WORKSHOP ON TAU CHARM AT HIGH LUMINOSITY

Electromagnetic Calorimeter Studies: Which options?

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MOTIVATIONS

- input understand which R&D project should be devoted to the development of an electromagnetic calorimeter for a high intensity flavor factory
- Optimizations and studies presented here are sometimes explicitly based on SuperB
  - high luminosity asymmetric e+e- collider
  - Center of mass energy 10.58 MeV, Y(4S) resonance
- Despite this aspect, the developed detector may still have an application in several other environments

TAU-CHARM High Luminosity Factory:

Energy in the range 3.1 – 4.4 GeV (J/Ψ – Ψ(4415) with a peak luminosity of 10^{35} cm^{-2} s^{-1}

80% polarization in the electron beam

Asymmetric energy for boost at IP

TAU-CHARM Factory at lower luminosity (10^{33} cm^{-2} s^{-1}) but mainly B Factories (10^{34} cm^{-2} s^{-1}) and SuperB (10^{36} cm^{-2} s^{-1})can be used as a starting point

MAIN ISSUES:

Machine background

cs

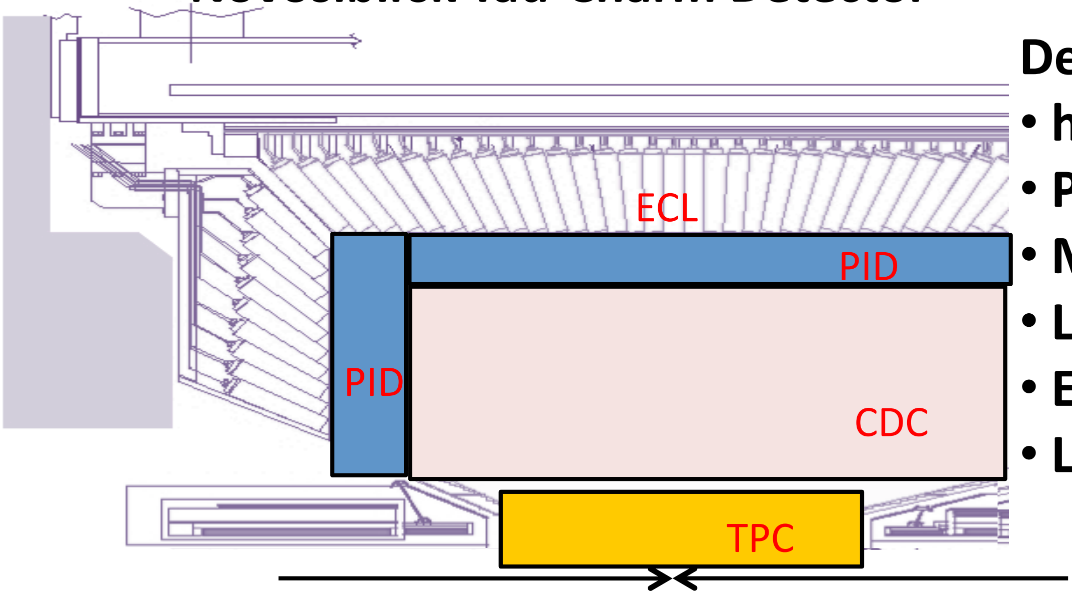
IMPACT ON

Detector segmentation

Radiation hardness

DETECTOR GENERAL CONSIDERATION

Novosibirsk Tau-Charm Detector

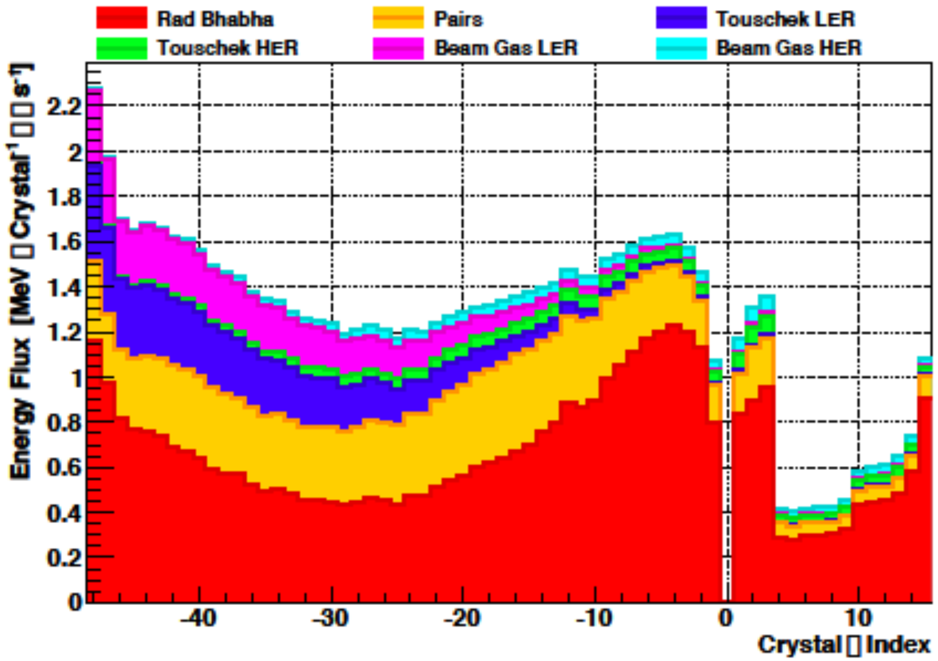


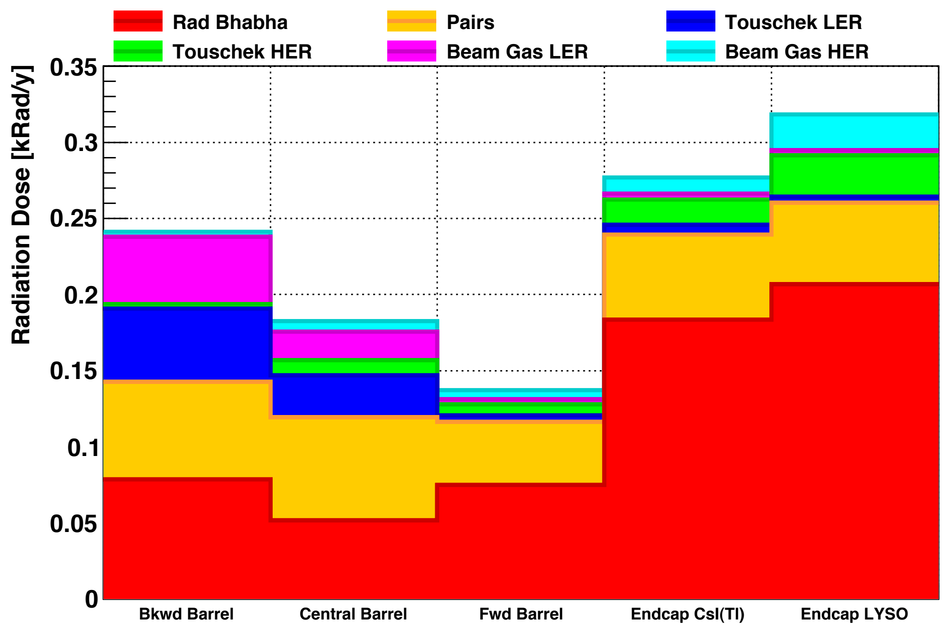
Detector requirements:

- **hermeticity**
- **PID e/μ/π/K separation up to 2 GeV/c**
- **Momentum resolution**
- **Low p_T track efficiency**
- **ECL energy resolution**
- **Low energy (~20MeV) photons efficiency**

Calorimetry at a High Luminosity Tau-Charm Factory: detection of photon's energy and position from 10 MeV up to few GeV with an energy resolution of the order of 2%/√E(GeV) + 1%

