Review of Calorimetry Session Posters

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CALTECH

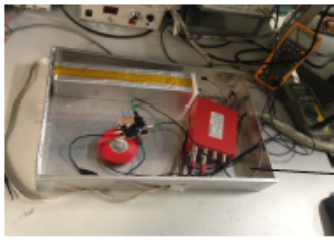
13th PISA MEETING ON ADVANCED DETECTORS
29 MAY, 2015

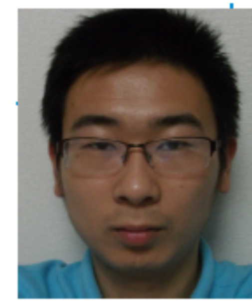
Calorimetry poster contributions

TITLE	PRESENTER	AREA
Research of pure CsI crystal readout by APD for ECL end cap of BELLE II	Jin (Tokyo)	Monolithic
Time performances and irradiation test of CsI crystals readout by MPPC (Mu2E)	Donghia (LNF)	Monolithic
Response of a Close to Final Prototype for the Barrel of the PANDA EM Calorimeter to Photons at Energies below 1 GeV	Rosenbaum (Gießen)	Monolithic
Energy and time resolution for a LYSO matrix prototype of the Mu2e experiment	Giovannella (LNF)	Monolithic
Studies of an array of PbF2 Cherenkov crystals with large-area SiPM readout (g-2)	Venanzoni (LNF)	Monolithic
The Calibration system of the Muon g-2 Experiment at Fermilab	Venanzoni (LNF)	Monolithic
Calorimetry at CMD-3 detector	Shebalin (BINP)	Monolithic
An LH target for the calibration of the MEG and MEG-II liquid xenon calorimeter	Nicolo' (PI)	Calibration
Performance results of a high-granularity electromagnetic calorimeter	Zhang (Utrecht)	Sampling
Upgrade of the ATLAS Tile Calorimeter for the High luminosity LHC	Usai (Arlington UT)	Sampling
The design of a photodetector unit of a new Shashlyk EM calorimeter for COMPASS II	Chirikov-Zorin (JINR)	Shashlyk
A new-concept calorimeter for future neutrino beams based on Kaon tagging	Longhin (LNF)	Shashlyk
Test beam results with a sampling calorimeter of CeF3 scintillating crystals and W absorber plates for calorimetry at the HL-LHC (CMS)	Gelli (R)	Shashlyk
Radiation Damage Induced by 800 MeV Protons in Fast Crystal Scintillators (CMS)	Zhang (Caltech)	Rad hardness
Test beam results of microchannel plates in "ionisation mode" for the detection of single charged particle and electromagnetic showers	Meridiani (ROMA1)	Timing
Microchannel Plate Phototubes Used as a Fast EM Shower Maximum Detector	Ramberg (Fermilab)	Timing
A high precision calorimeter for the CeSOX experiment	Papp (TUM)	Calorimeter

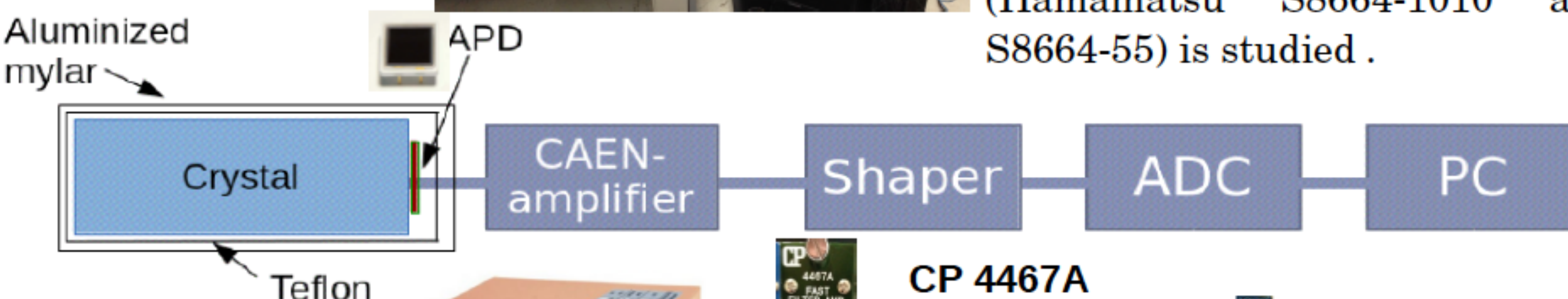
Research of pure CsI crystal readout by APD for ECL end cap of BELLE II

Yi-Fan Jin





A scintillation counter consisting of a pure CsI crystal (6x6x30 cm^3) and avalanche photodiodes (Hamamatsu S8664-1010 and S8664-55) is studied .



charge pre-amplifier
CAEN A1422B045F3
45 mV/MeV (1 V/pC)

CP 4467A
Fast Shaping Amplifier (NIM)
τ = 20—500 ns

Hoshin C008
16ch peak hold ADC (CAMAC)

Belle II, as upgrade of Belle, aims at searching for New Physics with 40 times higher luminosity. Fast pure CsI scintillation crystals (τ = 30 ns) have been proposed to cope with the high luminosity. Silicon avalanche photodiodes are considered as one of the upgrade options.

At the University of Tokyo, we studied a counter consisting of a pure CsI crystal (6x6x30 cm^3) and avalanche photodiodes (Hamamatsu S8664-1010 and S8664-55) .

The shot noise, thermal noise and additional noise were measured under shaping time ranging from 20 nanoseconds to 500 nanoseconds respectively. The total equivalent noise charge (ENC) has been calculated and compared with the value measured experimentally. The ENC is suppressed at theoretical limit.

With help of the cosmic muons, the equivalent noise energy (ENE) of the counter with several APDs has also been measured. Further studies on wrapping materials, optical grease have been done to enhance the light collection efficiency. Optimal scheme was established.

The application of new wavelength shifting (WLS) material, matching the emission spectrum of pure CsI and APD's quantum efficiency perfectly, increase the signal substantially.

