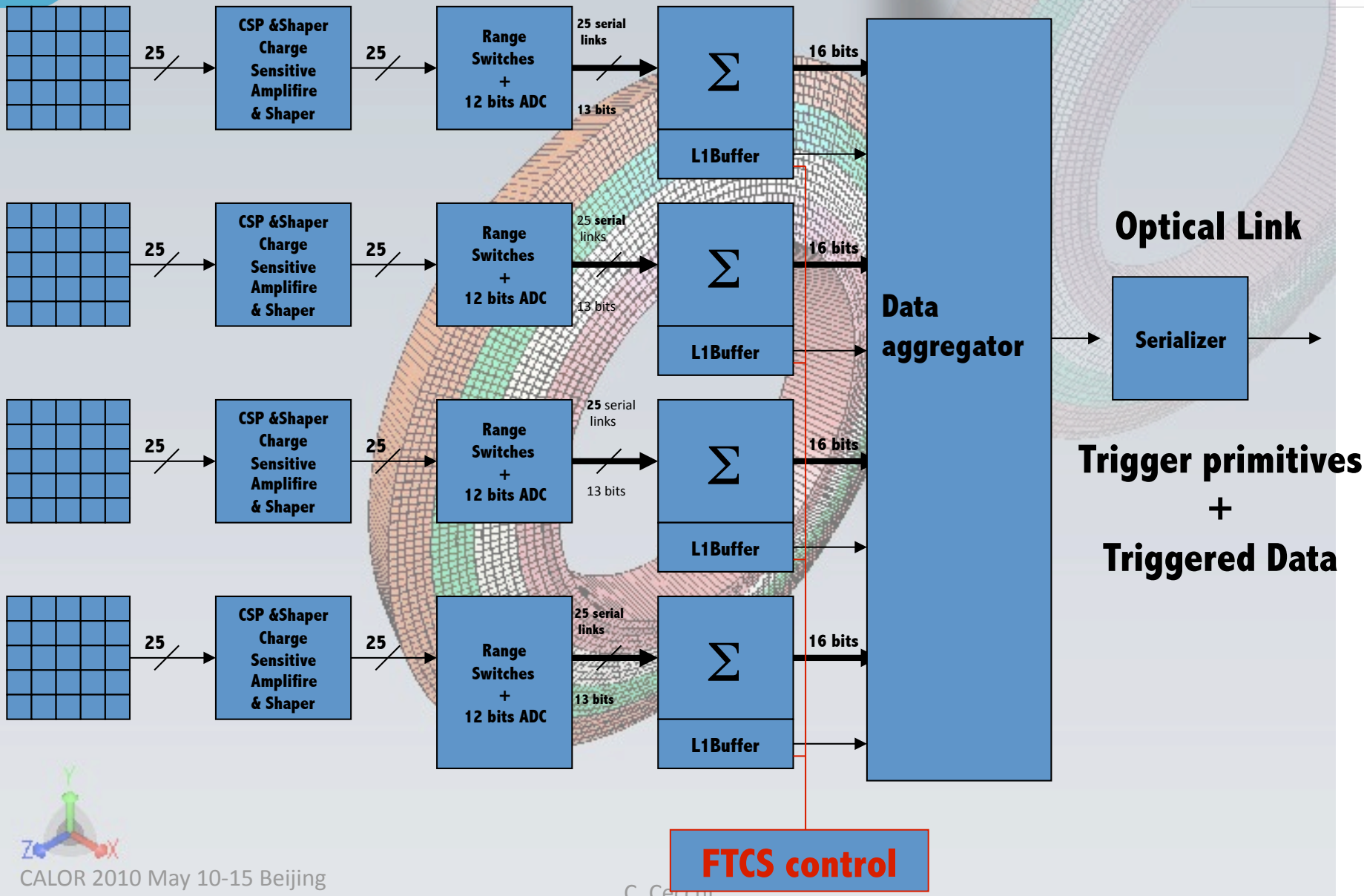
- **Towers of 12 crystals for the Barrel => 6 towers per trigger link**

Σ Σ Σ Σ Σ Σ optical

Two possible readout are under study: PiN diodes (as in the Barrel) and APD's.
-PiN would require intermediate step with PMT during uniformity measurements
-APD's strong temperature dependence