BACKGROUND STUDIES AT SUPERB

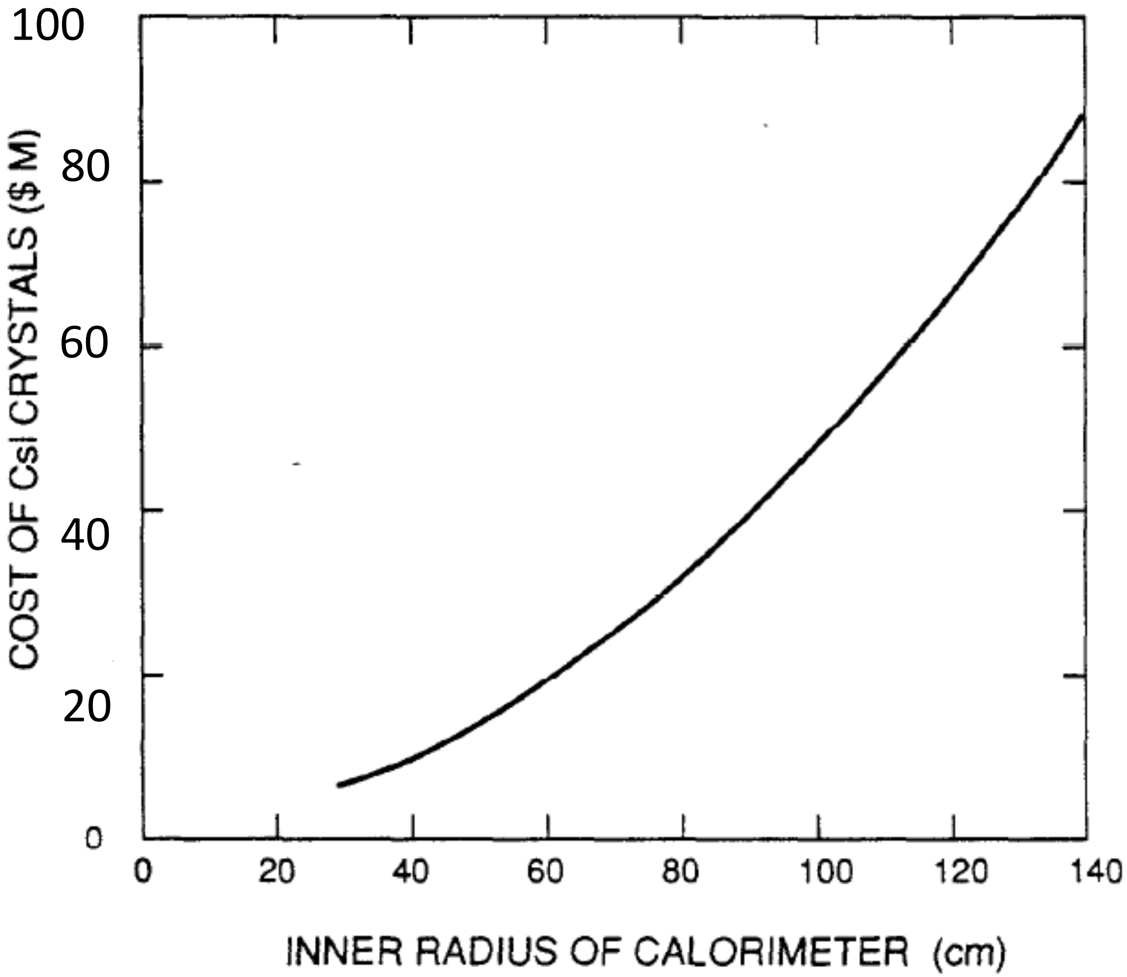




Notice difference in Flux/ crystal between Barrel and FWD due to different type of crystals

Dose is more important in FWD and BCKW regions of the detector

Cost is scaling with the inner radius of EMC



Example for 16 X_0 calorimeter for a crystal price of 4$/cc

Some points should be fixed

- **Interaction Region design**
- **Silicon tracking device design**
- **Dimensions of tracking detector**
- **Magnetic field**

REQUIREMENTS:

- **Thick enough active material to have good energy resolution in wide energy range**
- **Fast scintillator to have small pile-up noise**
- **Good time resolution to suppress beam background**

Crystals comparison

Crystal	NaI(Tl)	CsI(Tl)	CsI	PWO	LYSO(Ce)
Density (g/cm^3)	3.67	4.51	4.51	8.3	7.1
Melting Point (°C)	651	621	621	1123	2050
Radiation Legth (cm)	2.59	1.85	1.85	0.9	1.14
Moliére Radius (cm)	4.8	3.57	3.57	2.0	2.2
Hygroscopicity	yes	slight	slight	no	no
Luminescence (nm)	410	560	420/310	560/420	420
Decay Time (ns)	230	1250	35/6	30/10	45
Light Output (%)	100	165	3.6/1.1	0.3/0.08	80
d(LO)/dT (%/°C)	~0	0.3	-0.6	-1.9	-0.3
Radiation Damage	Yes	10%/ krad	2%/krad	Small	Small

- LYSO Crystals meets all the requirements
- LYSO is very expensive
- R&D campaign for superB started in 2010 with laboratory and beam tests

$$Lu_{2(1-x)}Y_{2x}SiO_5$$

CsI(Tl) very high LO but very high decay time + rad. Hard
Pure CsI very short decay time but very low LO

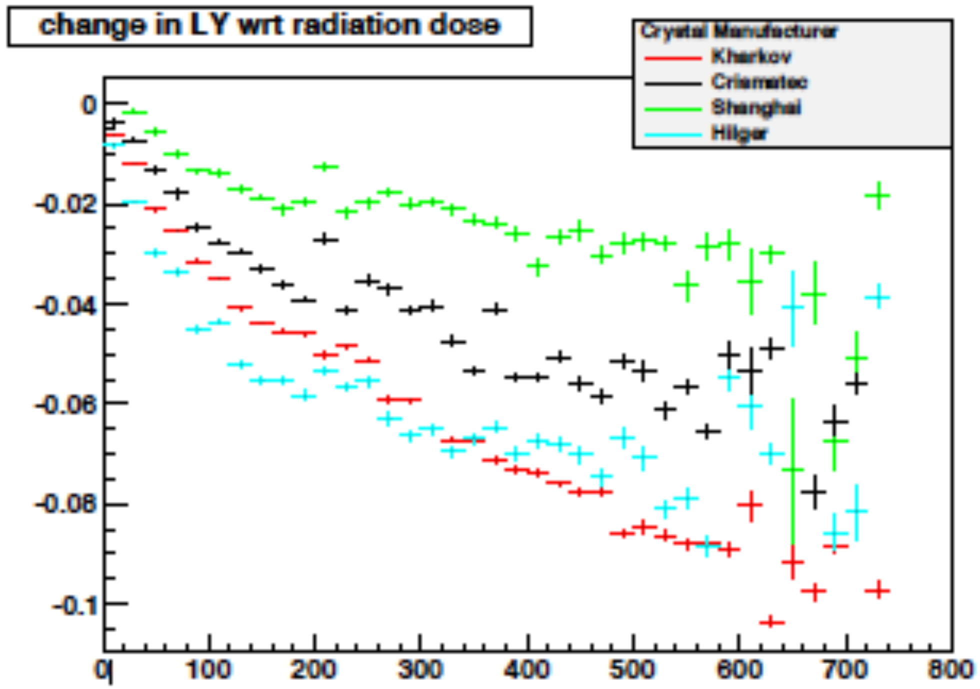
Calorimetry at B-FACTORIES

- Both b-factory experiments of the last decade (BABAR and Belle) use the same kind of electromagnetic calorimeter
  - CsI(Tl) crystals calorimeter
- Main CsI(Tl) characteristic is the very high light yield which means very good performances even at low energy (few GeV)
  - BABAR resolution $$\frac{\sigma(E)}{E} = \frac{2.30}{\sqrt[4]{E(GeV)}} \oplus 1.35\%$$
- How are CsI(Tl) performances in an environment with a luminosity a factor 10 higher?