We confirm that by using several APDs coupling to pure CsI scintillation crystal a innovative WLS, the required electronic noise of 0.5 MeV can be obtained.

Yi-Fan Jin

Homogeneous crystal calorimeters

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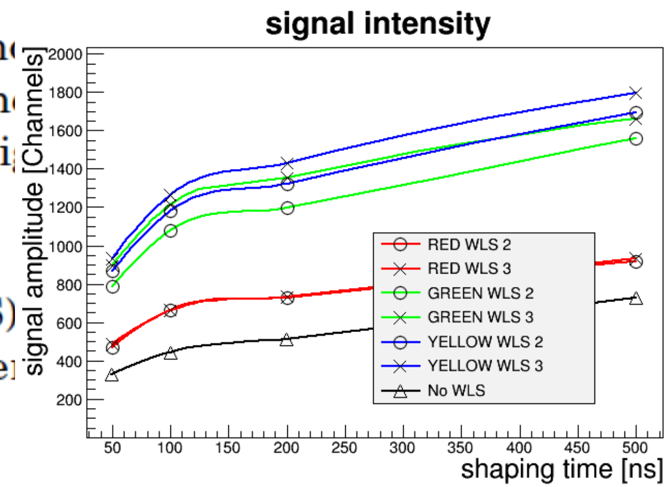

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innovative WLS, the required electronic noise of 0.5 MeV can be obtained.

Yi-Fan Jin

Characterization and performances of pure CsI crystals for the Mu2e experiment

M. Cordelli, R.Donghia, S. Giovannella, F.Happacher, S. Miscetti, I. Sarra, S.R.Soleti

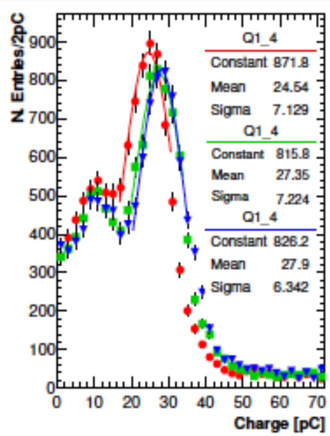
Pure CsI crystals tested:
- 2 3x3x20 cm³ from Siccas
- 2 new 3x3x20 cm³ from Optomaterial
- 4 new 2.9x2.9x23 cm³ and 7 3x3x20 cm³ from ISMA

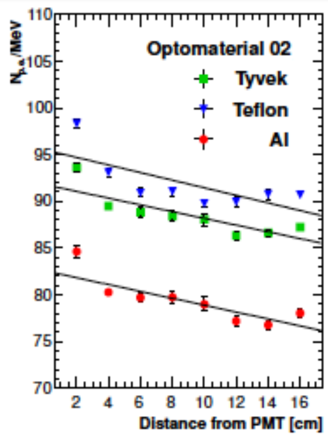
Setup for LY and uniformity measurements:
- ^{22}Na source placed between crystal and small tag crystal
- PMT readout

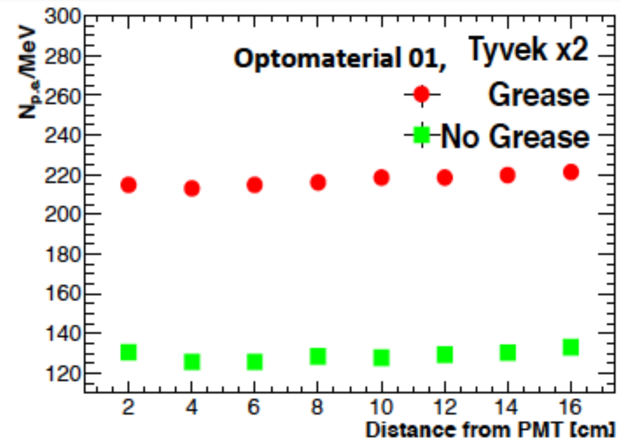
LY →

$$N_{p.e.}/MeV = \frac{Q}{Q_{e^-} G_{PMT} E_\gamma} = \frac{\mu_Q[pC]}{1.6\times 10^{-7}\cdot 3.8\cdot 0.511 MeV}$$

Uniformity → slope of the linear fit on the LY normalized to the central value as function of the source distance from PMT







Best performances obtained with Tyvek or Teflon configuration: **~ 90 - 130 N p.e/MeV**

Optical **grease** coupling adds an **improvement about 70%**

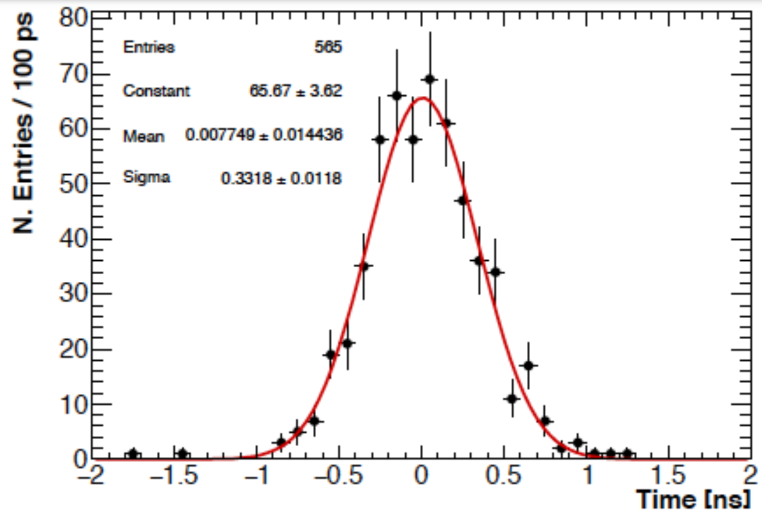
Uniformity has an average of about **0.5%/cm**