-Neutron induced signal see talk of R.Y. Zhu

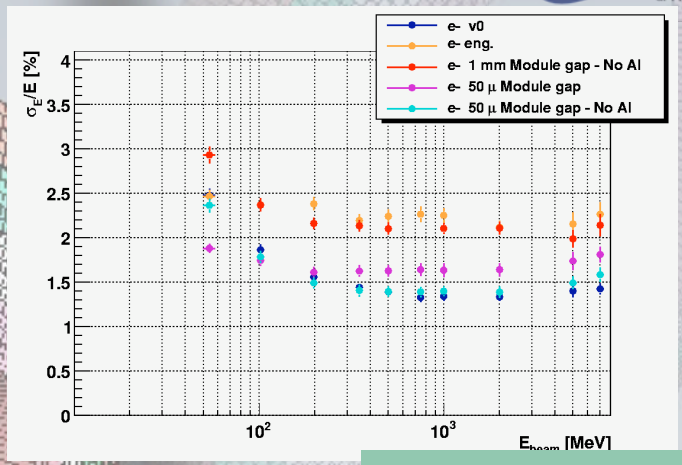
From crystals…to data…

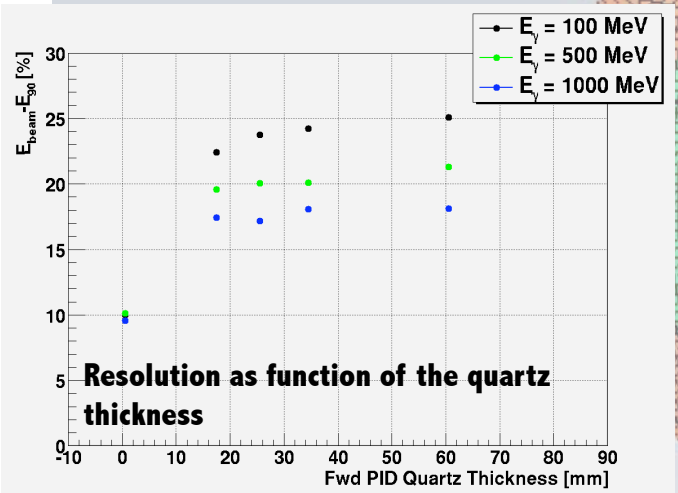


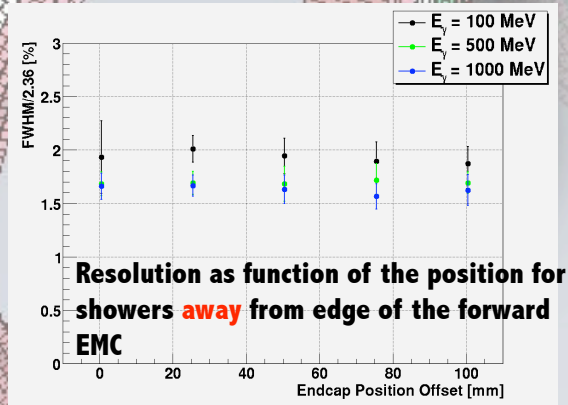
MC PERFORMANCE STUDIES

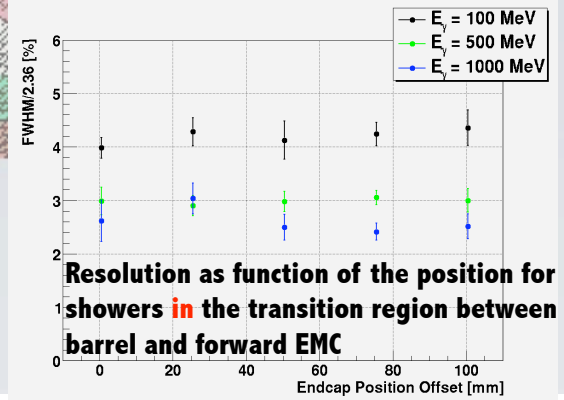
Fundamental point for the optimization of the detector:

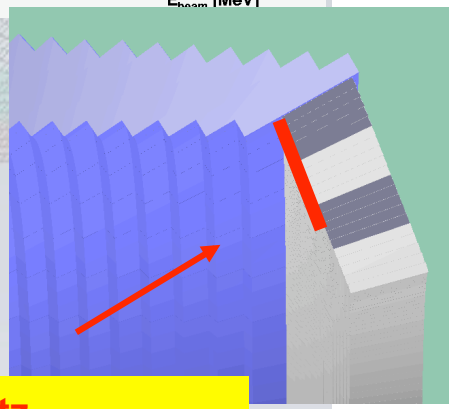
1. **Resolution study as function of space between crystals and modules**
   - **-Mechanical structure (very useful during design phase of the prototype module)**
2. **Detailed study of the effect of the material in front of the calorimeter for a possible PID forward detector**



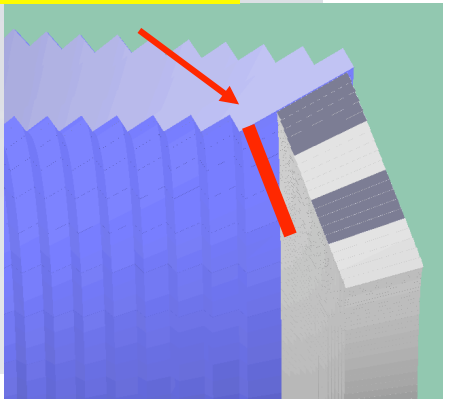








Quartz

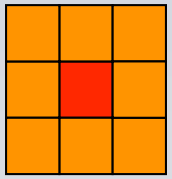


MC PERFORMANCE STUDIES cont'd

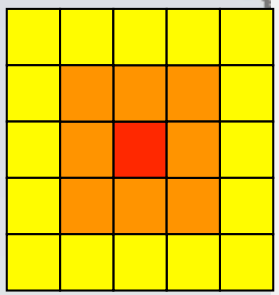
3. clustering algorithm for pattern recognition in case of overlapping events