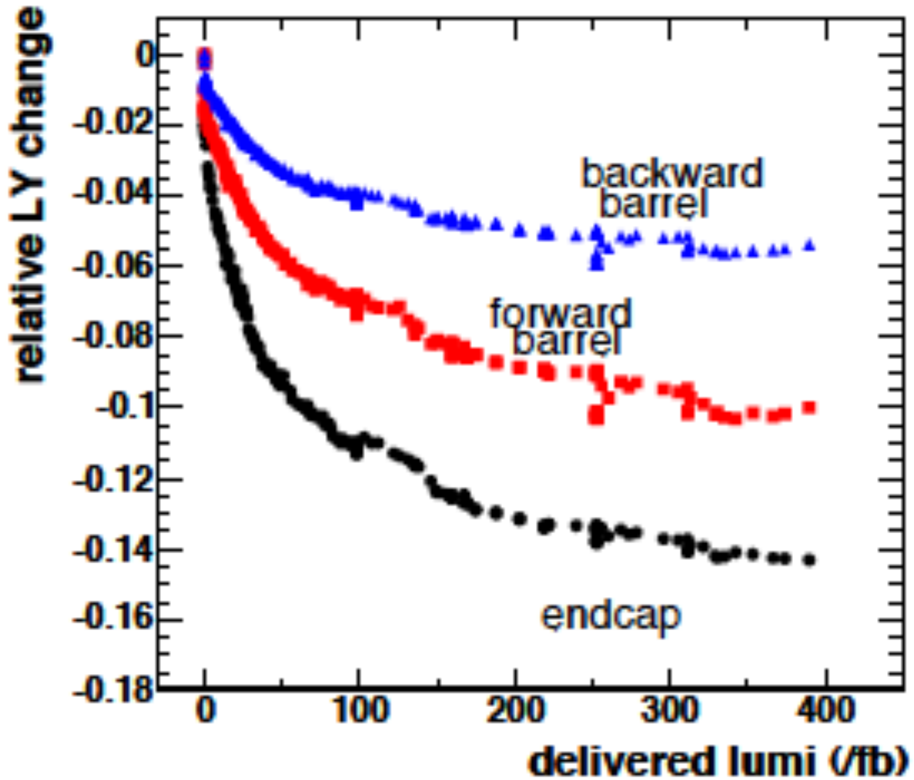
BaBar Calorimeter and future FF

- Asymmetric machine → asymmetric detector
- After 10 years with a Luminosity ~ $10^{34}cm^{-2}s^{-1}$:
  - "Barrel" EMC:
    - Small radiation damage
  - "Forward" EMC:
    - High radiation damage
- In the hypothesis to have a machine running for 10 years at $10^{35}cm^{-2}s^{-1}$:
  - "Barrel" could sustain this rates and radiation damage is not an issue (already studied for SuperB)
  - "Forward" maybe need a detector faster, with finer granularity and with an higher radiation hardness
  - The previous point bring us to the R&D on LYSO and Pure CsI
  - Belle2 will run from 2016 with Belle ECL upgrade for the FWD and BCKW foreseen 2018-2020
  - Backward ECL depends if machine a-symmetric or not, on required performance (SuperB Pb-scintillator calorimeter, BELLE2 same as FWD)

LY change for the BaBar Calorimeter

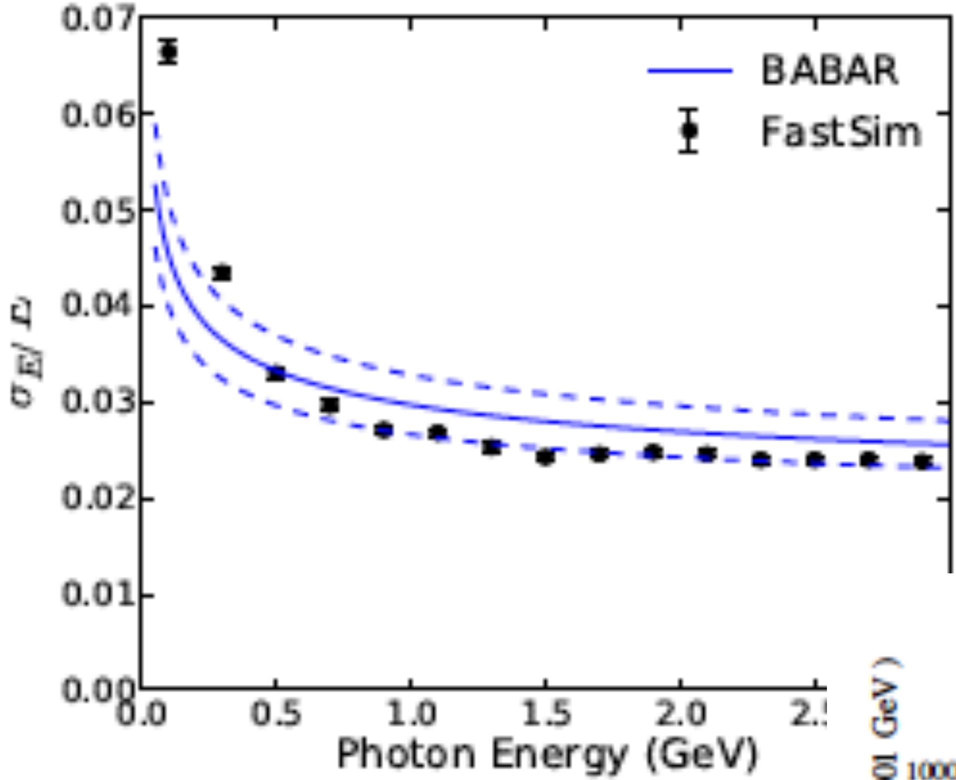


(b) Change in light yield versus dose (Rad.), for barrel forward



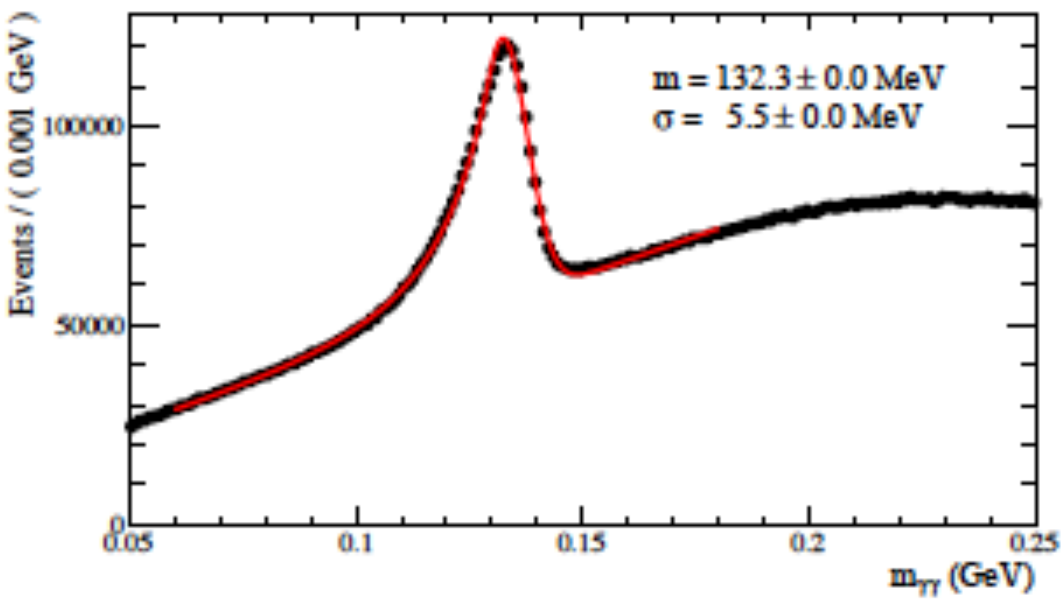
Depends on manufacturer.
Total LY decrease about 10%

BaBar Barrel performance at SuperB rates



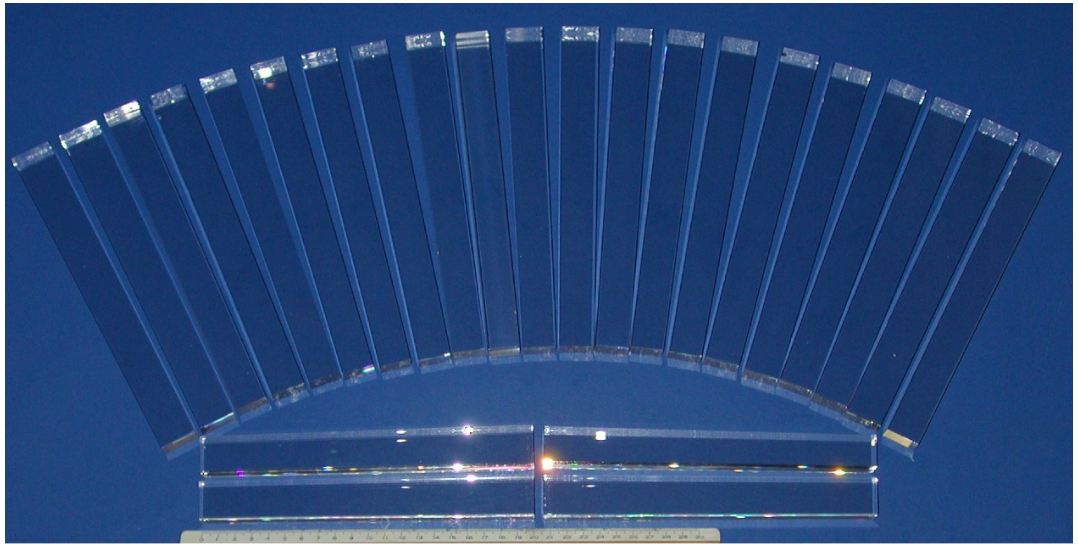
Shorter integration (100 ns) and shaping time (500 ns) w.r.t BaBar in order to reduce background contribution → Performance are similar to the BaBar calorimeter in terms of resolution