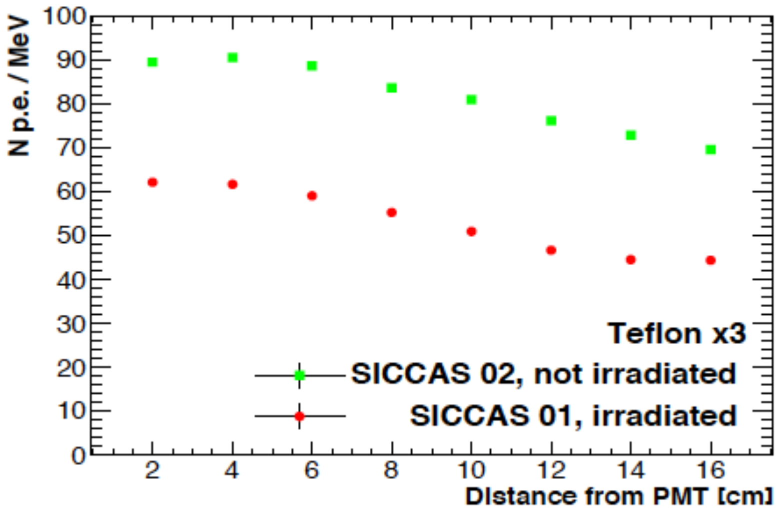
Homogeneous crystal calorimeters

Characterization and performances of pure CsI crystals for the Mu2e experiment

Timing resolution @ 22 MeV (energy deposited by a MIP in a CsI crystal)

	No Grease	Grease
Tyvek	~ 450 ps	~ 330 ps
Teflon	~ 410 ps	~ 330 ps





SICCAS crystals tested at CALLIOPE (ENEA g irradiation facility)

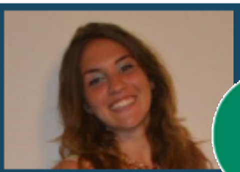
- ^{60}Co source (1.25 MeV)
- **Total dose: 90 krad**

After irradiation:

- Crystals wrapped with Teflon
- PMT-Crystal coupled in air without grease

Unchanged LRU
LY decrease of 33%

Raffaella Donghia
LNF – INFN and Roma Tre University
nf.infn.it

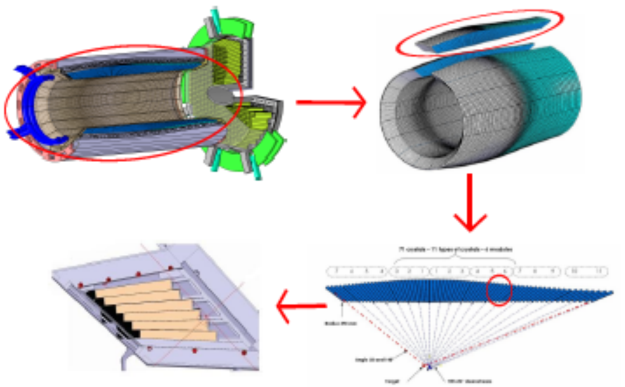


Rafaella Donghia

Response of a Close to Final Prototype for the $\overline{\text{P}}$ANDA Electromagnetic Calorimeter to Photons at Energies below 1 GeV

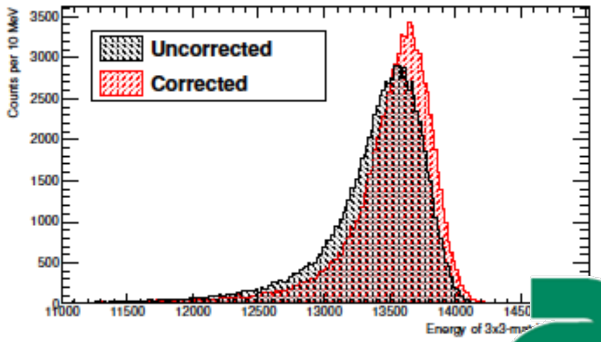
PROTO60: First step to the final design of the barrel EMC

- 60 tapered PWO crystals
- readout: single LAAPD (1 cm^2 quadratic)
- low-noise low-power preamplifier
- operatin at -25 °C



Higher order energy correction

- significant loss and leakage inbetween crystals
- correcting deposited energy with $\ln(E_1/E_2)$-method