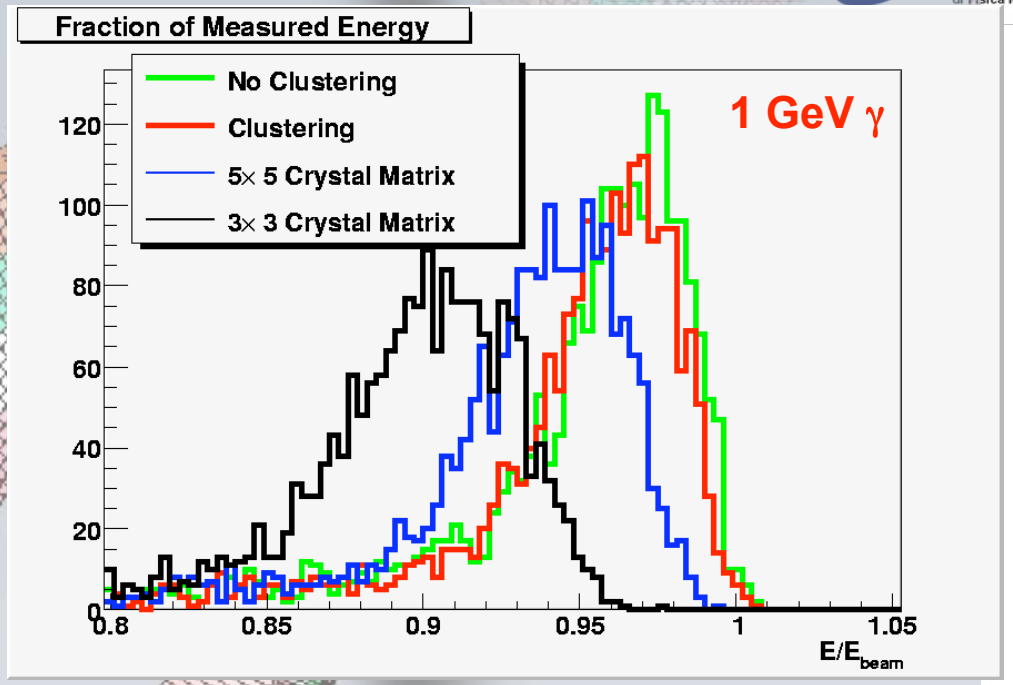
Maximum Energy Or Seed Crystal

δX <= 1

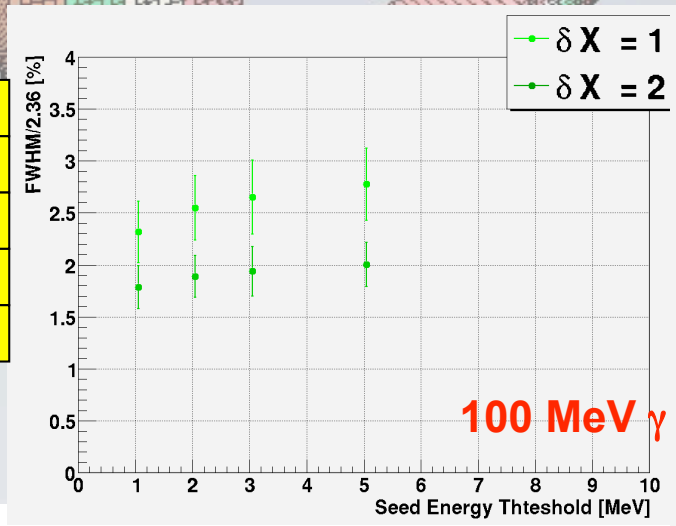


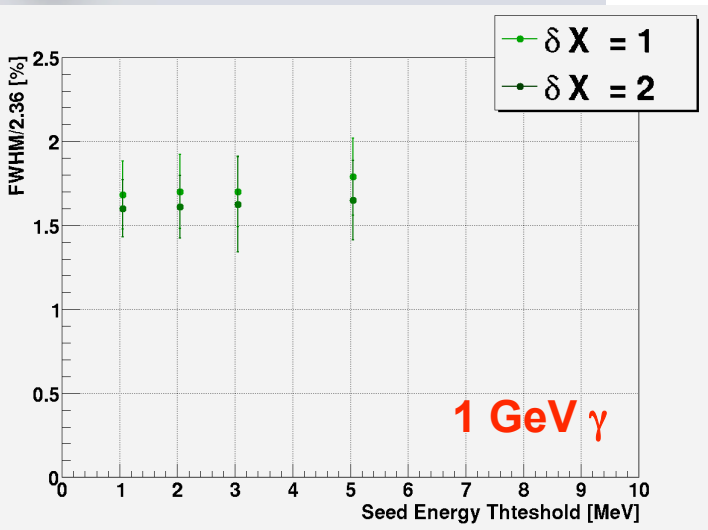
δX <= 2





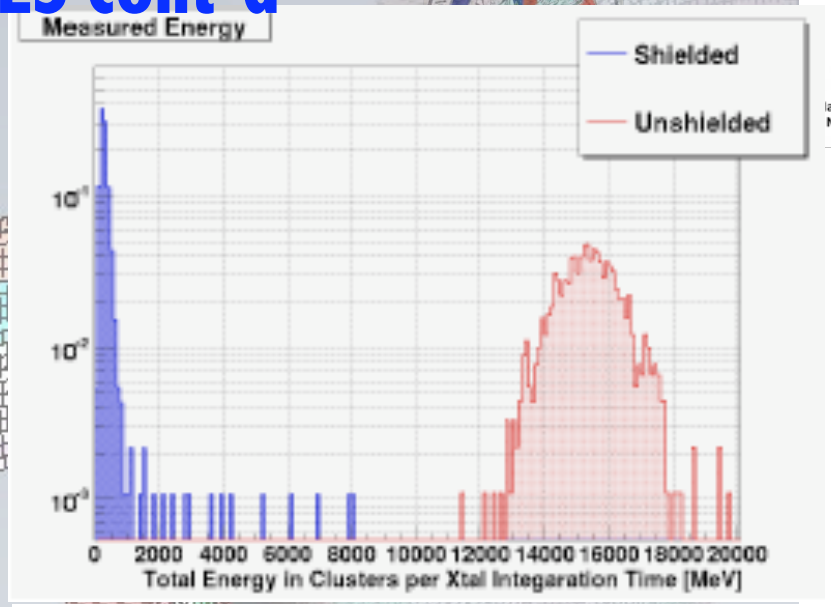
Fwd

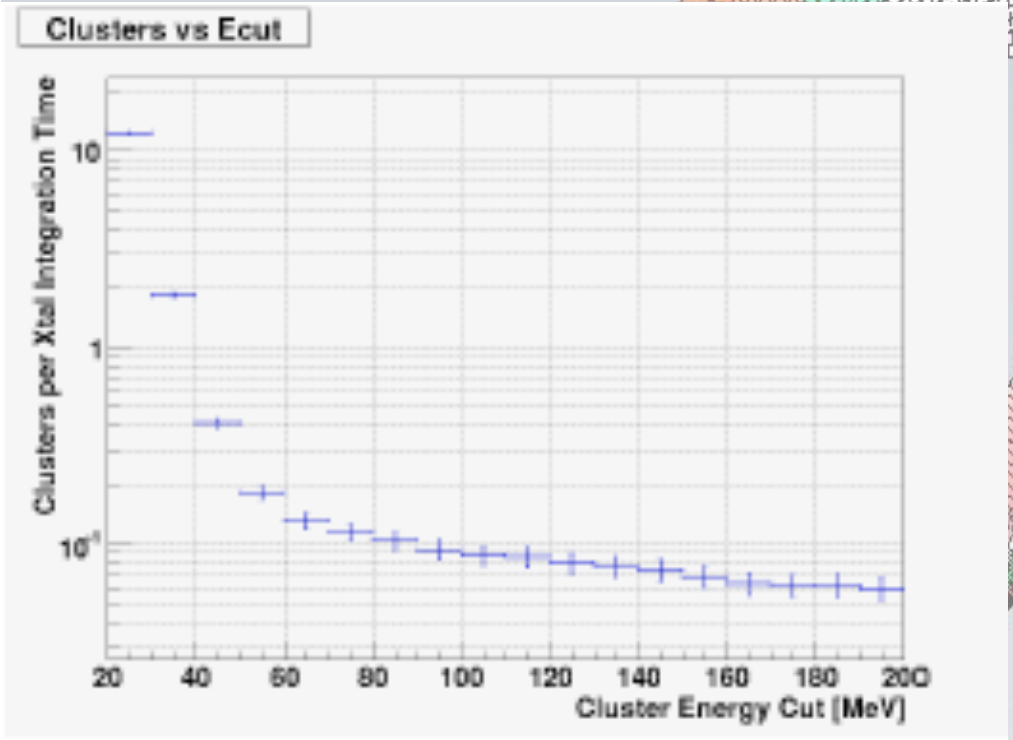


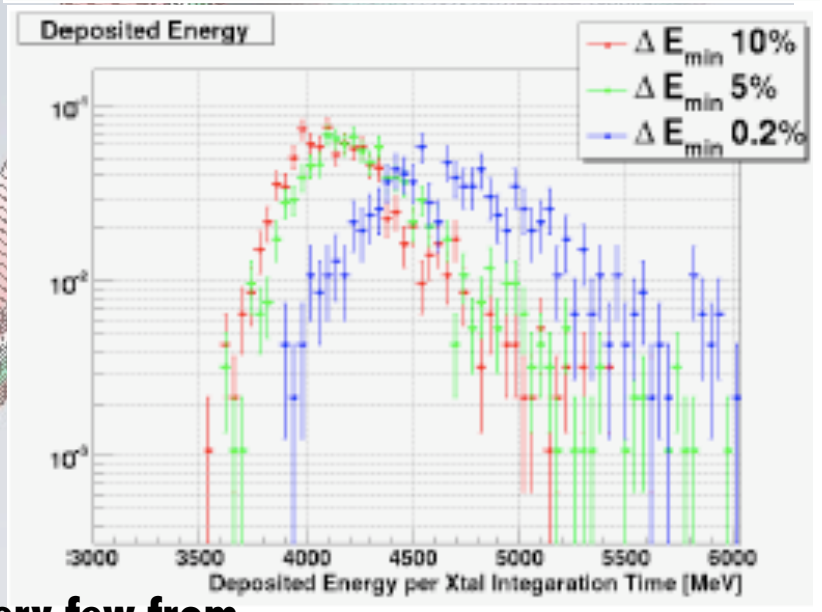


MC PERFORMANCE STUDIES cont'd

