Super$B$ EMC R&D Introduction

David Hitlin

Elba Super$B$ Meeting

May 31, 2008

EMC R&D for Super*B*

- There are two EMC R&D sessions this morning
  - Introduction – Hitlin
  - Status of determination of LYSO mechanical properties – Cecchi
  - Forward endcap geometry – Germani
  - An alternative forward endcap geometry – Porter
  - Rear endcap Pb/Tile calorimeter endcap – Eigen
  - Discussion
- Goals
  - Decide, if possible, on a forward endcap geometry
  - Make progress on rear endcap design

EMC R&D for SuperB

- With the likely time structure of SuperB, backgrounds and radiation damage to the EMC should be reduced from those at a 10^{36} conventional collider
- In the barrel region, rates and radiation dose should be tolerable
  - The barrel EMC should be usable at SuperB
- In the endcap region, at least, there will be multi-Bhabhas within the decay/integration time of the CsI(Tl) as well as showers from off-energy electrons that (hopefully) hit the inner shielding
- The forward CsI(Tl) endcap crystals must be replaced with crystals having a faster scintillation light decay time that are more radiation hard
- There are good physics motivations to increase solid angle coverage with a rear endcap used primarily as a veto
  - Lead/scintillator technology should suffice

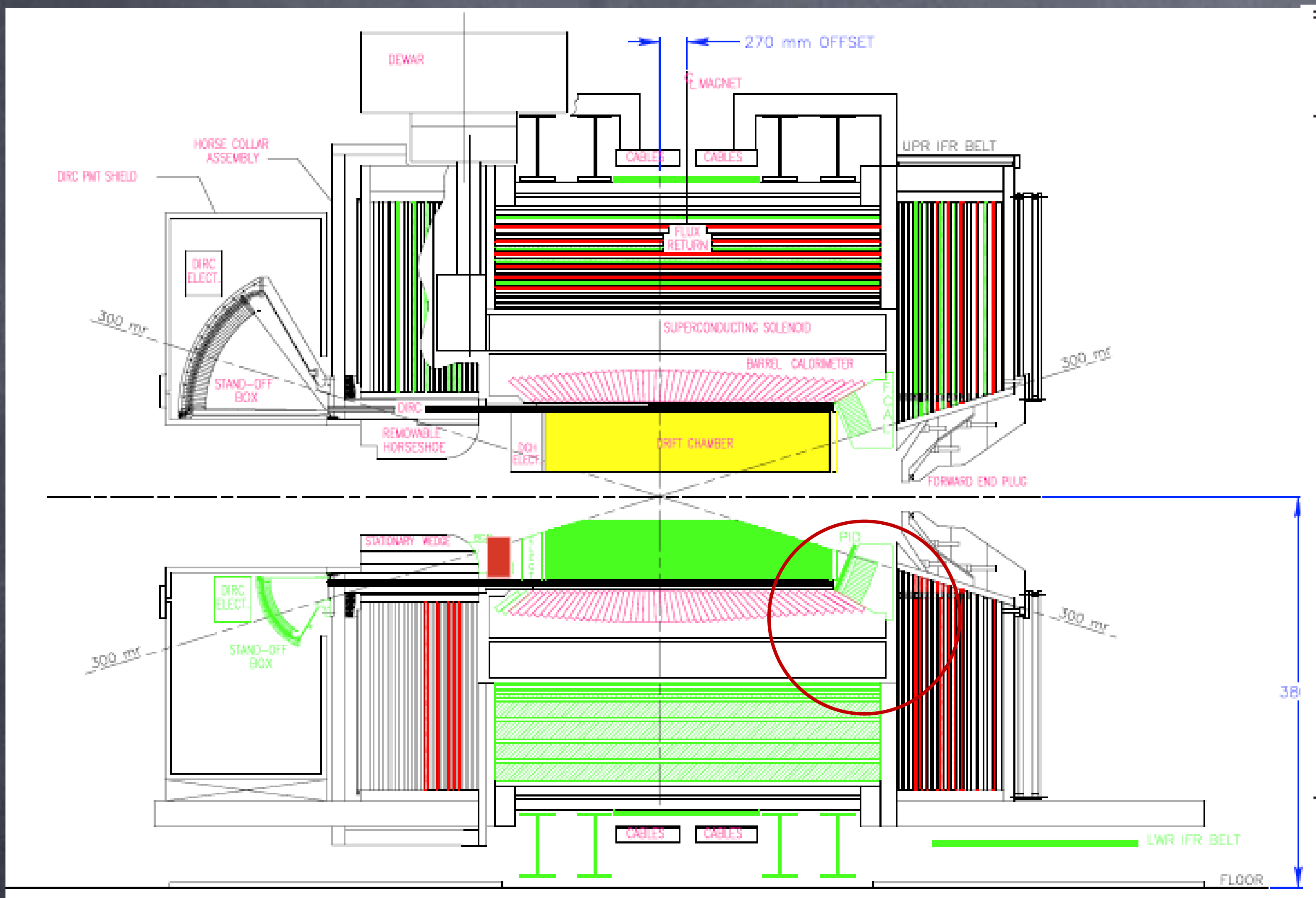
Participating institutions (to date):

Bergen, Caltech, Edinburgh, McGill, Perugia, QMC (U of London)

EMC R&D for Super*B*

- Forward endcap
  - We need
    - A crystal with a smaller Molière radius
    - A crystal that is more radiation hard
    - A crystal with a faster decay time
  - Why not, you ask, use $PbWO_4$?
    - Because we need a crystal that produces more light than a lead brick
  - We have an excellent candidate in LYSO, which is under development by Ren-Yuan Zhu at Caltech

Forward endcap layout



CDR Layout

Ring in ϕ	Radius (mm)	Crystal Face (mm)	Crystal Volume (cc)	# Crystals
1	597-620	24.4× 31.9	171	120
2	620-643	24.4× 33.1	178	120
3	643-666	24.4× 29.4	158	140
4	666-689	24.4× 30.5	164	140
5	689-712	24.4× 27.5	148	160
6	712-735	24.4× 28.4	152	160
7	735-758	24.4× 26.1	140	180
8	758-781	24.4× 26.9	144	180
9	781-804	24.4× 24.9	134	200
10	804-827	24.4× 25.6	137	200
11	827-850	24.4× 23.9	128	220
12	850-873	24.4× 24.6	132	220
13	873-896	24.4× 23.2	125	240
14	896-919	24.4× 23.8	128	240
			.36 m^3	2520 crystals

The CDR segmentation algorithm needs to be optimized:
- Smaller crystals at smaller radii
- Enforce boule yield constraints

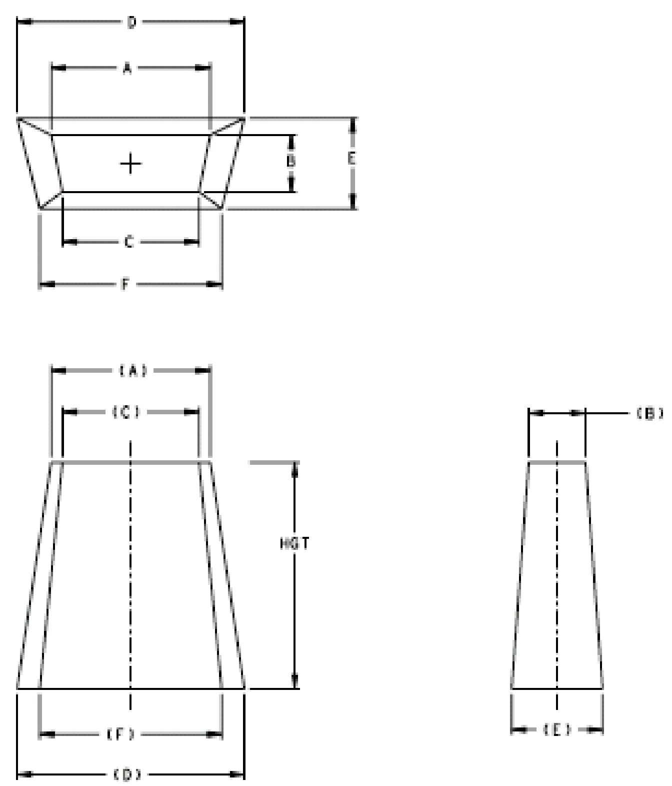
Candidate endcap crystal geometry

- Constraint: a 60mm diameter SIPAT boule must yield two crystals

Xtals Dimensions: Back <2.5 cm

Rule: minimum allowed number of crysrtals multiple of 5

	Ring	A	B	C	D	E	F
165 Xtals 33 Modules	1	20.65	22.03	19.88	22.65	24.43	21.79
	2	21.44	22.03	20.66	23.52	24.43	22.66
	3	22.23	22.03	21.45	24.39	24.43	23.53
180 Xtals 36 Modules	4	21.08	22.03	20.37	23.18	24.43	22.39
	5	21.80	22.03	21.09	23.98	24.43	23.19
	6	22.52	22.03	21.81	24.77	24.43	23.99
200 Xtals 40 Modules	7	20.89	22.03	20.25	23.02	24.43	22.31
	8	21.54	22.03	20.90	23.74	24.43	23.03
	9	22.19	22.03	21.55	24.46	24.43	23.75
235 Xtals 45 Modules	10	21.23	22.03	20.64	23.44	24.43	22.78
	11	21.84	22.03	21.24	24.11	24.43	23.45
	12	22.44	22.03	21.85	24.78	24.43	24.12
265 Xtals 53 Modules	13	21.06	22.03	20.52	23.29	24.43	22.68
	14	21.62	22.03	21.07	23.90	24.43	23.30
	15	22.17	22.03	21.63	24.51	24.43	23.91
250 Xtals 50 Modules	16	21.34	22.03	20.83	23.63	24.43	23.06
	17	21.86	22.03	21.35	24.21	24.43	23.64
	18	22.38	22.03	21.87	24.78	24.43	24.21
270 Xtals 54 Modules	19	21.19	22.03	20.72	23.48	24.43	22.96
	20	21.67	22.03	21.20	24.02	24.43	23.49
	21	22.15	22.03	21.68	24.55	24.43	24.02