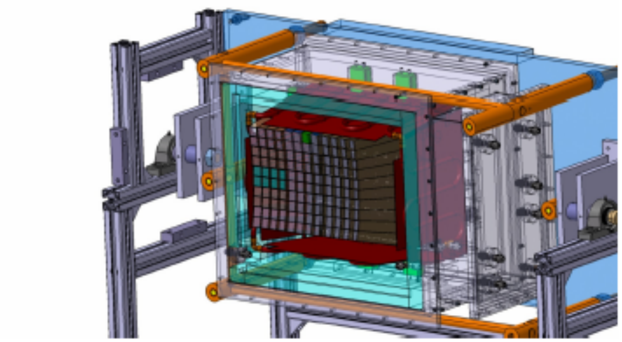


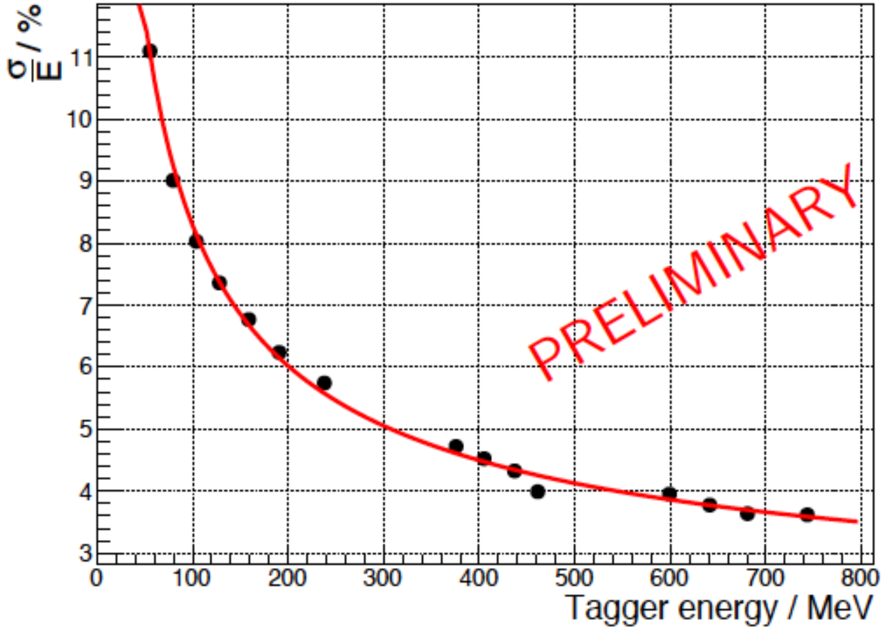
Christoph Rosenbaum

Response of a Prototype for the $\overline{\text{P}}$ANDA EMC

PROTO120

- 120 PWO crystals of the 3 most tapered types
- close to final mechanics and cooling
- readout: 2 LAAPDs per crystals ($1 cm^2$ rectangular)
- custom designed APFEL ASIC





Author: Christoph Rosenbaum

Christoph Rosenbaum

Response of a Prototype for the $\overline{\text{P}}$ANDA EMC May 29th, 2

Homogeneous calorimeters

Energy and time resolution for a LYSO matrix prototype of the Mu2e experiment

N. Atanov,[a] V. Baranov,[a] F. Colao,[b] M. Cordelli,[b] G. Corradi,[b] E. Danè,[b] Yu.I. Davydov,[a] K. Flood,[c] S. Giovannella,[b] V. Glagolev,[a] F. Happacher,[b] D.G. Hitlin,[c] M. Martini,[b,d] S.~Miscetti,[b] T. Miyashita,[c] L. Morescalchi,[e,f] G. Pezzullo,[e,g] A. Saputi,[b] I. Sarra,[b] S.R. Soleti,[b] G. Tassielli,[h] V. Tereshchenko[a]

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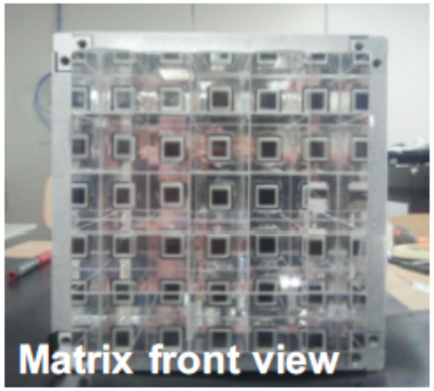
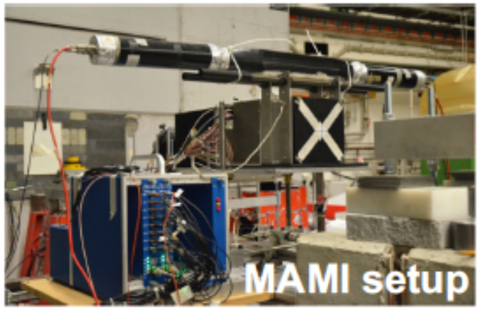
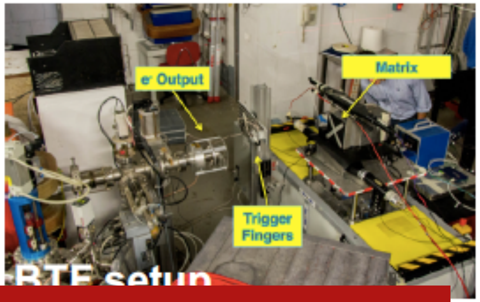
- 5 × 5 matrix prototype with (30 × 30 × 130) mm^3 LYSO crystals from SICCAS
- Each crystal wrapped with a 60 mm thick layer of super reflective ESR-3M
- Crystal readout: (10 × 10) mm^2 S8664 Hamamatsu APD
- APDs optically connected to crystals with Saint-Gobain BC-630 grease
- Custom made FEE providing both amplification and regulation of bias voltage



Matrix transverse and longitudinal dimensions: 2.8 R_M, 11.2 X_0





Matrix tested with:

- **tagged photons with energy 20-380 MeV, with few permil precision (MAMI, Mainz)**
- **e^+, e^- in the energy range: 100-500 MeV (BTF, Frascati) Trigger provided by two orthogonal (0.6 × 1 × 5) cm^3 fingers read out by (3 × 3) mm^2 SiPM**

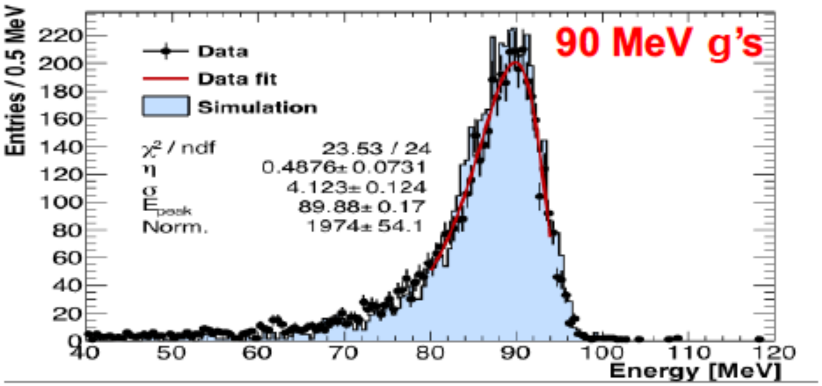
- Data acquired with CAEN waveform digitizer V1720, 250 Msps, 12 bit resolution, 0-2 V dynamic range
- APDs illuminated by green laser (l = 530 nm) through 250 mm Ø fused silica optical fibers. Laser pulsed syncronized with an external trigger with a frequency of ~ 1 Hz.
- Equalization of matrix channels at 10% level with minimum ionizing ... es
- Calibration of cell response with beam (450 MeV @ BTF, 92.5 Me... firing on each cell center