4. background study (radiative Bhabha events) is one of the most important, it has implications on
   - Electronics (shaping time, integration, pile up



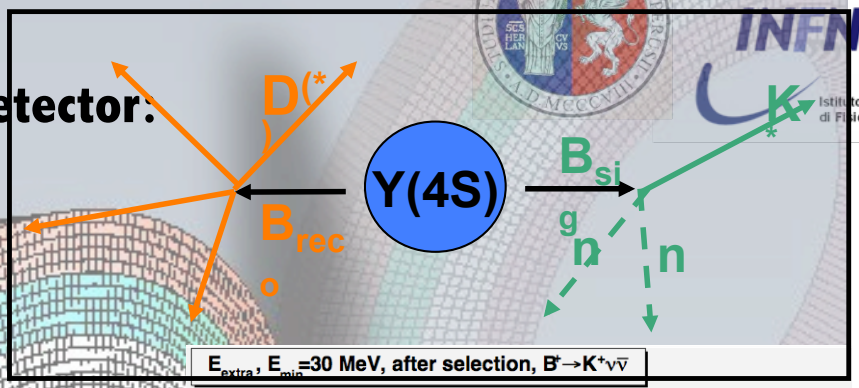




Most of the clusters are coming from neutrons, very few from electrons and photons

Physics study $B^+ \to K^+ \nu\nu$

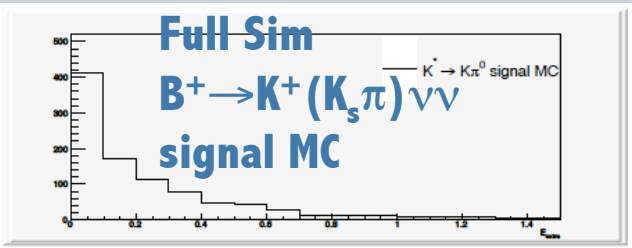
Example for the optimization of the detector:



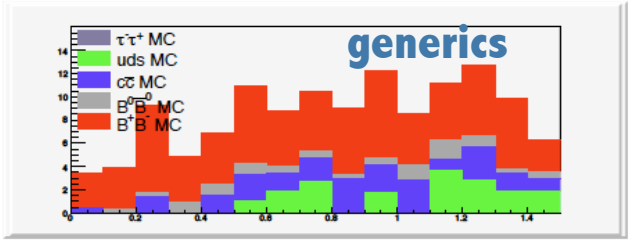
Full Sim

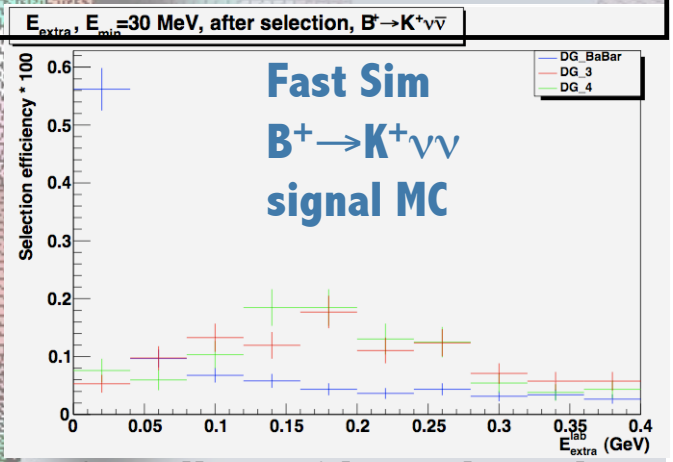
$B^+ \to K^+ (K_s \pi) \nu\nu$

signal MC



generics

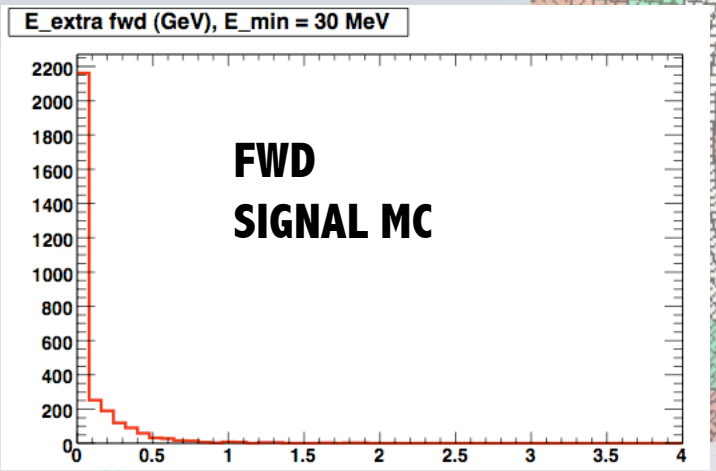




Fast Sim

$B^+ \to K^+ \nu\nu$

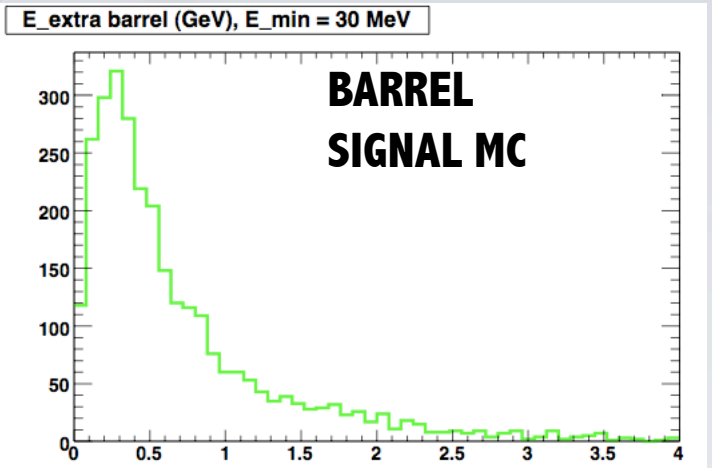
signal MC



FWD

SIGNAL MC

Eextra = neutral energy after all tag side tracks and neutral cluster have been accounted for.



BARREL

SIGNAL MC

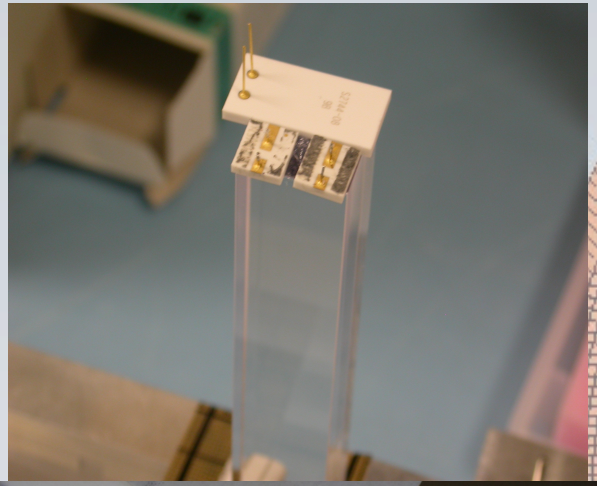
FWD EMC shows expected shape for signal MC

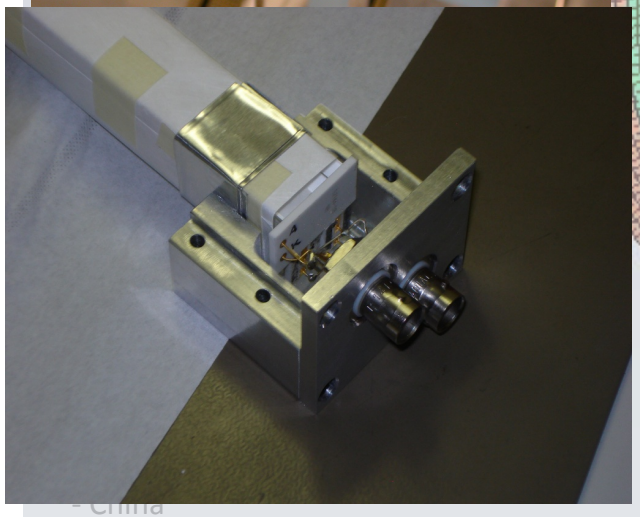
In the barrel a more detailed study of the bckg is needed to obtain good performance.