LSO/LYSO is in mass production

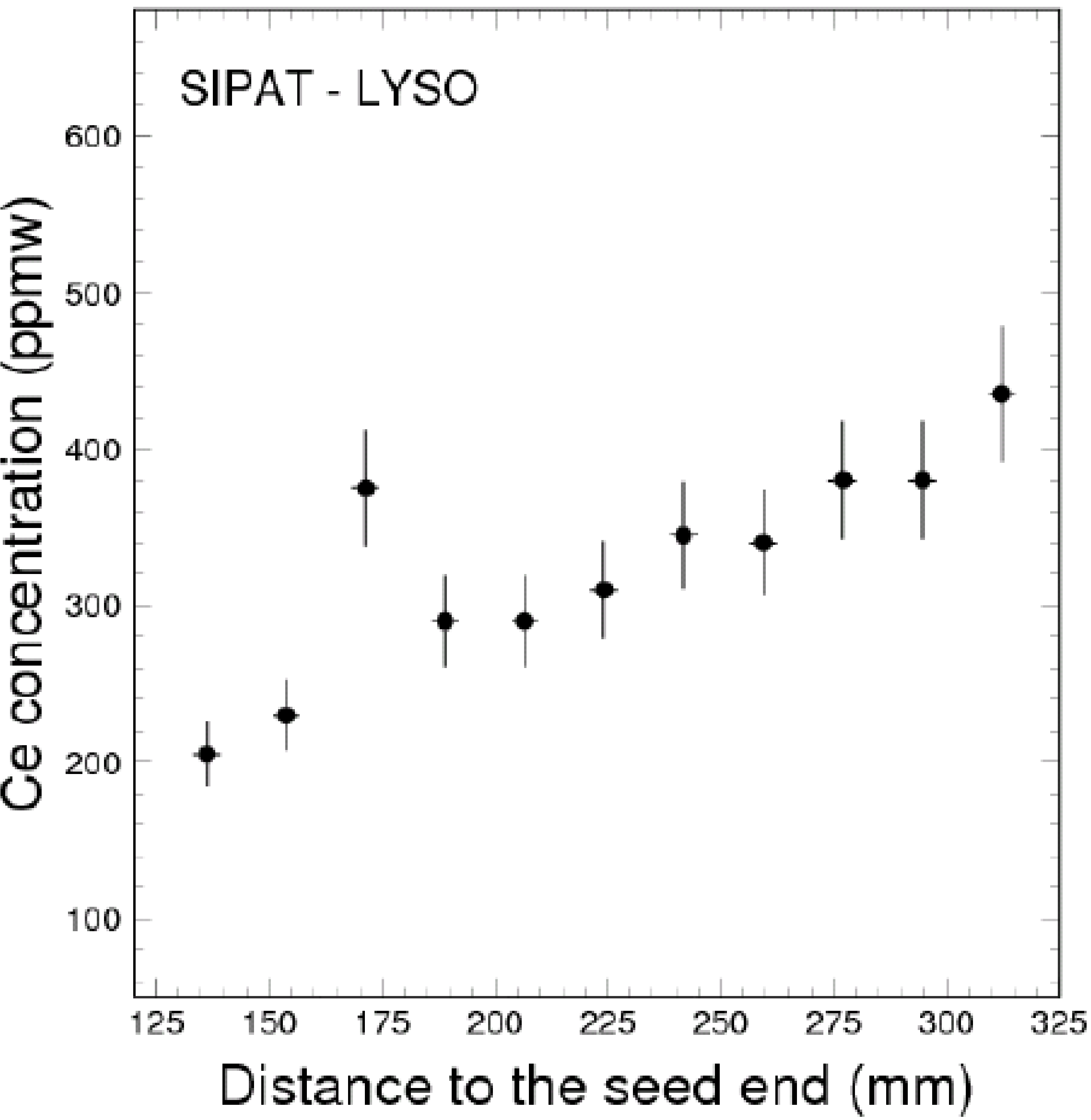
CTI: LSO

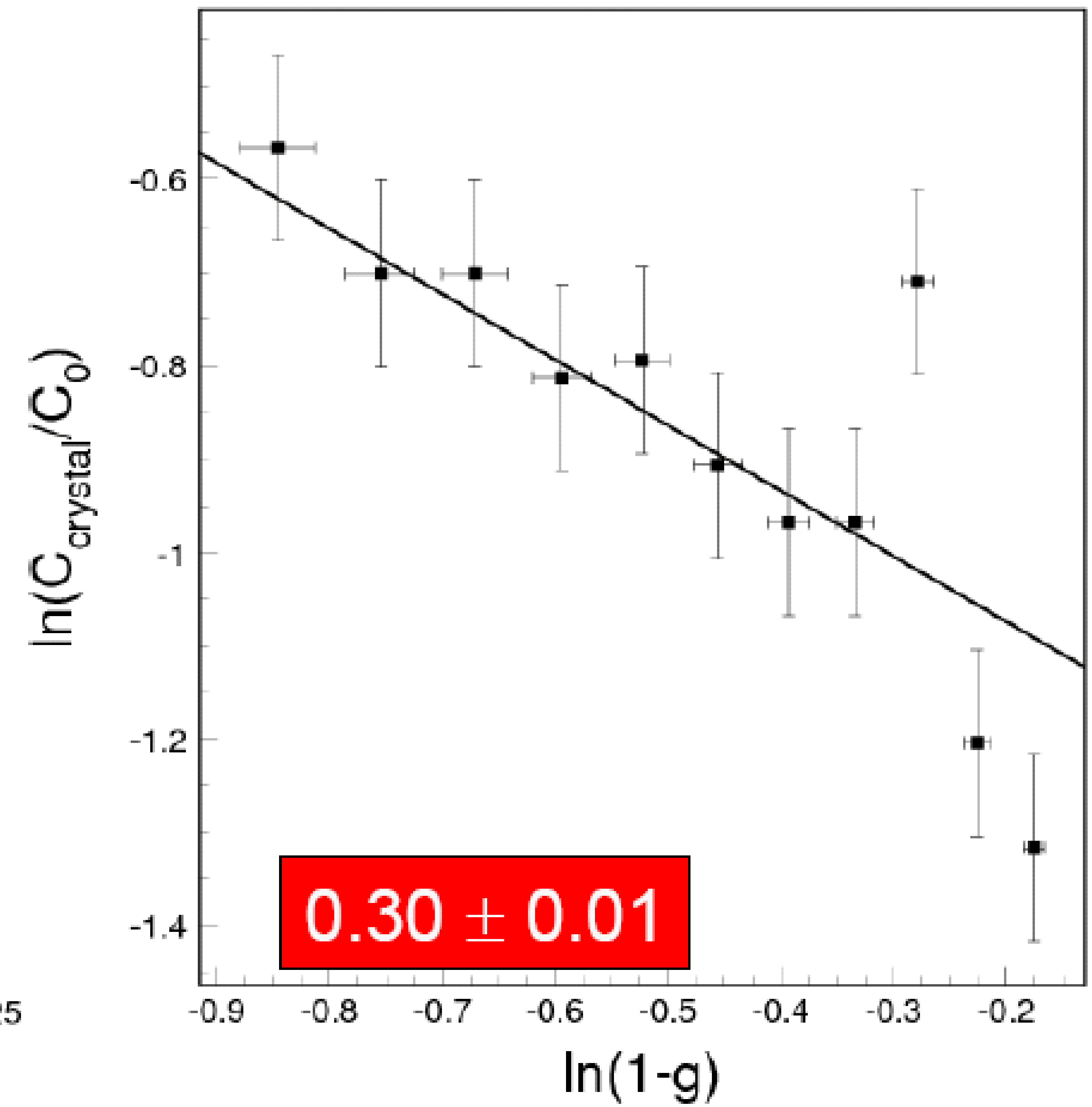
CPI: LYSO

Saint-Gobain LYSO

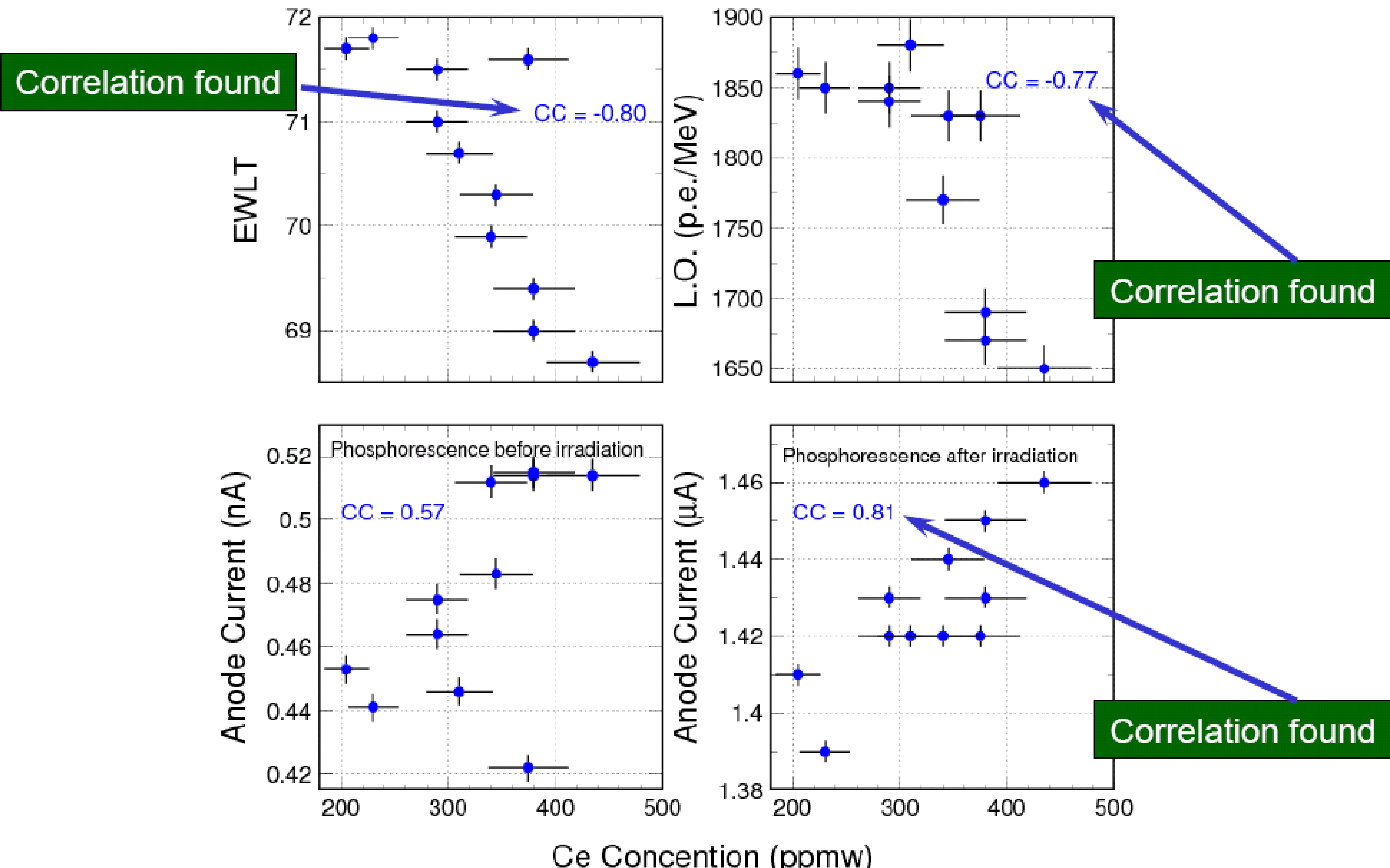
Cerium Segregation in LSO

Ce is not easy to enter LSO lattice.
It may be important to make it uniform.



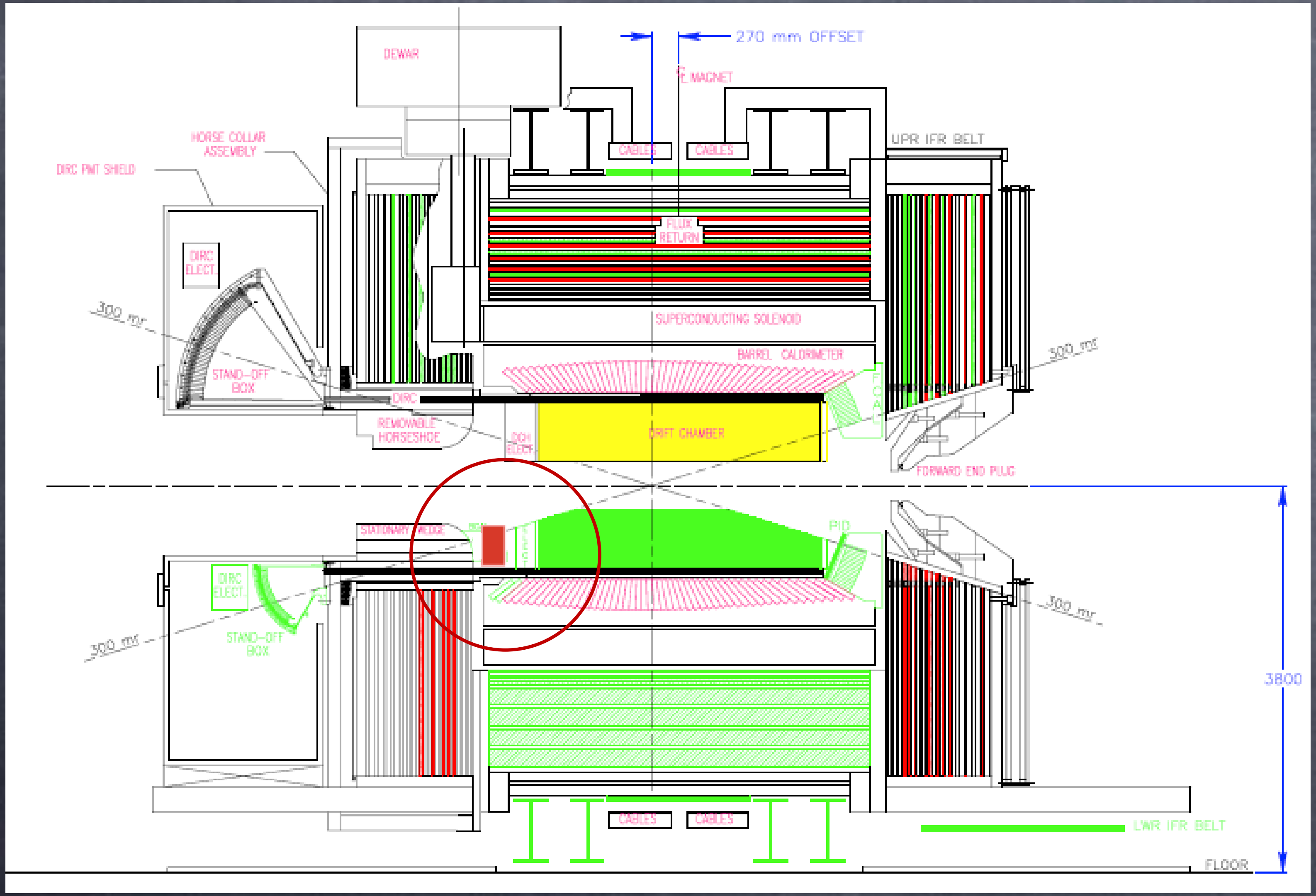