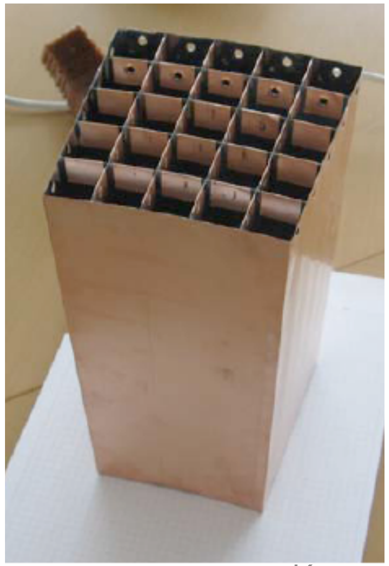
γγ mass resolution for π^0 events with SuperB simulated background



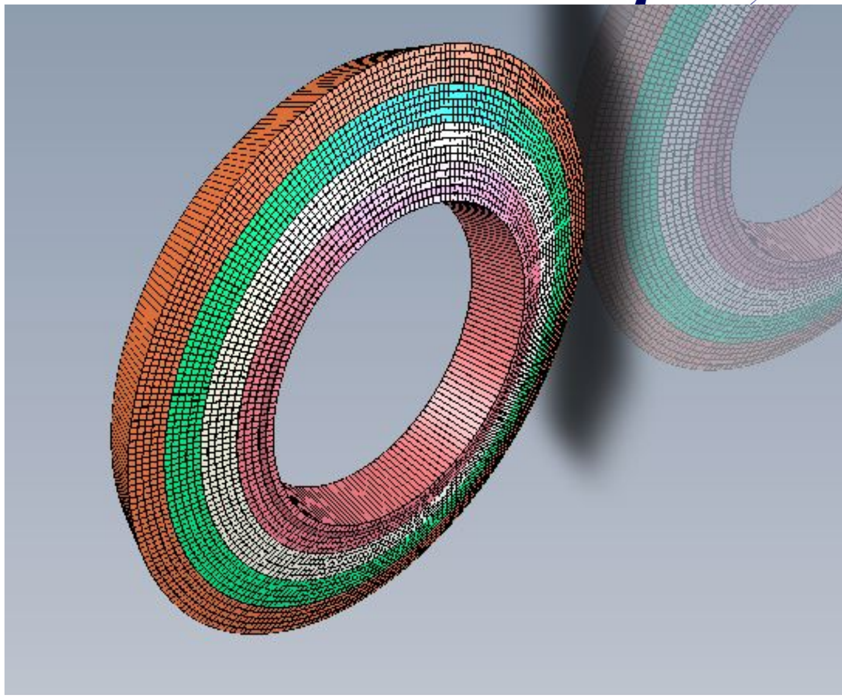
LYSO Matrix prototype

- **A 5x5 matrix of LYSO crystal was built in order to perform beam tests**
  - **3 different LYSO producer**
    - **Saint-Gobain (SG) 12 crystals**
    - **SIPAT 10 crystals**
    - **SICCAS 3 crystals**
  - **Crystal are 20cm long (~17.4X_0)**
  - **Glass fiber alveolar structure**
- **Before beam tests all crystals have been studied in laboratory**

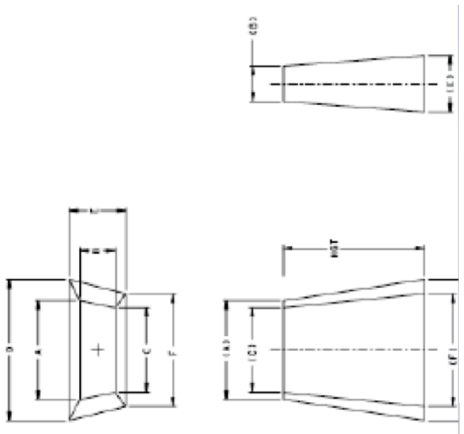


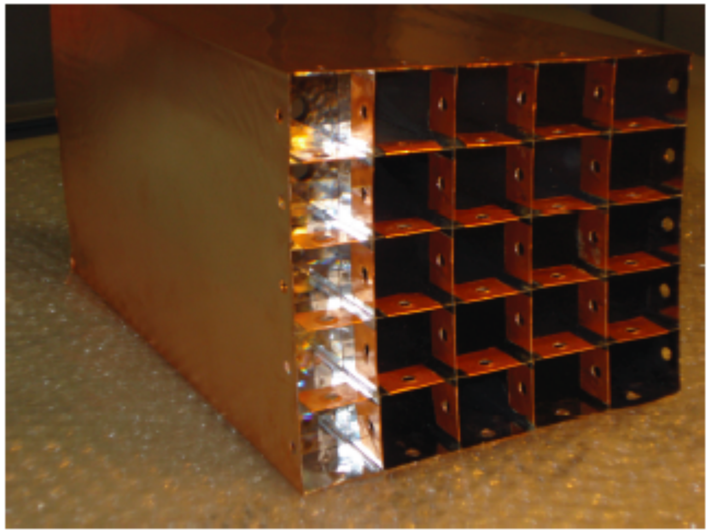


Geometry and mechanics design



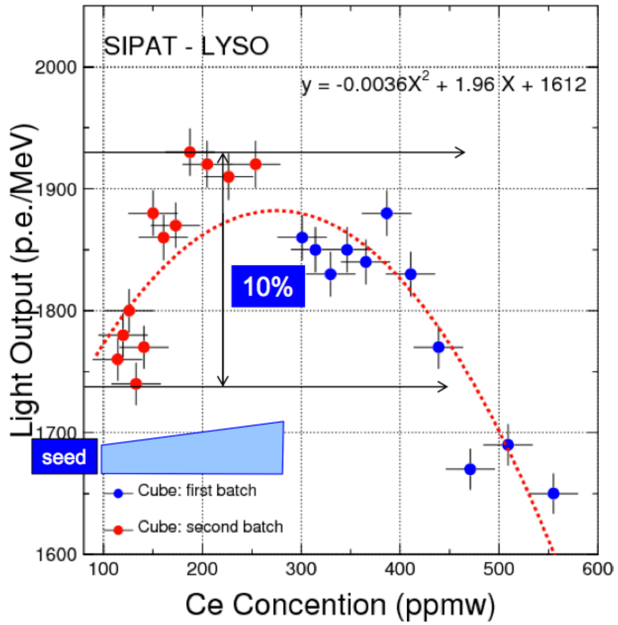
- General Layout
  - 20 rings of crystal arranged in 4 groups of 5 layers each
  - Each group of 5 layers arranged in modules 5x5
- Crystal dimensions
  - Approx 2x2 cm^2 front face and 2.5x2.5 cm^2 back face
  - 20cm long (~$17.5X_0$)
- Two mechanical structure prototypes (5x5 matrix) made by RIBA (Faenza, Italy)
  - Beam Test
  - Mechanical test