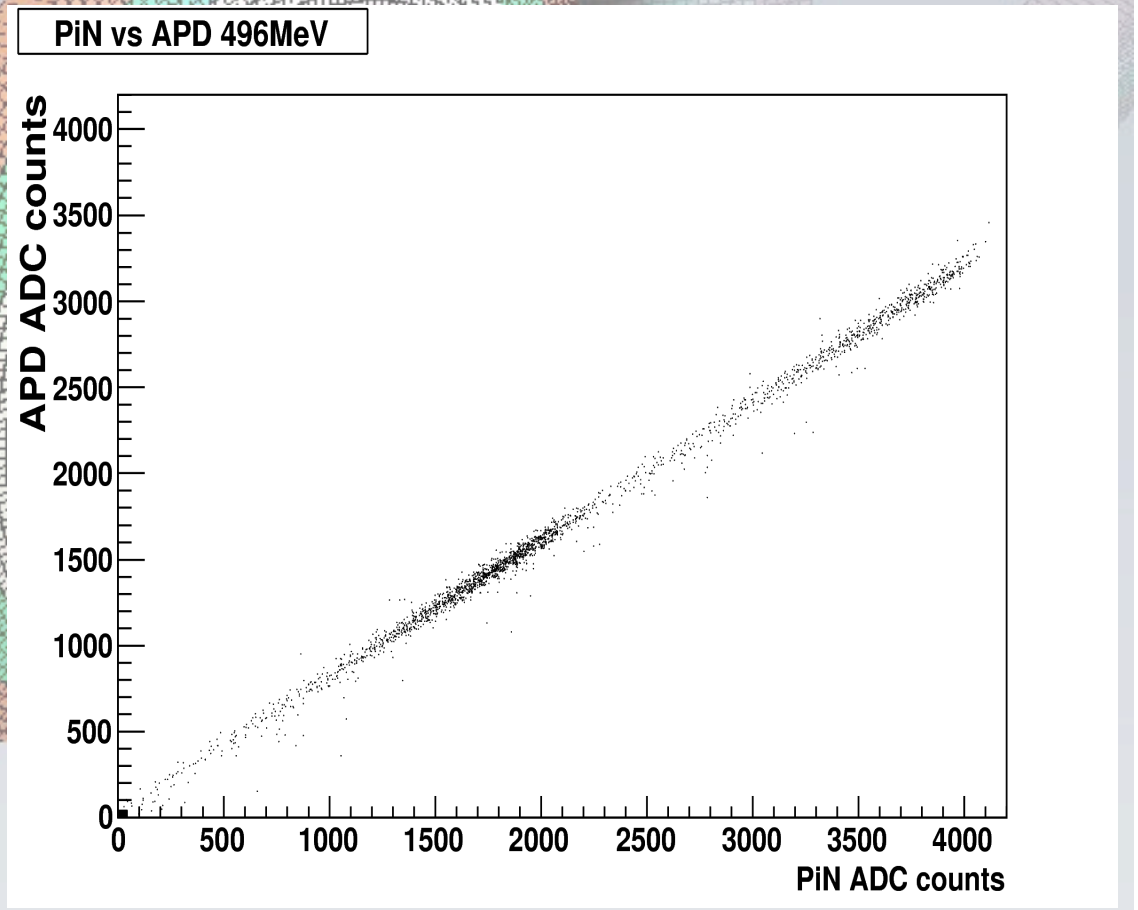
TEST BEAM June 2009 @BTF (Frascati)

1 LYSO crystal (2x2x20cm) with by two different sensors

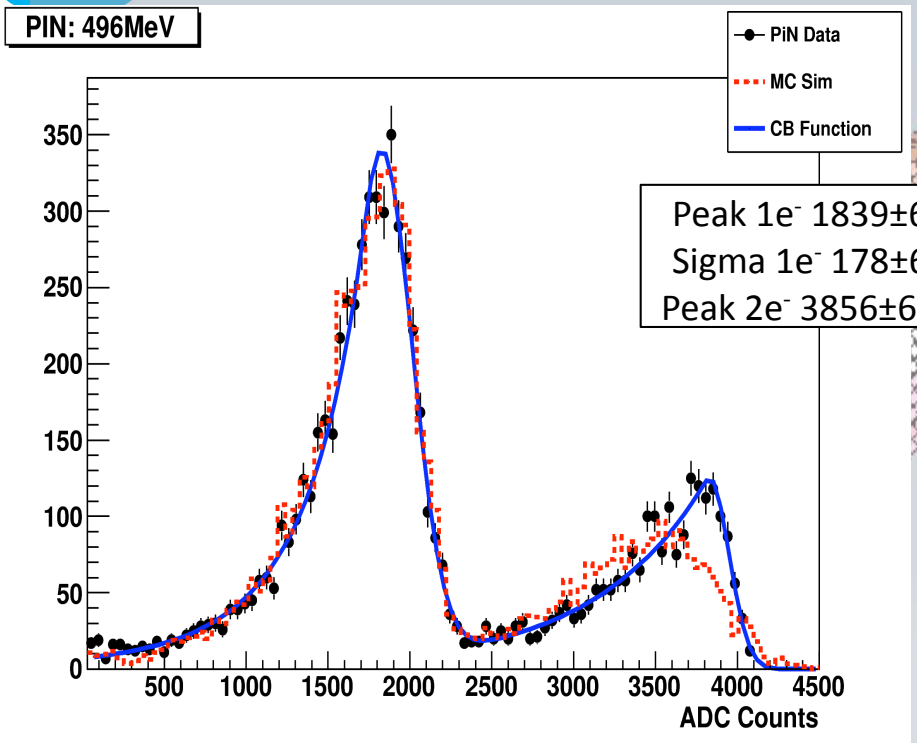
- 1 Photodiode PiN Hamamatsu S2744-08 (1x2cm)
- 2 APD Hamamatsu S8664-55 (0.5x0.5cm each)
- same APD used by CMS