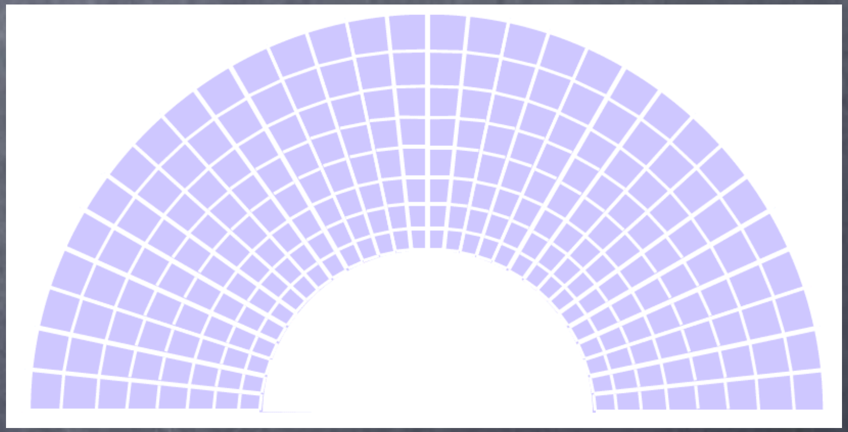
Correlation: Ce and EWLT/L.O./Phors.



Rear endcap tile pattern concept (Eigen)

- Pb plates with tile/fiber SiPM readout
- Is projective geometry needed?
- Since tiles are read out individually, there are a large number of channels even in a small device
  - Can channels be analog-summed?