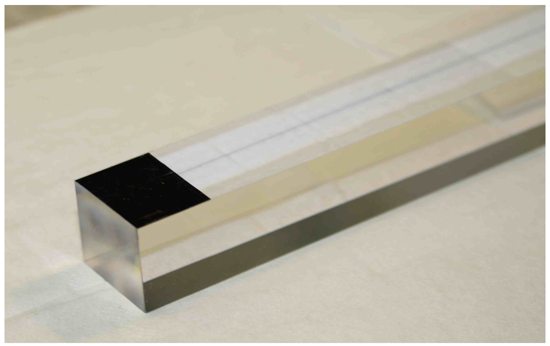


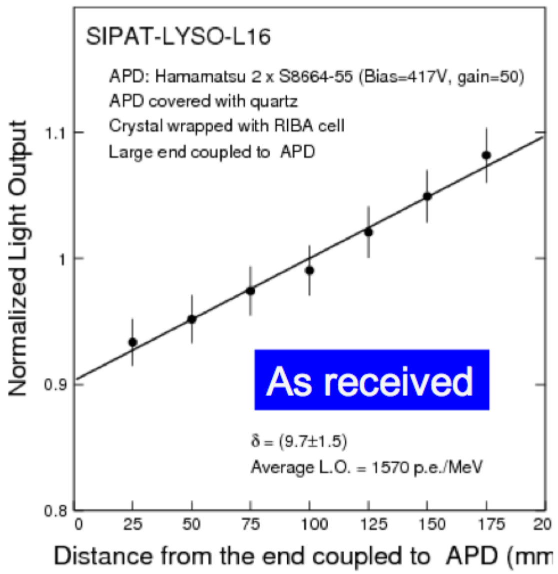
Light Output uniformity

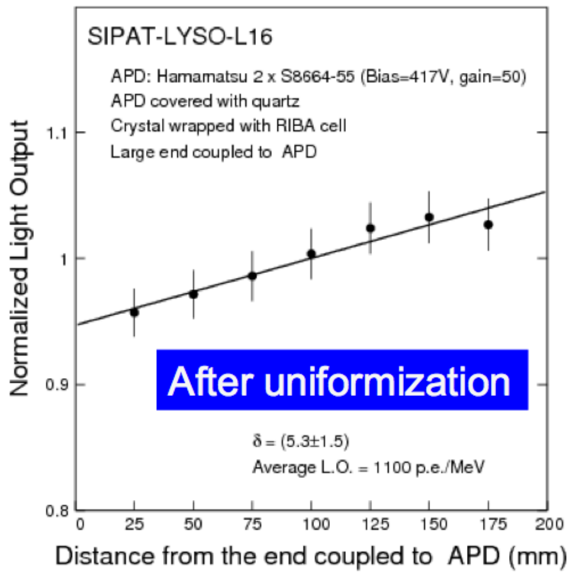
- **Light output non-uniformity related to Ce concentration along crystal**
- **Significant non-uniformity impacts on energy resolution**
- **Uniformization with 15mm black band painted on the opposite side of readout**
  - **Pro: Fast and reversible**
  - **Con: ~30% of light loss**



R. Zhu, EMC SuperB Meeting February 2011

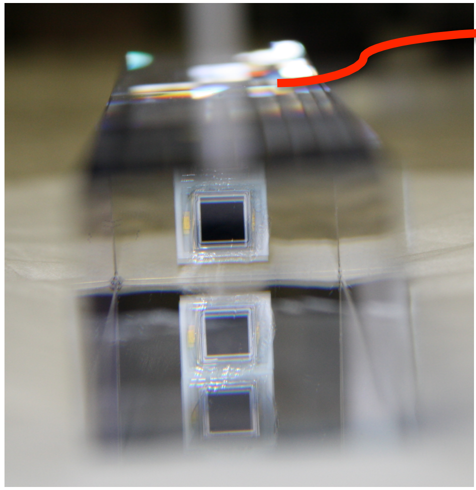


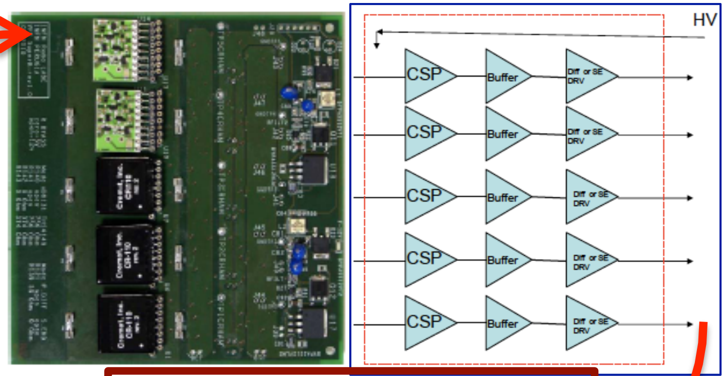




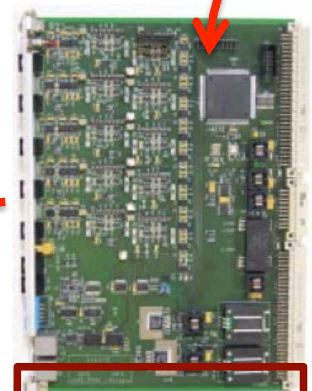
Front End Electronics

- **Sensor:**
  - 5x5 mm^2 Hamamatsu S8664 APD
- **Very Front-End:**
  - Custom made board with commercial Cremat CSP (1.4V/pC)
- **Shaping Amplifier:**
  - Custom VME board with commercial Cremat Shaper (100ns)
- **DAQ:**
  - Caen V1720 250MHz differential digitalizer

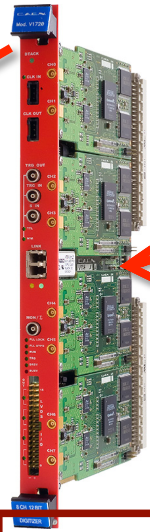




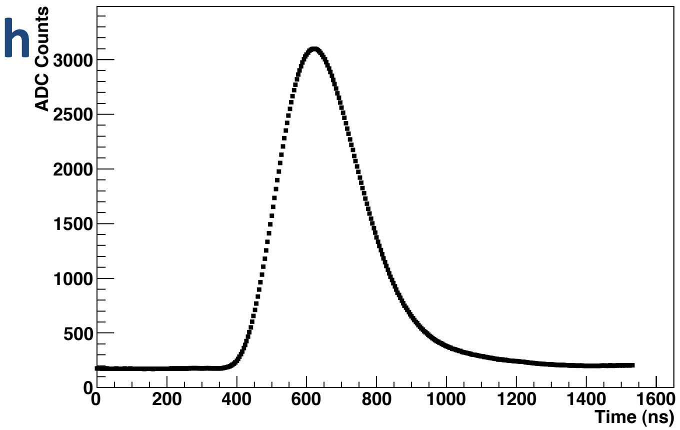
Very Front-End Board



VME Shaper Board

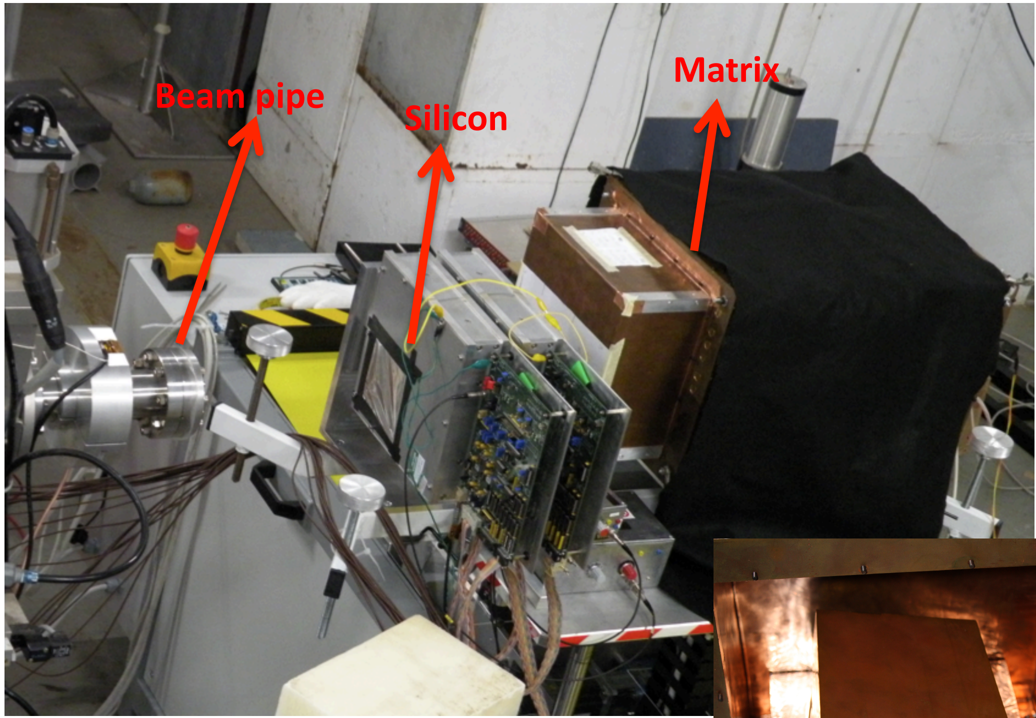


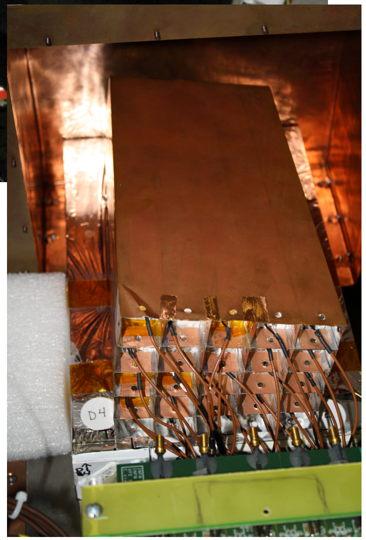
VME Digitalizer



Beam Test at BTF Frascati

- Beam Test Facility @ LNF.
  - 50-500 MeV
  - 50Hz with 1-10^9 e^-/spill
- Higher gain in read out chain wrt CERN test beam (~3)
- Silicon beam telescope:
  - Single-side 228µm strip pitch
  - 2 planes x-y
  - Active area 8.75x8.75 cm^2