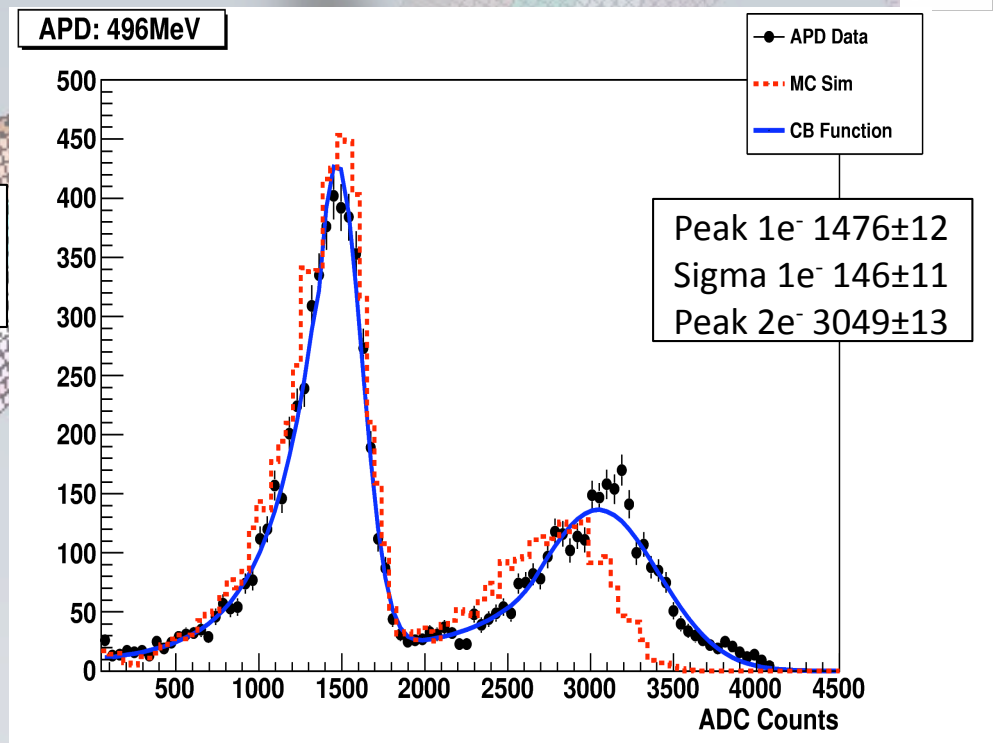






TEST BEAM June 2009 @BTF (Frascati)