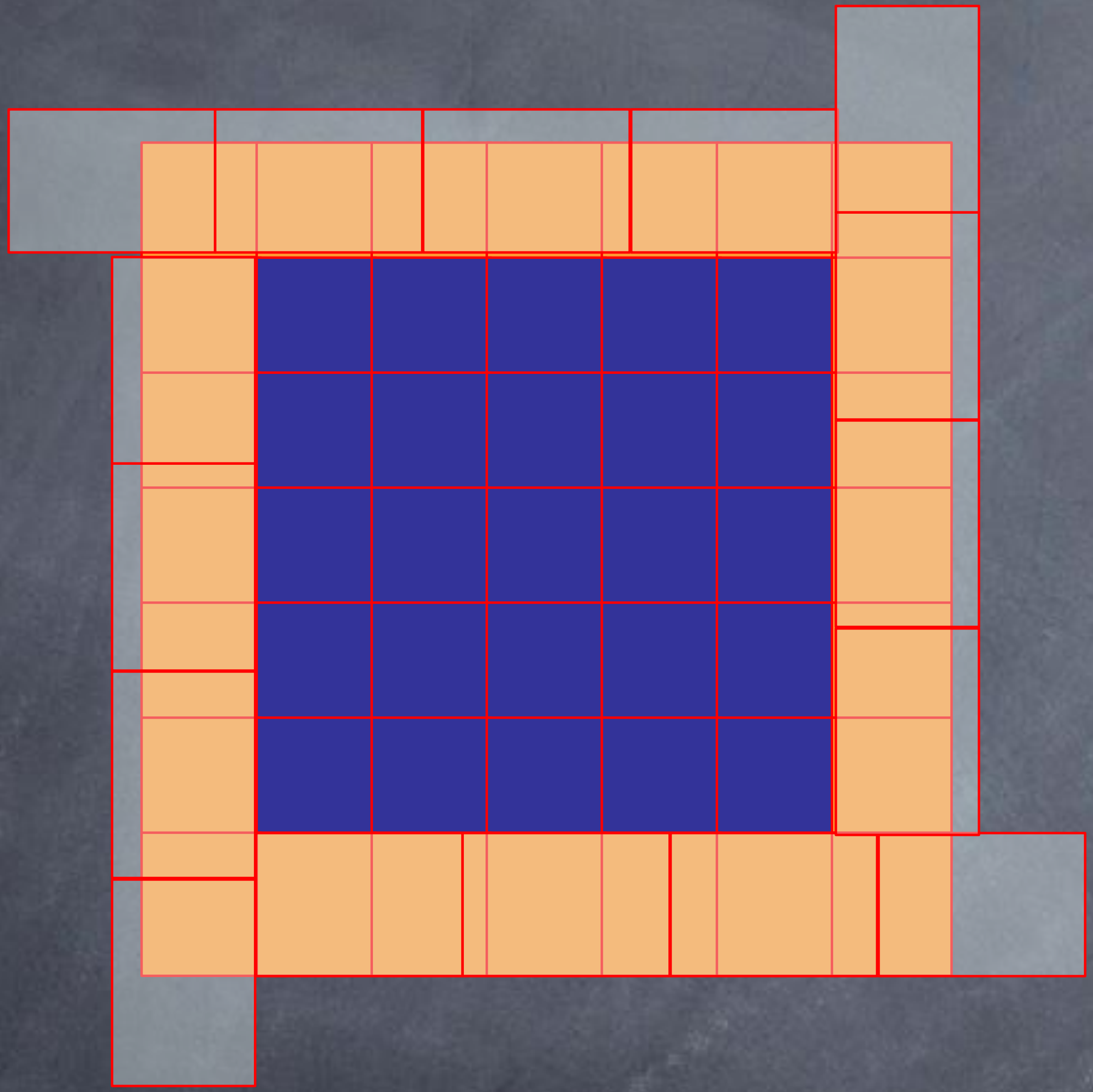


Sichuan Institute of Piezoelectric and Acousto-optic Technology (SIPAT)

LYSO crystal R&D

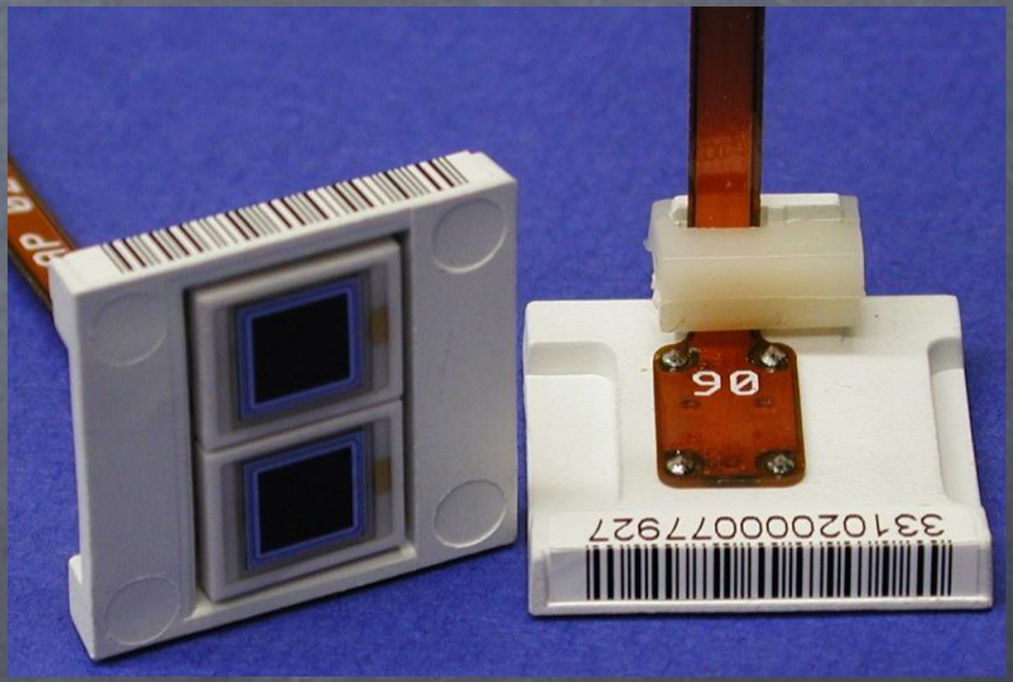
- Crystals are expensive ($50/cc) at present, but we believe that the price can be brought down to ~$15/cc
- More work remains to be done on improving the crystal growth process
  - Characterize trace impurities – improve radiation hardness
  - Improve uniformity of cerium and yttrium doping in the Czochralski process
  - Optimize crystal yield of a given size in a particular boule diameter
  - Reduce phosphorescence
  - ………
- Further develop new supplier relationship

5x5 Projective LYSO array with CsI(Tl) surround



A 7x7 array is best, but it can be approximated by a 5x5 array surrounded by CsI(Tl) to catch the outer few percent of shower

16 spare *BABAR* CsI(Tl) crystals may be available



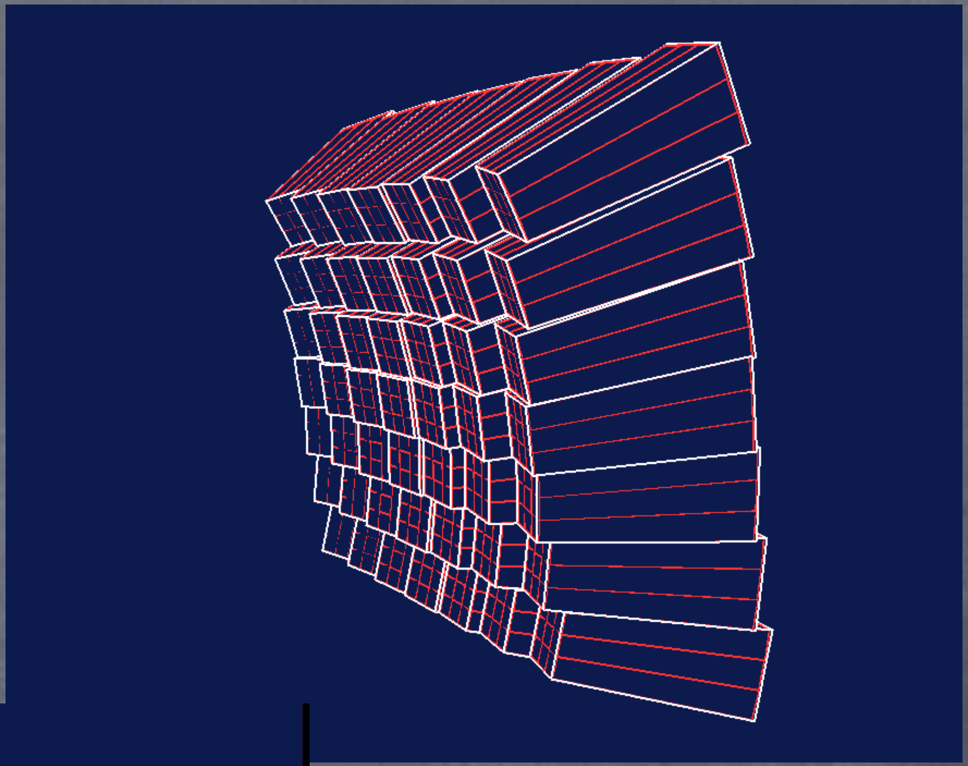
CMS APD readout module
2 @ 5mmx5mm APD
(10x10mm APDs are now available)

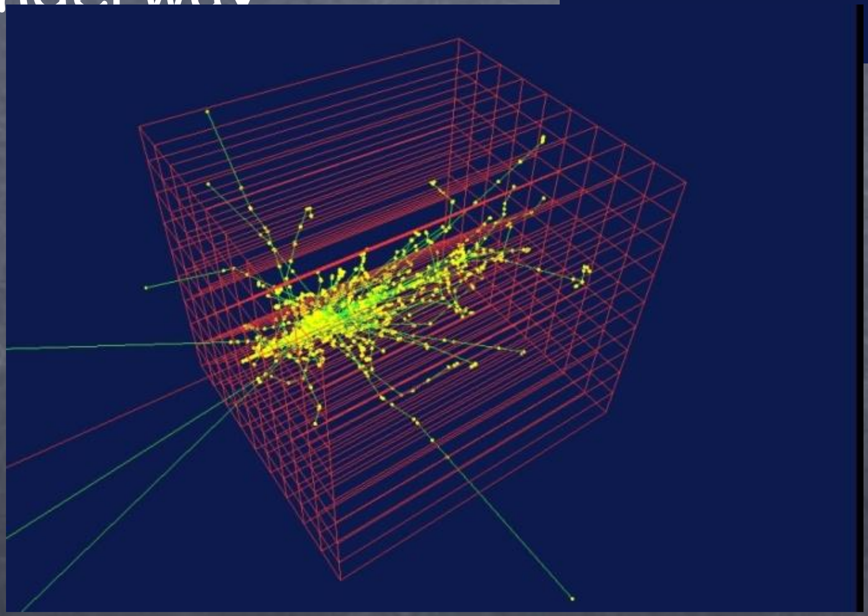
Beam test budget estimate (M&S)

Item	Unit cost ($)	Cost (K$)
LYSO Crystal @ $50/cc (for the test only) x24	6250	150
CMS type dual APD module 2 x Hamamatsu S6664-55 (x(24+16))	250	10
Preamplifier/Shaper (x24+16)	200	8
DAQ system		10
Source carriage		2
Beam test mounting structure		20
Total M&S (w 25% contingency)		250

Monte Carlo studies

- The Perugia group is developing a GEANT4 simulation to optimize the crystal dimensions, the wrapping, the mounting structure,
  etc.
  - Initial studies have been presented
  - Optimization is underway