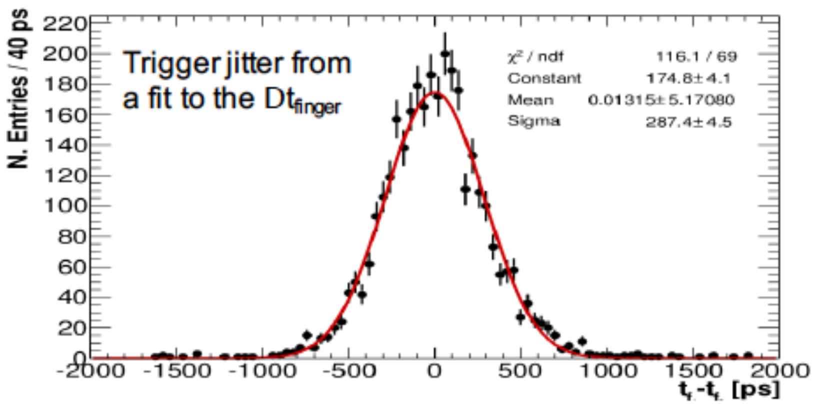
Simona Giovannella

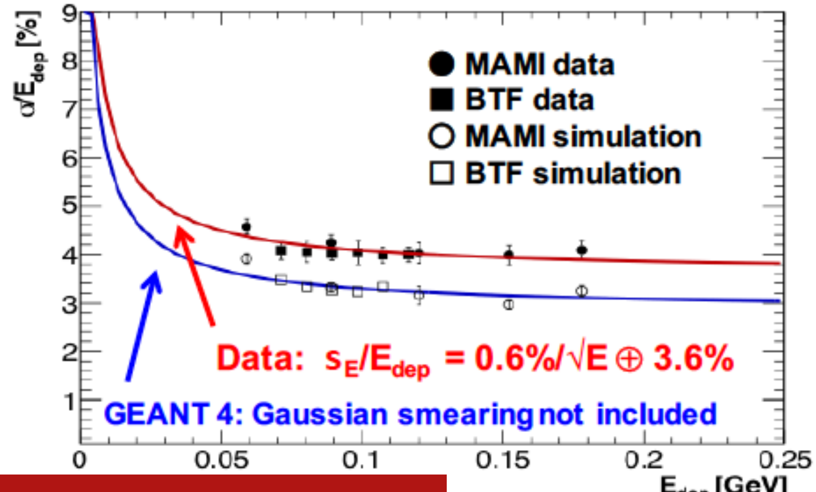
Energy and time resolution for a LYSO matrix prototype of the Mu2e experiment

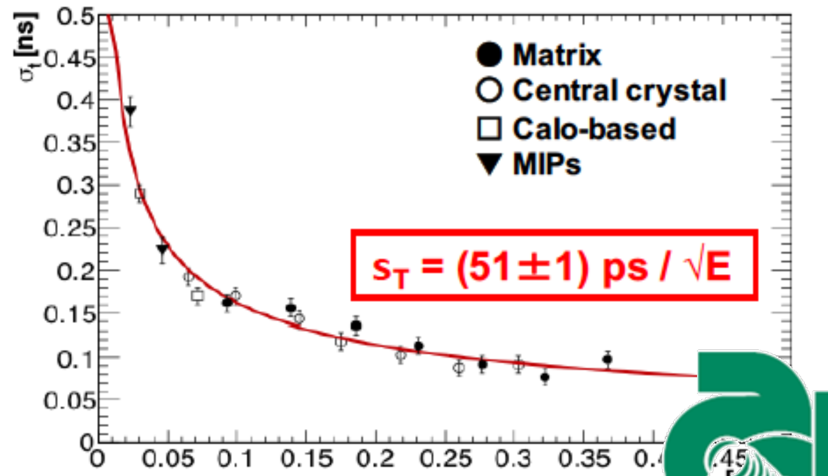
Homogeneous calorimeters

- Total energy spectra compared with GEANT4 MC simulation, with 2 mm beam spread included. Additional 2.6% Gaussian smearing needed in MC to describe data
- Time resolution measured @ BTF using both central crystal and the whole matrix. Trigger jitter subtracted. Minimum ionizing particles used to exploit the low energy region









Simona Giovannella

Homogeneous calorimeters

Studies of an array of PbF_2 Cerenkov crystals with large-area SiPM readout

A. T. Fienberg[a], L.P. Alonzi[a,1], A. Anastasi[c,g], R. Bjorkquist[b], D. Cauz[d,i], R. Fatemi[j], C. Ferrari[c,f], A. Fioretti[c,f], A. Frankenthal[b], C. Gabbanini[c,f], L. K. Gibbons[b], K. Giovanetti[l], S. D. Goadhouse[k], W. P. Gohn[j], T. P. Gorringe[j], D. W. Hertzog[a], M. Iacovacci[e,h], Kammel[a], J. Kaspar[a], B. Kiburg[a,2], L. Li[m,n], S. Mastroianni[e], G. Pauletta[d,i], D. A. Peterson[a], D. Počanić[k], M. W. Smith[a], D. A. Sweigart[b], V. Tishchenko[j,3], G. Venanzoni[c], T. D. Van Wechel[a], K. B. Wall[a], P. Winter[a,4], K. Yai[a,o]

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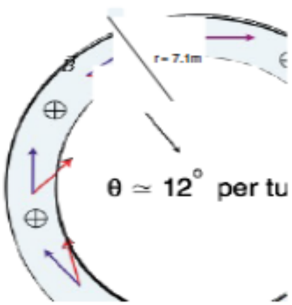
Principle of the Muon g-2 experiment

A tale of two frequencies

Polarized μ's are injected into the $(g\text{-}2)_\mu$ storage ring where a strong (1.45T) magnetic field both traps the muons and causes their spin vector to precess.