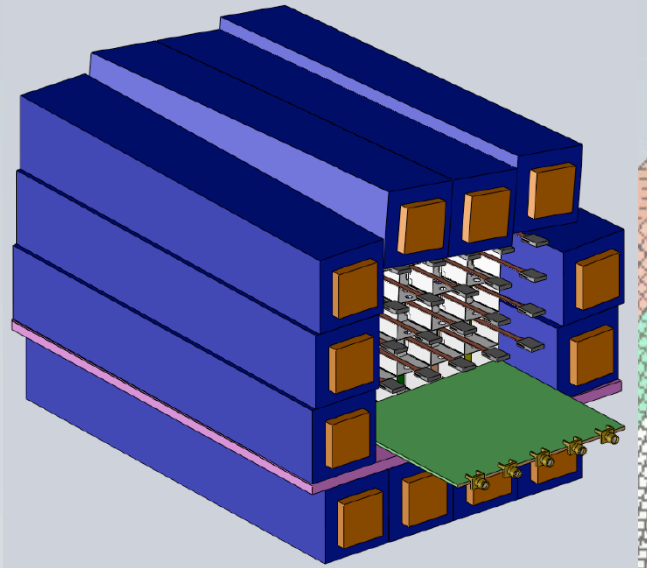


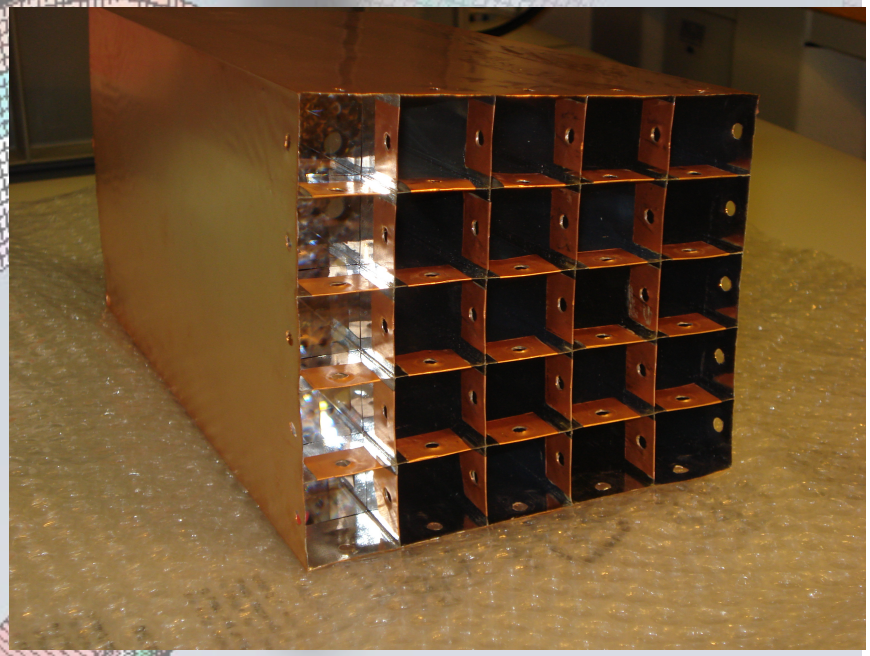


- one e- and two e- peaks are evident
- fits are made with the sum of two CrystalBall function
- beam position is measured by a fibrometer (resolution ~cm)

TEST BEAM October and November 2010 (CERN and BTF)

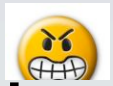
Put under test matrix of 5x5 LYSO crystals + external ring of CsI crystals (CLEO)





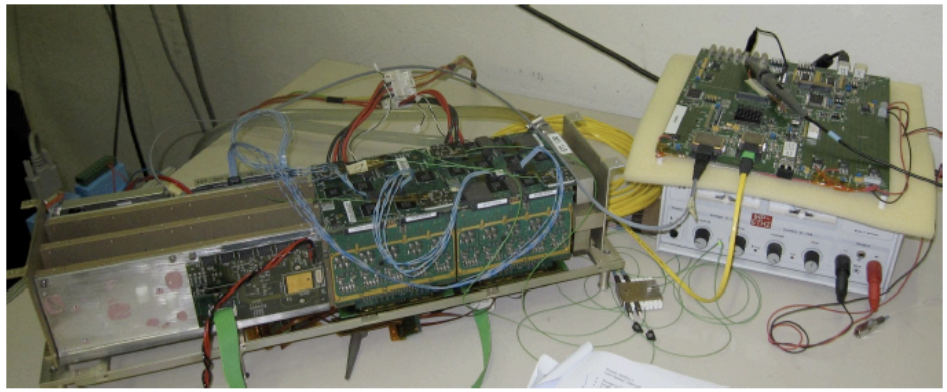
5 channels of the new electronics are under production and will be tested in June:

- **test OK**  **assembly up to 25 channels for October TB**

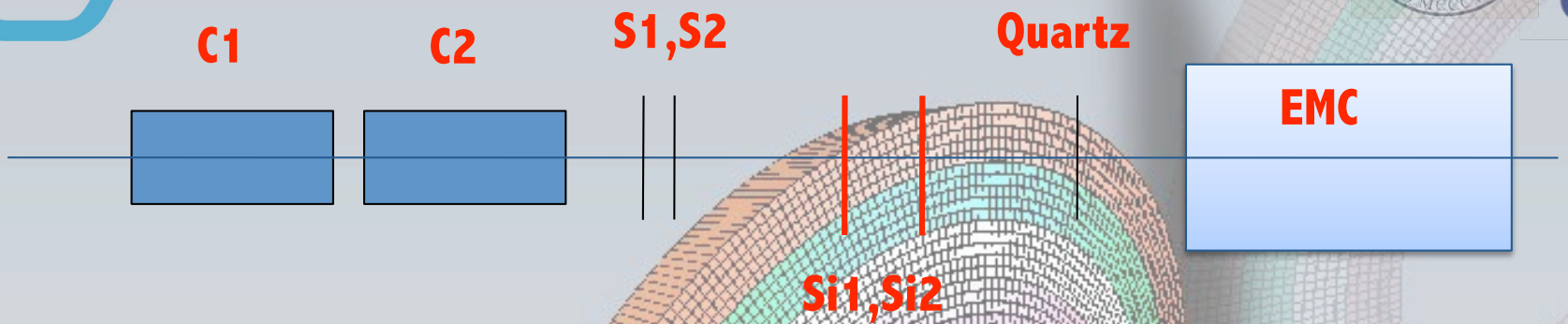
- **VFE to be modified**  **recover and use 5 channels + 20 channels with APD's and CMS DAQ**

CMS Readout

CREPE Card



BEAM LINE



• C1/C2 Cerenkov counters, CERN setup: the detectors are provided by CERN in the beam line, two channels, electron/pion separation, radout via ADC VME system. DAQ system integrated with beam telescope and new electronics channels . @LNF we do not have/need external particle identification.

• S1/S2 : two 10cm x 10cm x 1cm plastic scintillators, to be used in the trigger and to synchronize the two independent DAQ systems, @LNF and @CERN

• Beam telescope (2 X-Y planes, Fermi sensors, single sided detectors, they are nearly 10x10 cm^2, 50 micron strips, 225 micron pitch, 384 strips per wafer, 400 micron silicon) ready.

CONCLUSIONS

- Studies for a new LYSO calorimeter for the SuperB factory have been developed

- Different aspects are under/have been investigation/investigated:
  - LYSO characterization (LY, uniformity, Ce doping)
  - performance studies; well advanced detailed study (occupancy and background, material in front of the endcap…) are on going
  - mechanics; developing analysis for the whole structure, prototype structure for the BT is ready
  - electronics; readout is under investigation (APD's, PiN), electronics is under development and will be photodetector independent, first prototype will be ready for test in June, October 2010 Beam Test
  - Beam Test organization is on going

  October 2010 at CERN (up to 3.5 GeV)

  November 2010 at BTF (50 – 500 MeV)