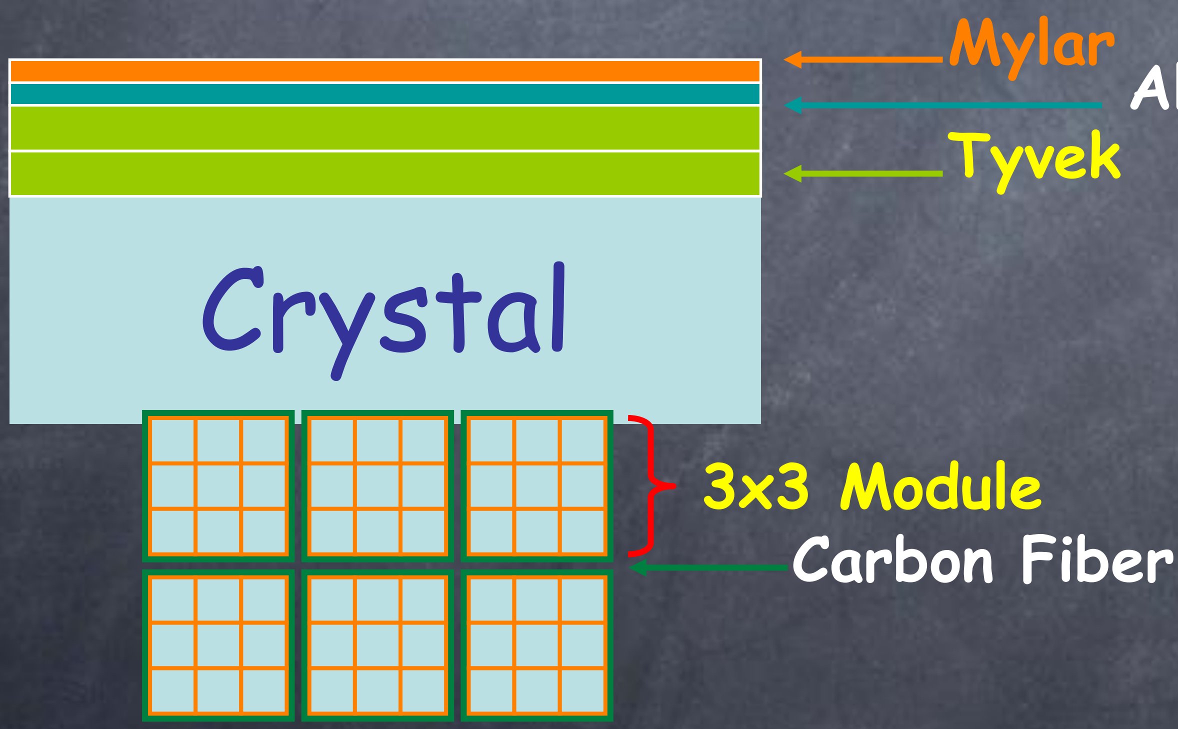
Stefano Germani

Dead Material comparison

BABAR-like geometry :

(B.Aubert et al. Nucl.Instrum.Meth.A479:1-116,2002)

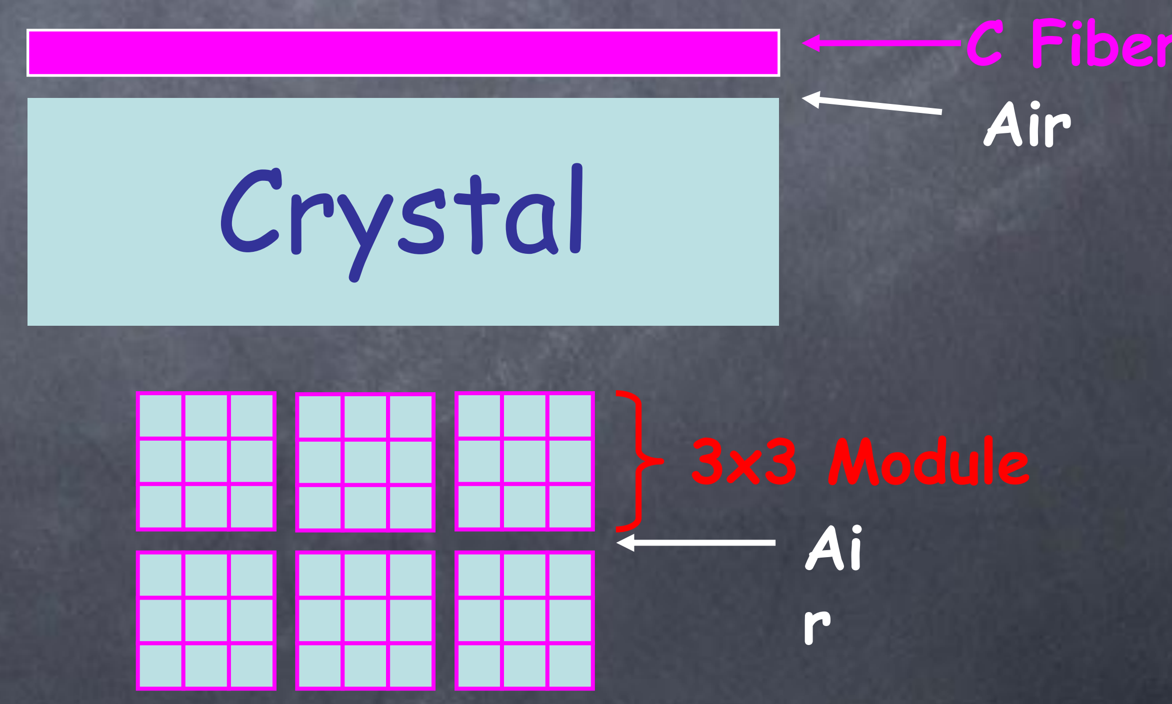
- Each Crystal wrapped with
  - 2 x 165 μm Tyvek
  - 25 μm Al
  - 13 μm Mylar
- Each module wrapped with
  - 300 μm Carbon fiber



CMS-like geometry :

(CMS EDR IV)

- Crystal inside Carbon Fiber matrix
  - Inner wall thickness 400 µm
  - Outer wall thickness 300 µm
  - Crystal Carbon fiber clearance 100 µm
- Module Gap 100 µm



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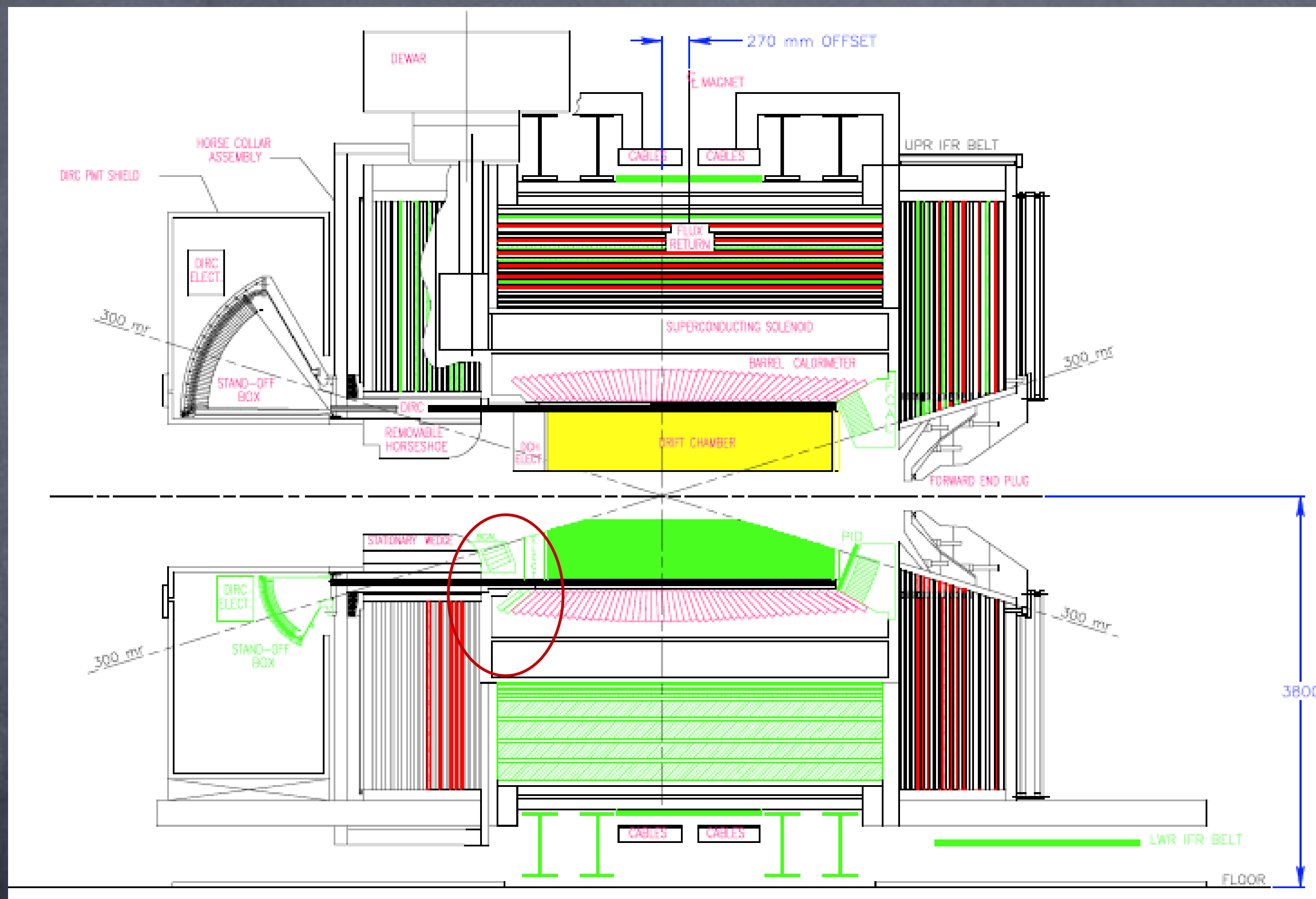
Rear endcap layout+real barrel extension