The momentum turns at the cyclotron frequency while the spin rotates due to the combination of Larmor and Thomas precession.



momentum rotation $\omega_c = \frac{eB}{\gamma mc}$

spin rotation $\omega_s = \frac{geB}{2mc} + (1-\gamma)\frac{eB}{\gamma mc}$

The difference of these frequencies is independent of γ and proportional to the anomalous magnetic moment

$$\omega_a \equiv \omega_s - \omega_c = \frac{a_\mu eB}{mc}$$

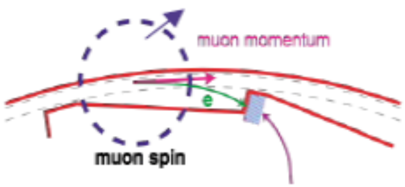
To measure a_μ, the task is to measure the difference frequency ω_a and the magnetic field B, which can be absolutely tied to the precession frequency of free protons ω_p.

Measuring ω_a

The parity-violating weak decay of the muon leads to a strong correlation between it's decay-time spin vector and the emitted positron direction.

24 calorimeter stations symmetrical around the storage ring measure the direction and energy of accepted positrons to observe ω_a over 10 muon lifetimes.

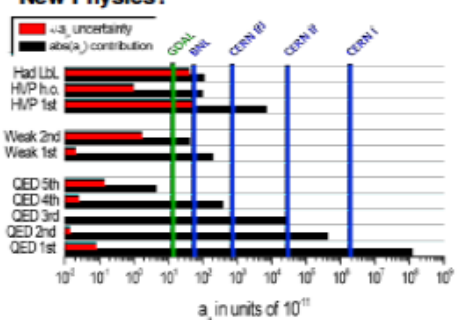
$$\mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$$

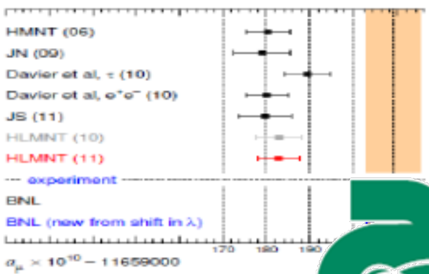


Measuring ω_p

Precise knowledge of the magnetic field measured by Nuclear Magnetic Resonance (NMR) probes can be related to the absolute field experienced by the muons through the precession frequency of free protons ω_p.

New Physics?