- Data:
  - 5 energies: from 487MeV to 99 MeV
  - 3 different positions

Beam Test analysis and energy reconstruction

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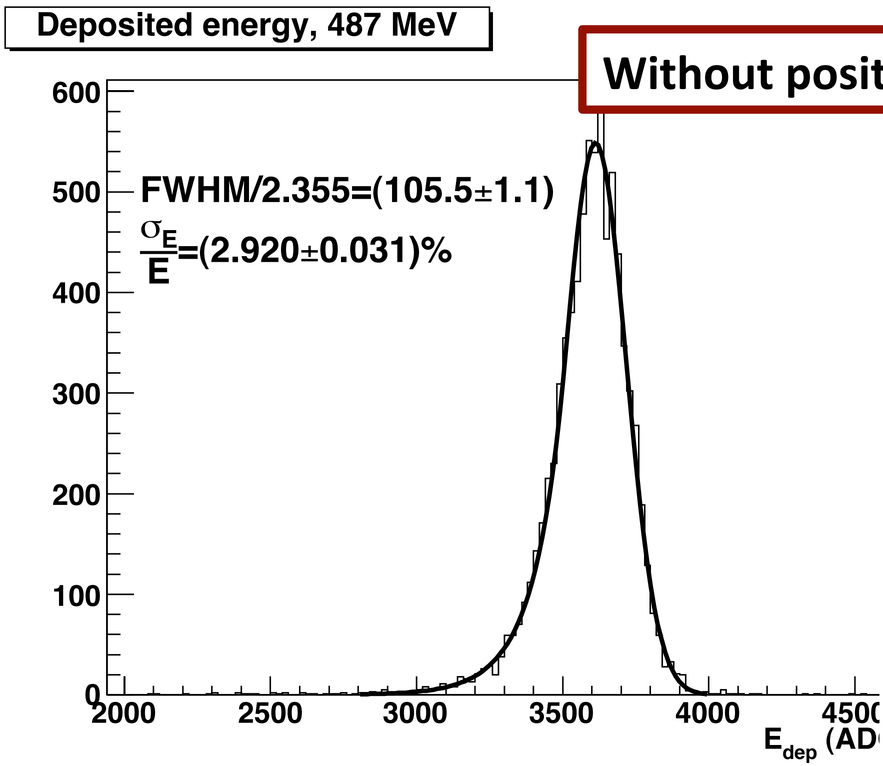
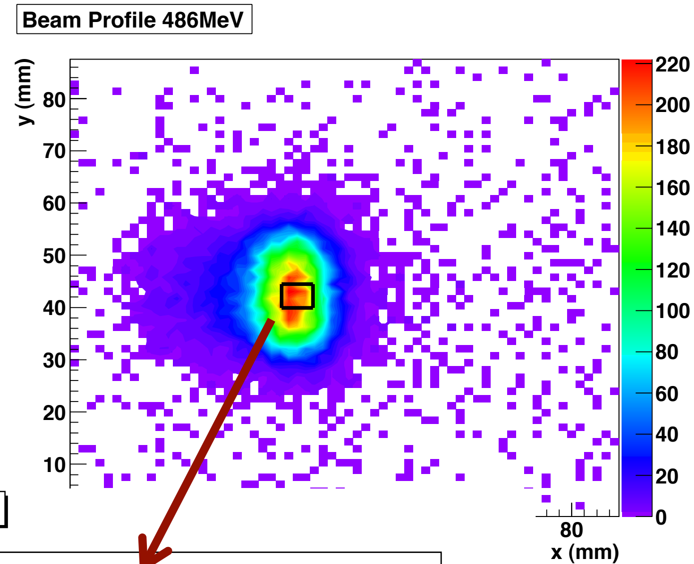
INFN
Istituto Nazionale di Fisica Nucleare

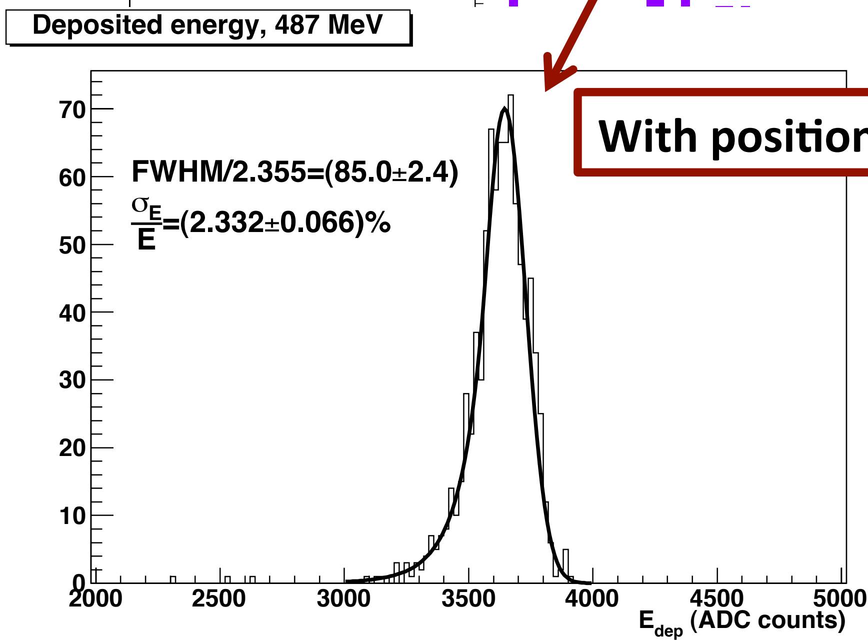
- Ex : 487 MeV total reconstructed energy