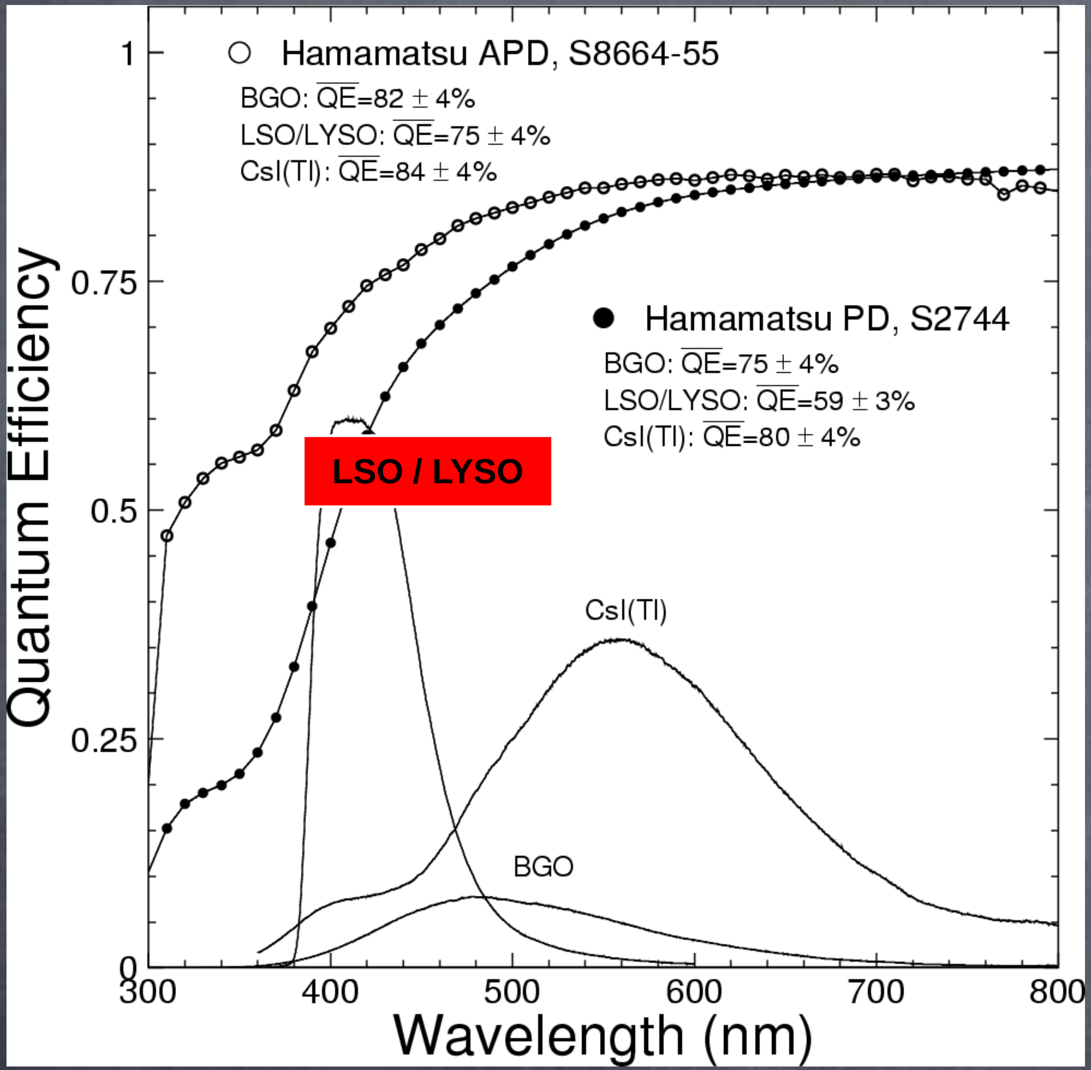
Conclusions

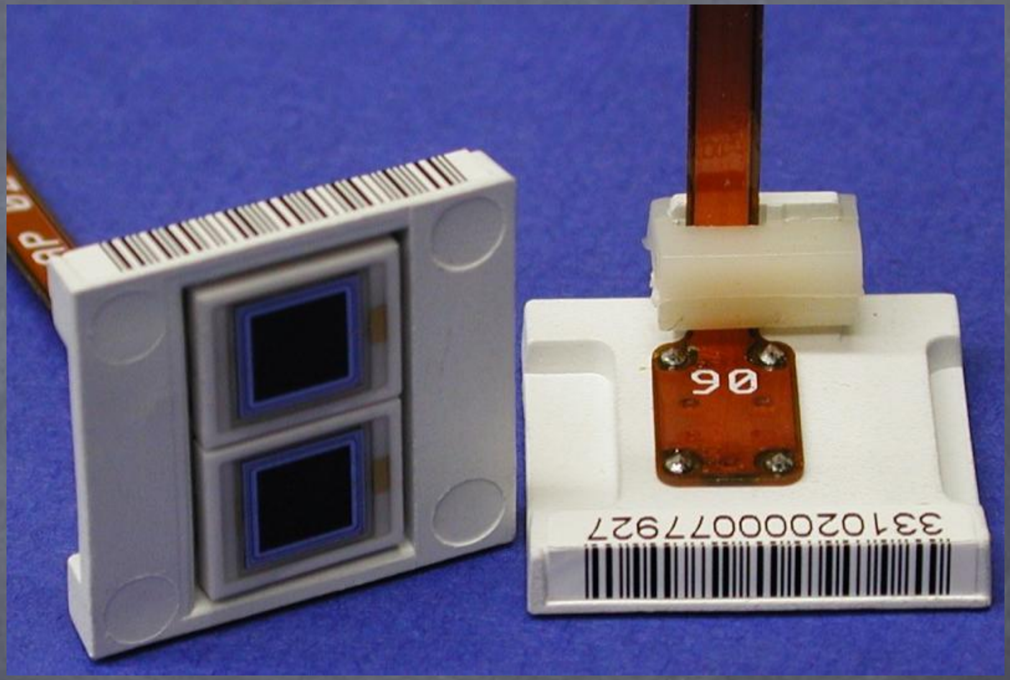
- We have organized the nucleus of a group to do the R&D needed for the Super*B* TDR: to design (and eventually) build an upgraded EMC for SuperB
- We have focused initial effort around a LYSO beam test of a projective array of size adequate to understand in detail shower response and containment
- Very little effort thus far on the rear endcap calorimeter
- There are EMC R&D meetings approximately every two weeks on Wednesday at 8:30AM PST/5:30PM ECT
- There are a lot of interesting issues still to be addressed, and lots of opportunities to contribute
- More details will be presented in the parallel sessions

Scintillating Crystals for HEP

Crystal	NaI(Tl)	CsI(Tl)	CsI	BaF_2	BGO	$PbWO_4$	LSO(Ce)	GSO(Ce)
Density (g/cm³)	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	42	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*?	-

Photo-Luminescence-weighted Q.E.