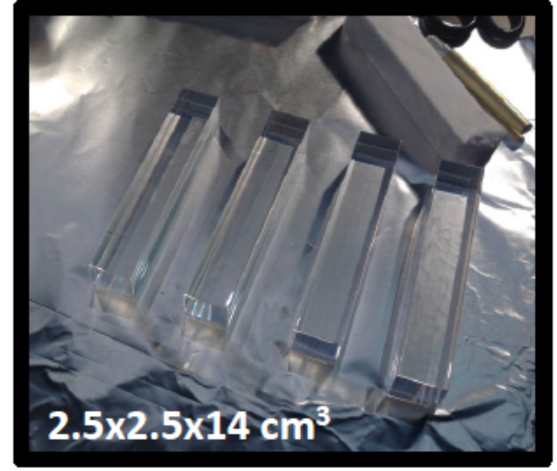


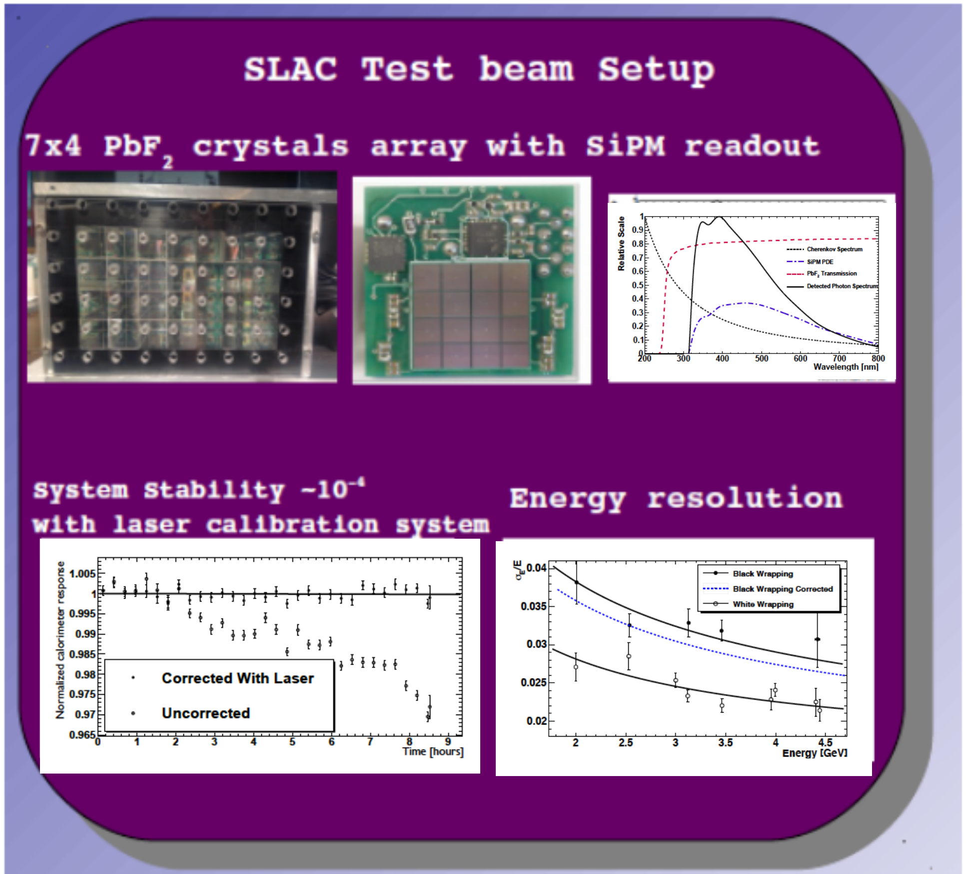
Graziano Venanzoni

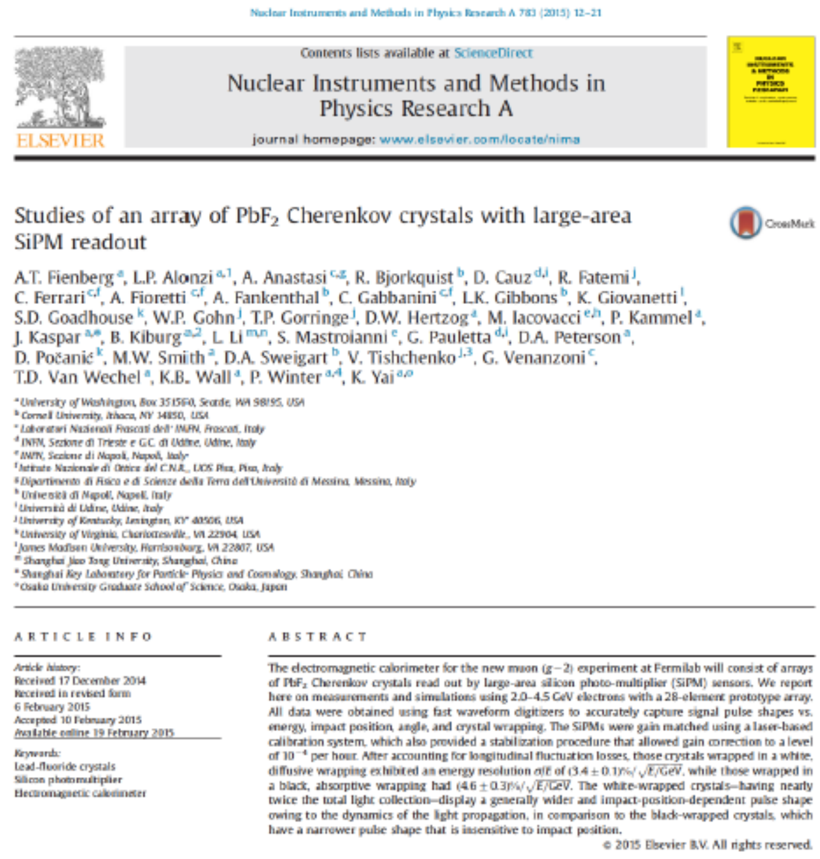
Homogeneous calorimeters

G-2 Calorimeter: PbF_2 crystals with SiPM readout

- Cherenkov light gives short pulse duration (few ns)
- High density (7.77 g/cm^3), small Molière radius (2.1 cm), short radiation length (0.93 cm)
- SiPMs unaffected by magnetic fields
- Segmentation reduces pileup
- Event rate in MHz range
- Few thousand pe per event (~1.5 pe/MeV)



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Studies of an array of PbF_2 Cherenkov crystals with large-area SiPM readout

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A R T I C L E I N F O

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Electromagnetic calorimeter

A B S T R A C T

The electromagnetic calorimeter for the new muon $(g-2)$ experiment at Fermilab will consist of arrays of PbF_2 Cherenkov crystals read out by large-area silicon photo-multiplier (SiPM) sensors. We report here on measurements and simulations using 2.0–4.5 GeV electrons with a 28-element prototype array. All data were obtained using fast waveform digitizers to accurately capture signal pulse shapes vs. energy, impact position, angle, and crystal wrapping. The SiPMs were gain matched using a laser-based calibration system, which also provided a stabilization procedure that allowed gain correction to a level of 10^{-4} per hour. After accounting for longitudinal fluctuation losses, those crystals wrapped in a white, diffusive wrapping exhibited an energy resolution σ/E of $(3.4 \pm 0.1)\%/\sqrt{E/\mathrm{GeV}}$, while those wrapped in a black, absorptive wrapping had $(4.6 \pm 0.3)\%/\sqrt{E/\mathrm{GeV}}$. The white-wrapped crystals—having nearly twice the total light collection—display a generally wider and impact-position-dependent pulse shape owing to the dynamics of the light propagation, in comparison to the black-wrapped crystals, which have a narrower pulse shape that is insensitive to impact position.

Homogenous calorimeters

The Calibration System of the new *g-2* experiment at Fermilab

A. Anastasi[b,c], D. Babusci[b], G. Cantatore[d,g], D. Cauz[d,i], G. Corradi[b], S. Dabagov[b], P. Di Meo[j], G. Di Sciascio, R. Di Stefano[c,j], C. Ferrari[a,b], A. Fioretti[a,b], C. Gabbanini[a,b], D. Hampai[b], M. Iacovacci[c,h], M. Karuza[d,k], S. Mastroianni[e,h], D. Moricciani[f], G. Pauletta[d,i], L. Santi[d,i], G. Venanzoni[b]

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[f]INFN Sezione di Roma Tor Vergata, Italy
[g]Università di Trieste, Trieste, Italy
[h]Università di Napoli, Napoli, Italy
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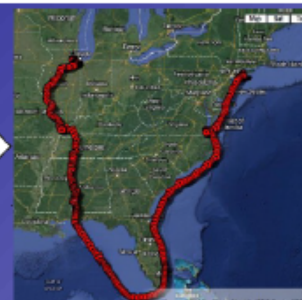
[k]University of Rijeka, Rijeka, Croatia