Without position selection





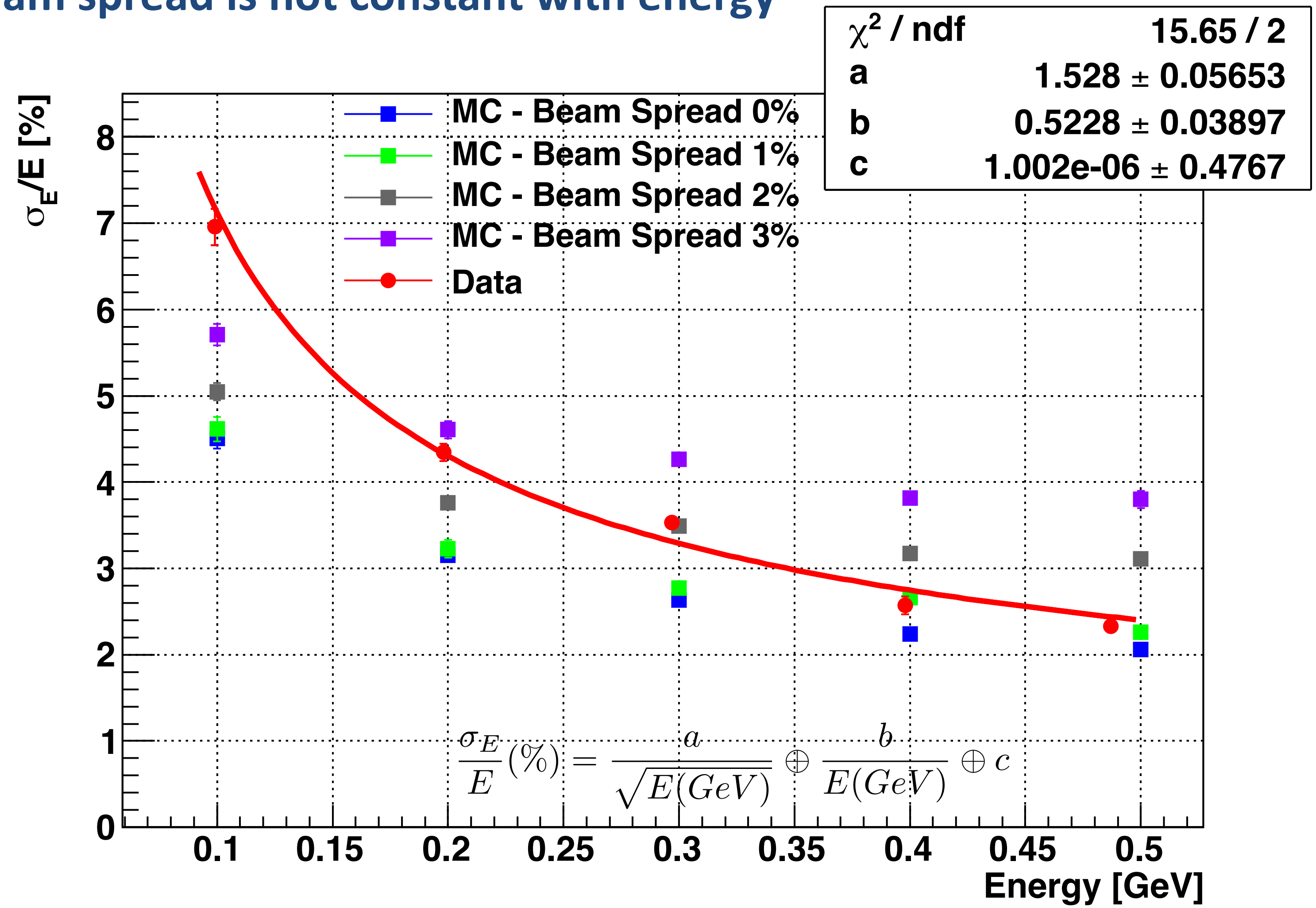
With position selection



- Channel intercalibration
  - RMS minimization (e^- events)
  - Cosmic muons

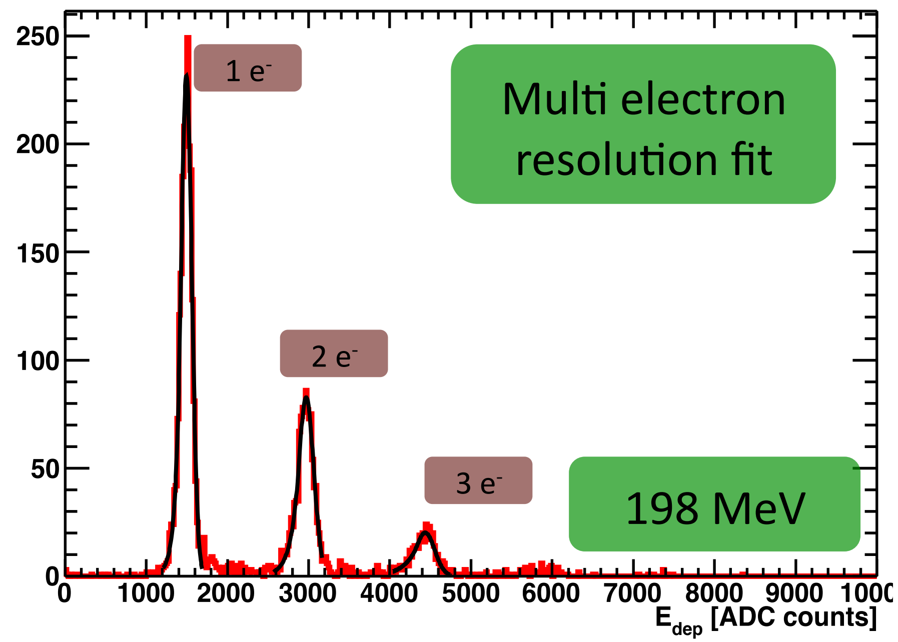
Beam Test analysis: results

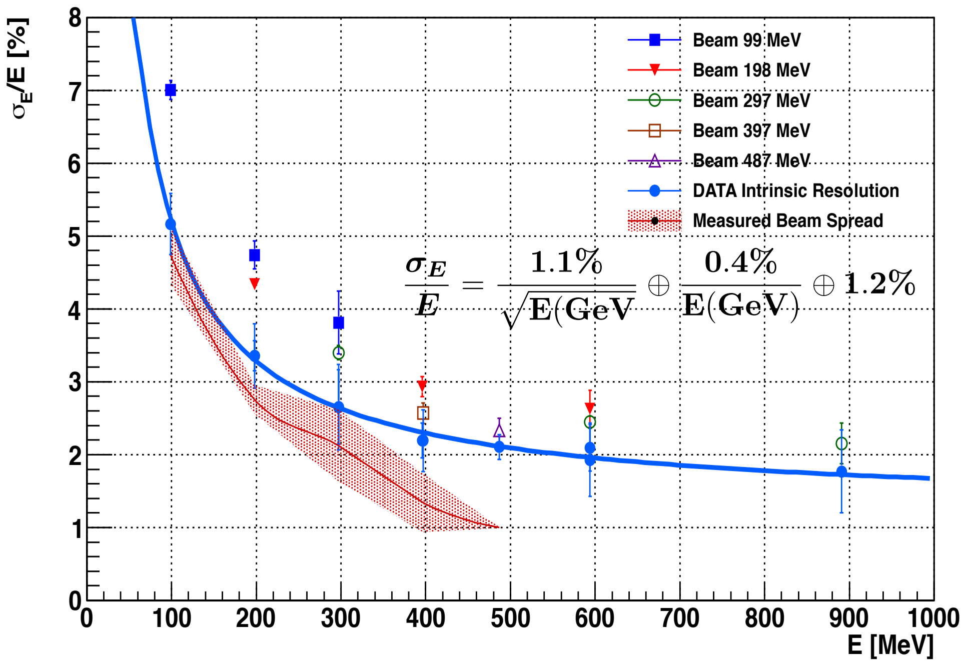
- **Beam energy spread is not precisely know**
- **(estimation ~1%@500MeV)**
  - **MC test by changing the beam spread**
  - **Beam spread is not constant with energy**



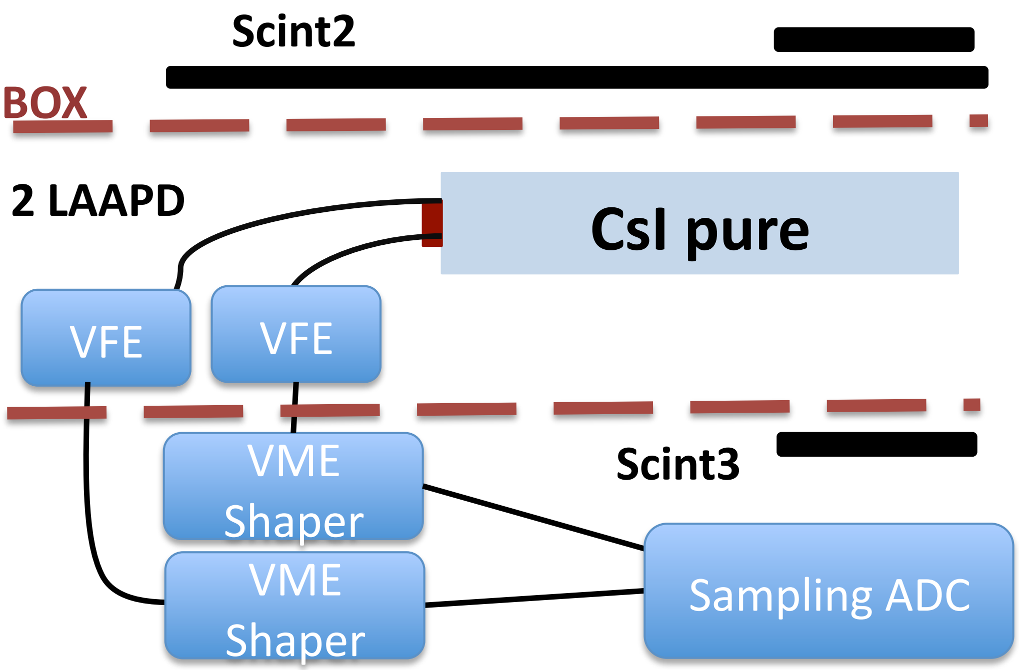
Beam Test analysis: beam spread extraction

- Extract BS directly from data using multi particle events
  - Assume difference in resolution between N e- with energy E and 1 e- with energy NxE is due to different beam energy spread
  - Obtain beam spread and matrix resolution from minimization





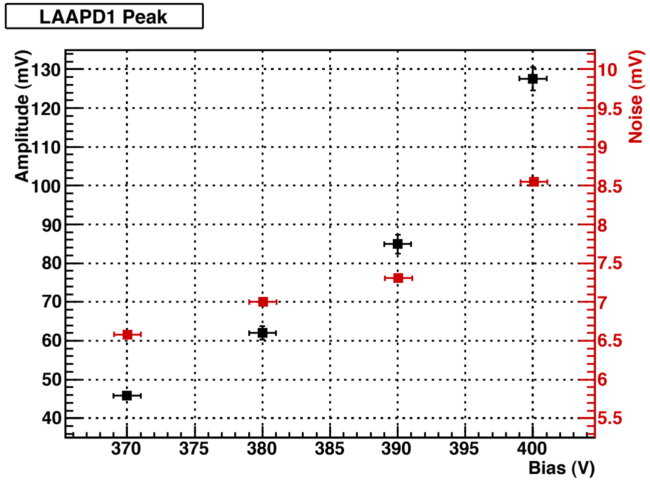
New R&D on pure CsI crystals for Belle2 upgrade