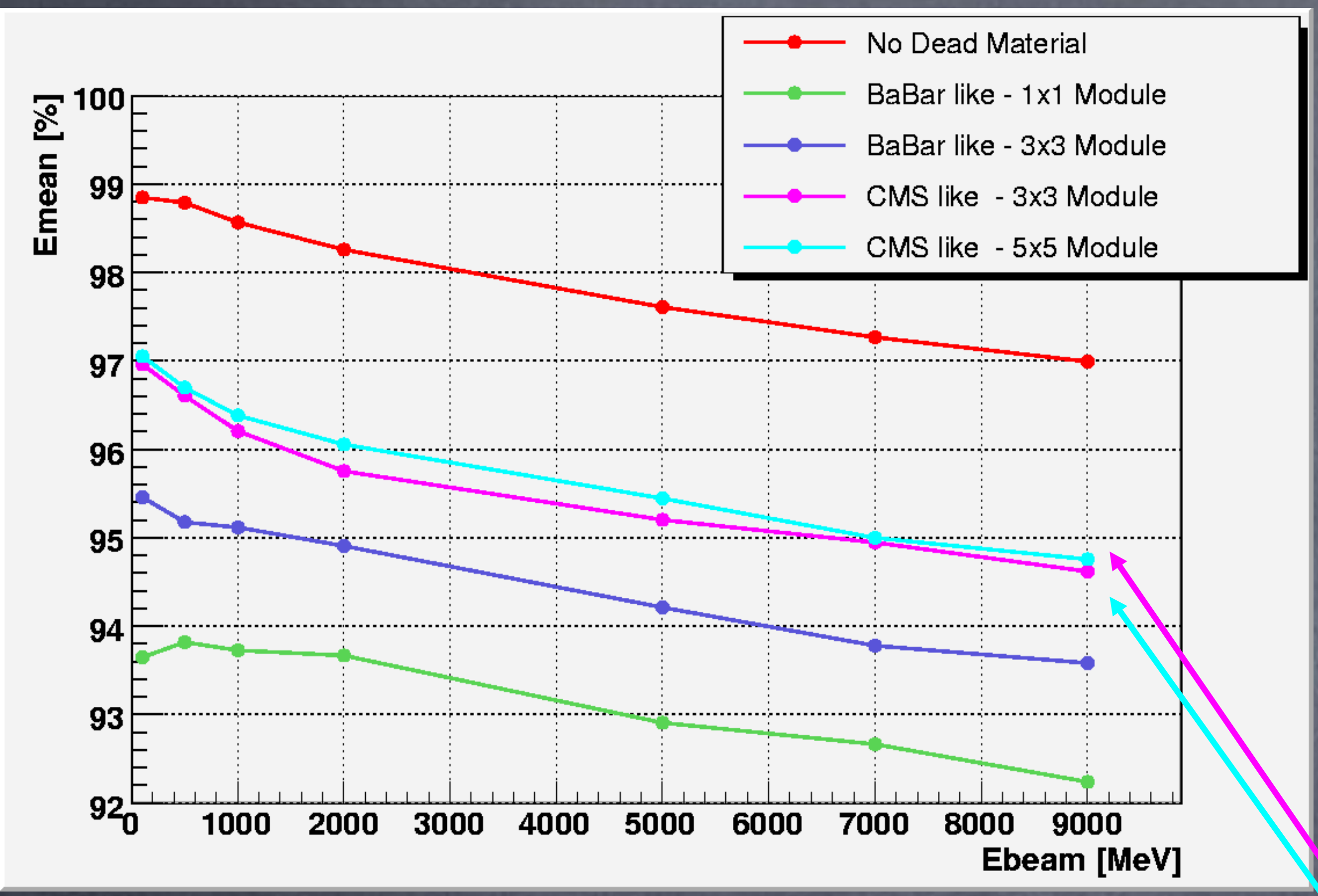




Edep mean and mpv

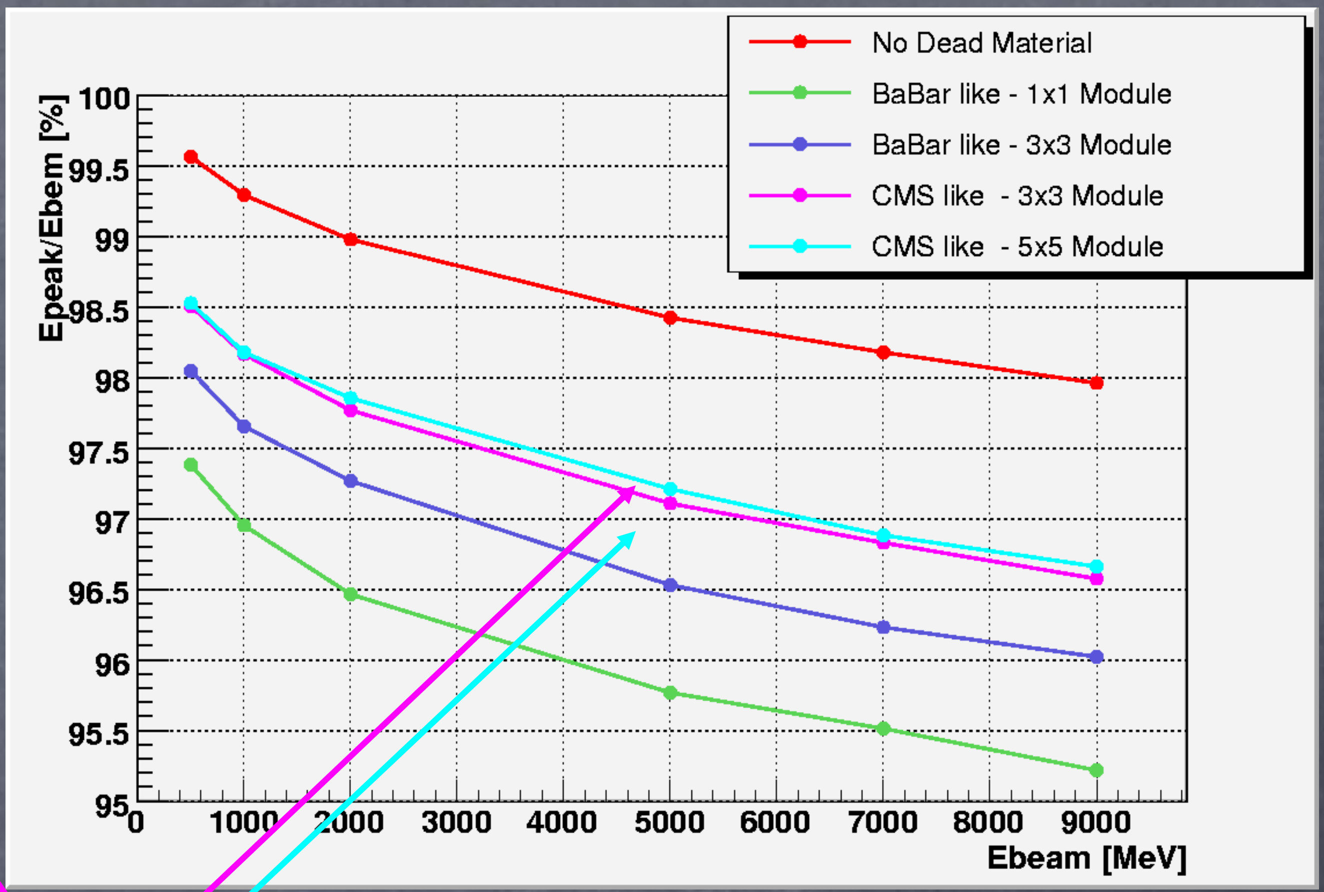
Edep mean :

Fit independent



Most Probable Value:

Fit Function parameter P_1



Xtal - Xtal C-Fiber thickness:

-Inside Module : 400 μm

-Across Module: 600 μm

Very small difference!!!

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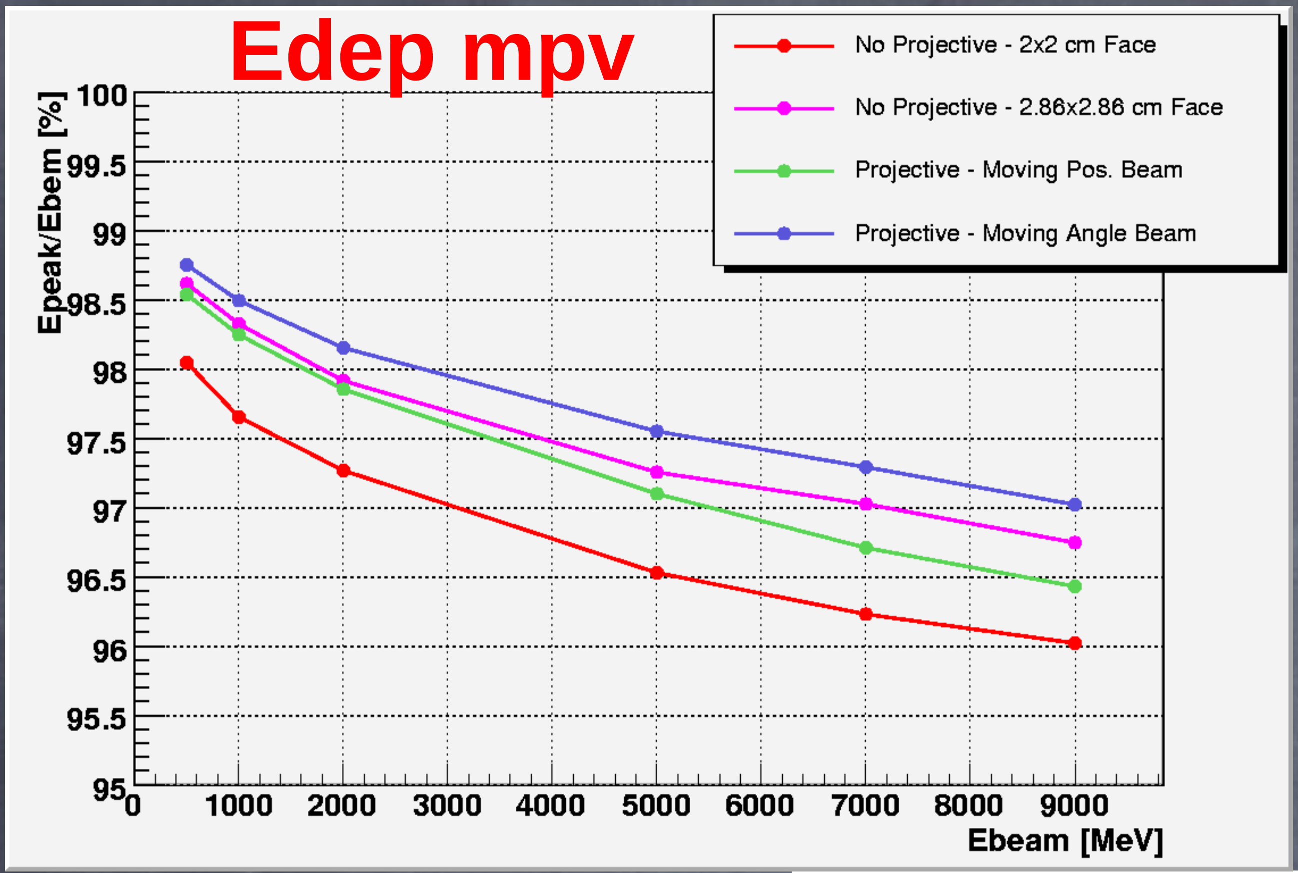
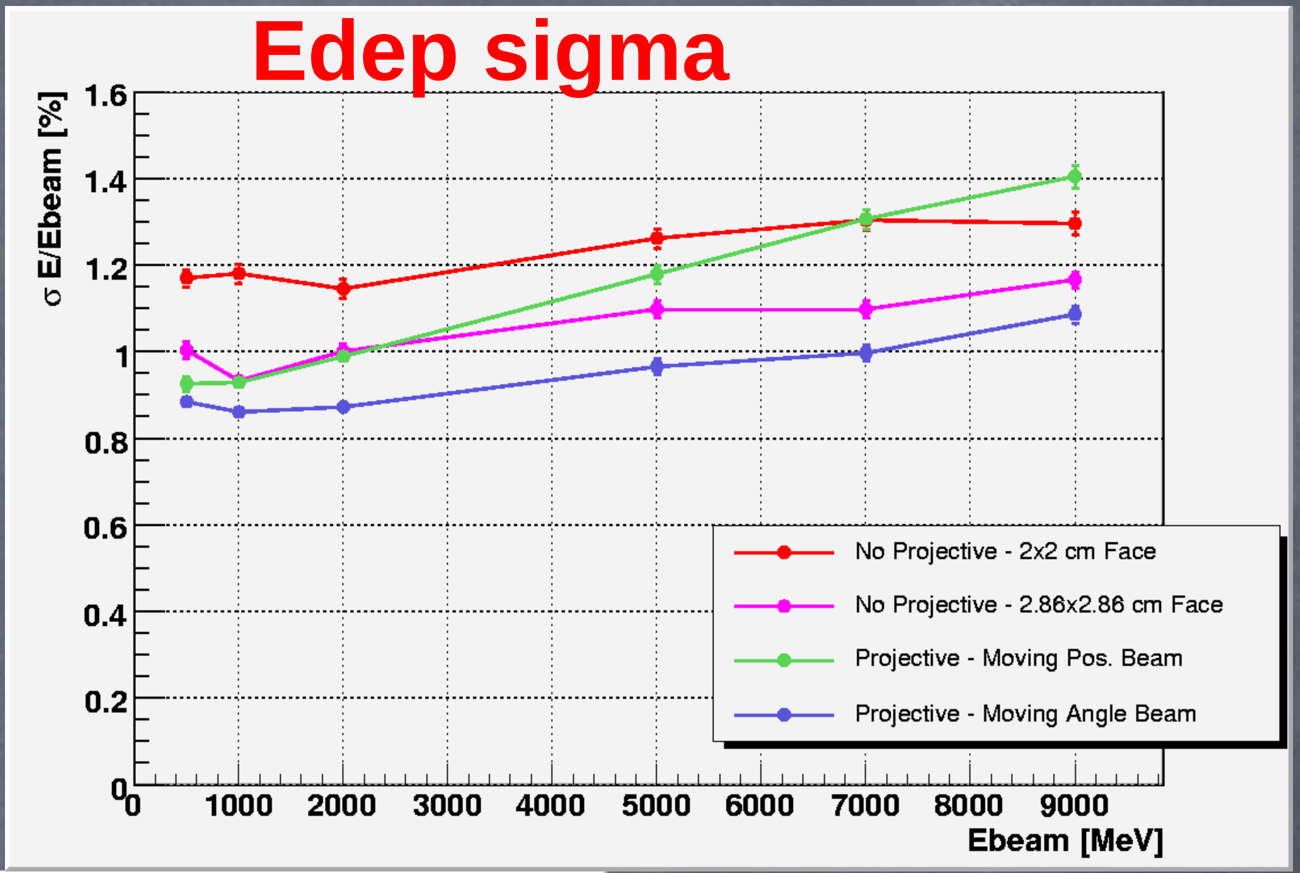
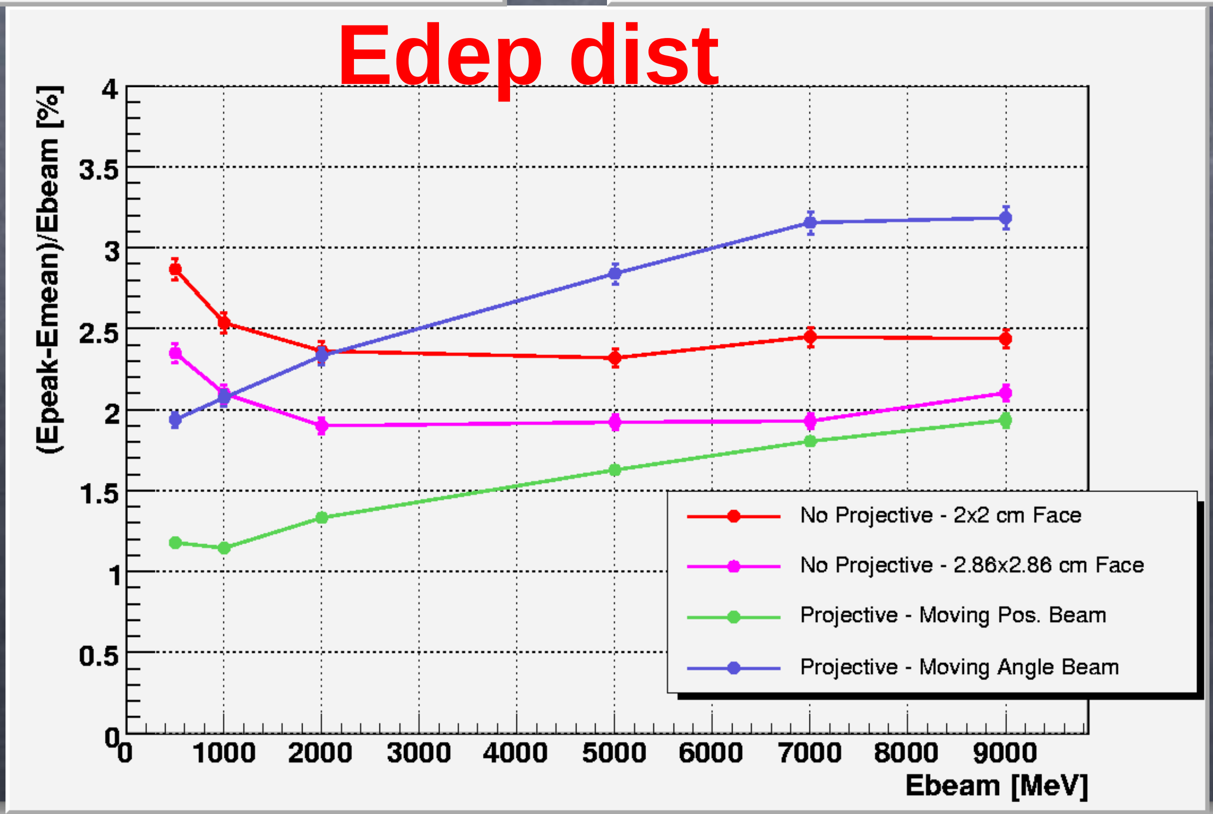
Edep vs Projectivity





Preliminary



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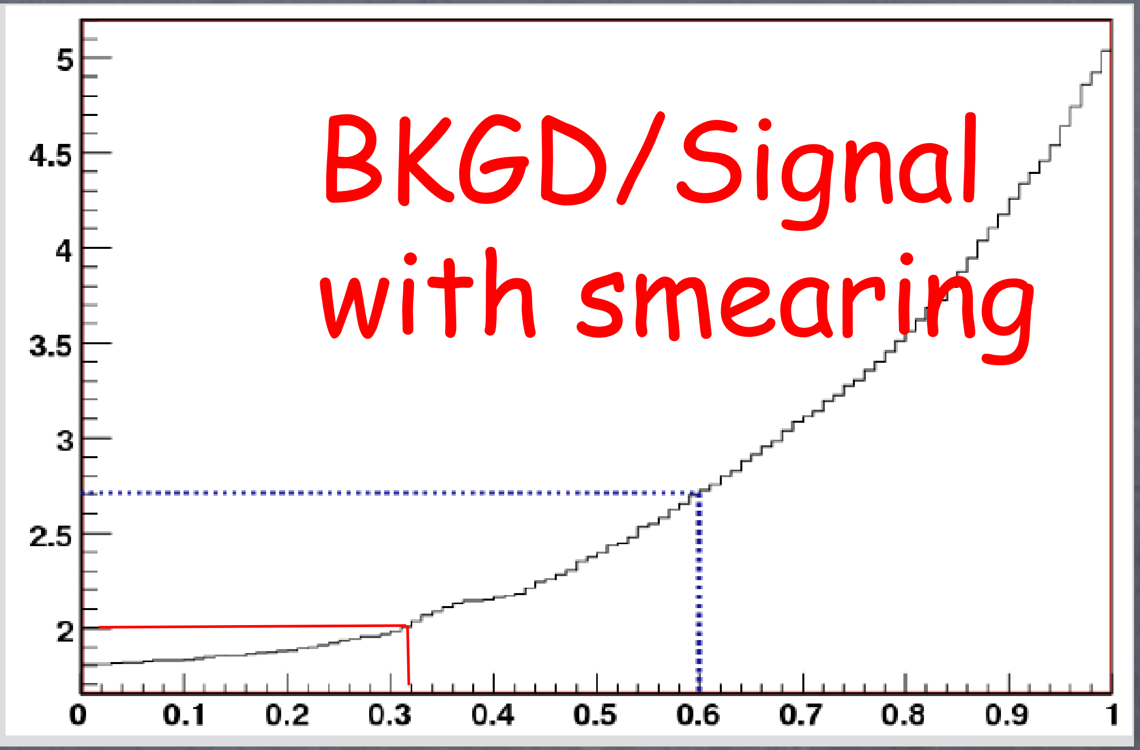
Rear endcap acceptance studies

- Many of the main physics objectives of Super$B$ involve missing energy signatures
  - Use of the recoil technique
    - Excellent reconstruction efficiency for hadronic B decays, especially those involving D^*s
    - Excellent particle ID
      - Hermeticity
- Improving backward calorimeter coverage can pay large dividends in signal/background
- Study using $B \to \tau\nu$ benchmark



Backward polar angle coverage (radians)

M. Mazur