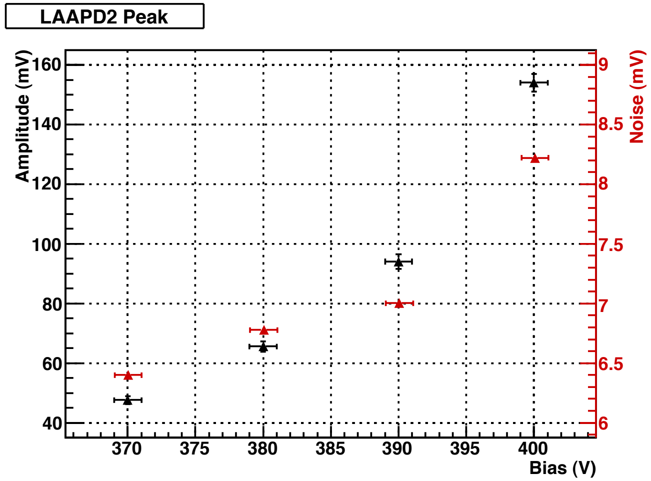


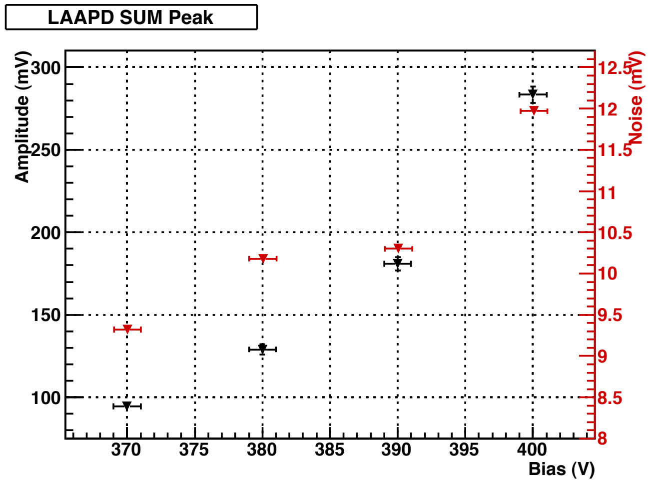
Idea is to replace the FWD and BCKW ECL of Belle2 experiment with pure CsI crystal calorimeter. One possibility for the photodetector is Large Area APD (LAAPD)

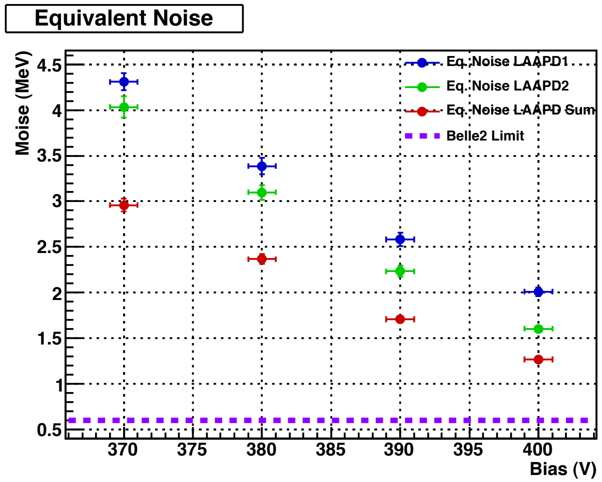
- **DAQ with TB system (BOX + VFE + SHAPER + V1720)**
  - **Cremat CSP CR-111 : 1.4V/pC**
  - **Cremat Shaper : 100ns**
- **Trigger: Scint1 – Scint2 – Scint3 coincidence**
  - **Same cosmics (which trigger) don't go inside crystal completely**

First results on signal and noise level









- Signal is increasing with applied voltage, but also noise.
- These devices have a very large capacitance which increase the noise level
- Best equivalent noise level obtained at the moment is 1.3 MeV.
- to have good performance in terms of resolution our request is a noise level of about 0.5 MeV

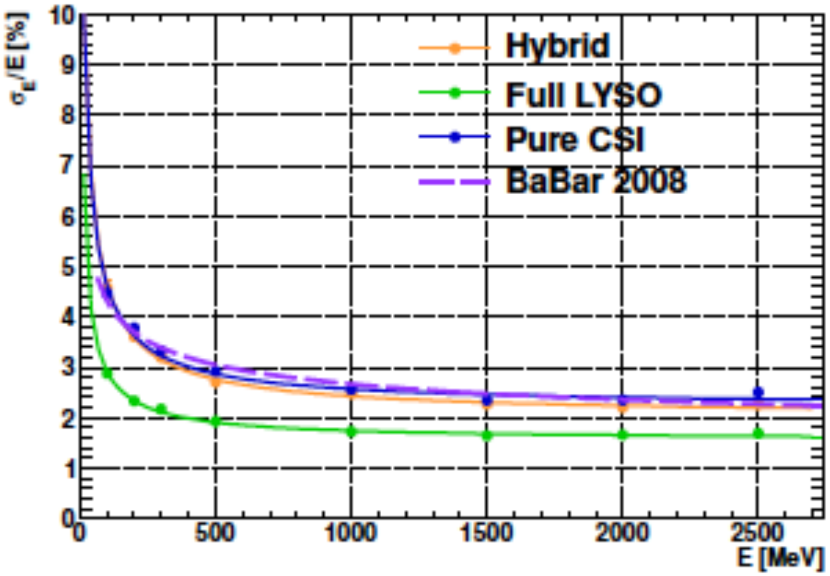
New APD with signal enhanced in the UV region (Pure CsI emission peak 310 nm) have to be tested, they have a smaller capacitance and about 60% QE in the region of interest w.r.t. 20% of the used ones. Test Beam of 4X4 crystals in November at BTF

Hybrid solution was proposed for SuperB FWD EMC

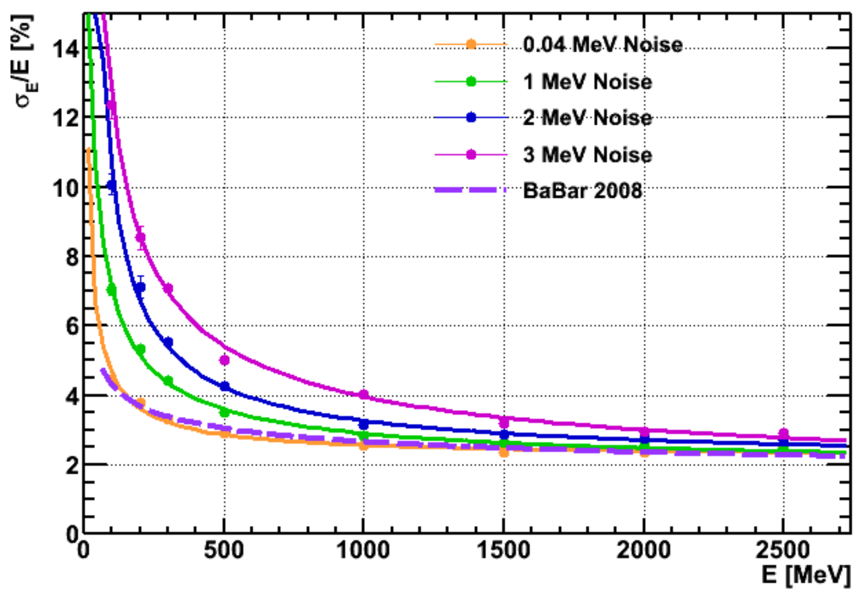
Considering:

- cost of the LYSO
- required performance compared to the Barrel ones
- rad hardness resistance for the duration of the exepriment
- possibility of upgrade

→Hybrid solution (LYSO inner rings + CsI(Tl) outer rings) was adopted for the FWD



Pure CsI for different noise level



Conclusions

- Dedicated studies on the Tau Charm are necessary
    - background simulation
    - design of the IR
    - design of the detector and definition of the envelopes for each sub-det
- CsI(Tl) option (BaBar and Belle calorimeter)
    - is a good solution for the barrel region
    - could be a a possible solution in the FWD and BCKW but need to be studied
- Pure CsI crystals are a good option R&D is already advanced, some more is needed
- LYSO is in my opinion a “too performant” solution compared to the cost, it is related on the option proposed for the Barrel calorimeter