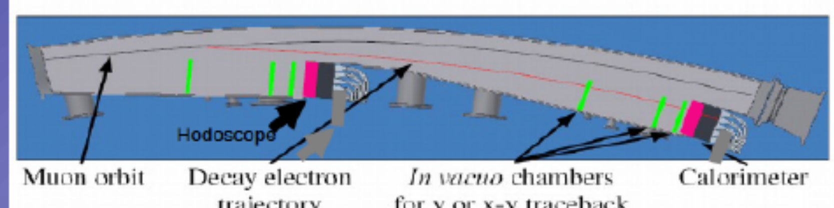
From BNL



To FNAL

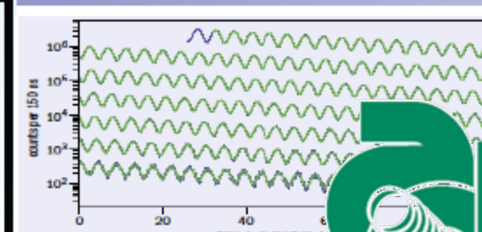
$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{Had} + a_\mu^{Weak}$$

$$a_\mu^{Th} - a_\mu^{exp} \sim 3\sigma \rightarrow$$



- **E989 at Fermilab**

$$\left.\begin{array}{l}\sigma_{stat} = \pm 0.1 \text{ ppm} \\ \sigma_{syst} = \pm 0.1 \text{ ppm}\end{array}\right\} \sigma = \pm 0.14 \text{ ppm}$$



Graziano Venanzoni

In E989 the Gain fluctuations must be monitored at the sub-per mil level during the fill [0-700μs]

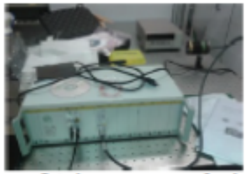
E821 Error	Size [ppm]	Plan for the New $g-2$ Experiment **E989**	Goal [ppm]
Gain changes	0.12	Better laser calibration and low-energy threshold	0.02
Lost muons	0.09	Long beamline eliminates non-standard muons	0.02
Pileup	0.08	Low-energy samples recorded; calorimeter segmentation	0.04
CBO	0.07	New scraping scheme; damping scheme implemented	0.04
E and pitch	0.05	Improved measurement with traceback	0.03
Total	0.18	Quadrature sum	0.07

Laser Calibration System

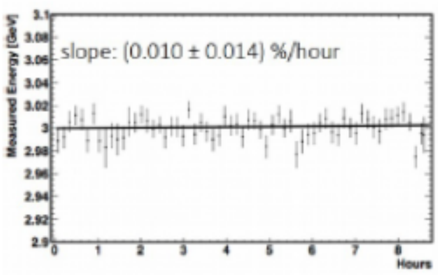
Laser
PicoQuant LDH-P-C 405M:
Pulse width[ps]:300
Energy/pulse[pJ]:500
Nominal Avg.Power[mW@kHz]:20@40000
Wavelength:405 nm
Photons/pulse:1,02·10⁹

Fiber Bundle:
Diameter per fiber[μm]:1000
Material: PMMA
NA: 0.49

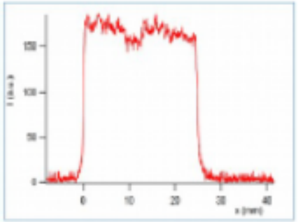
Engineered Diffuser THORLABS:
Uniformity > 2-3%
Transmittance -10%



Multi-Laser driver

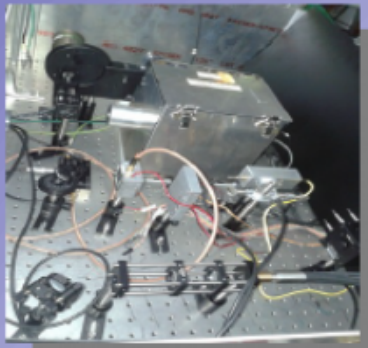


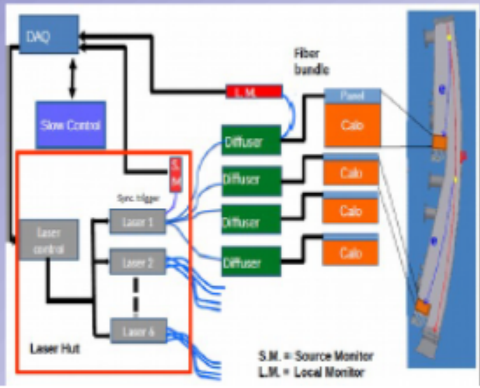
Time stability~10^{-4}/h



Light output

Distribution System





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Test of candidate light distributors for the muon $(g-2)$ laser calibration system

A. Anastasi [a,c], D. Babusci [a], F. Baffigi [b], G. Cantatore [d,g], D. Cauz [d,i], G. Corradi [a], S. Dabagov [a], G. Di Sciascio [f], R. Di Stefano [e,j], C. Ferrari [a,b], A.T. Fienberg [l], A. Fioretti [a,b], L. Fulgentini [b], C. Gabbanini [a,b,*], L.A. Gizzi [b], D. Hampai [a], D.W. Hertzog [l], M. Iacovacci [e,h], M. Karuza [d,k], J. Kaspar [l], P. Koester [b], L. Labate [b], S. Mastroianni [l], D. Moricciani [f], G. Pauletta [d,i], L. Santi [d,i], G. Venanzoni [a]

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[g] Università di Trieste, Trieste, Italy
[h] Università di Napoli, Napoli, Italy
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ABSTRACT

The new muon $(g-2)$ experiment E989 at Fermilab will be equipped with a laser […] for all the 1296 channels of the calorimeters. An integrating sphere and an alternativ[…] engineered diffuser have been considered as possible light distributors for the ex[…] here a detailed comparison of the two based on temporal response, spatial […] and time stability.

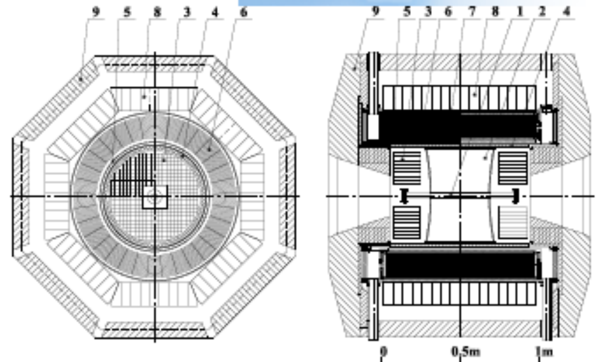
Graziano Venanzoni

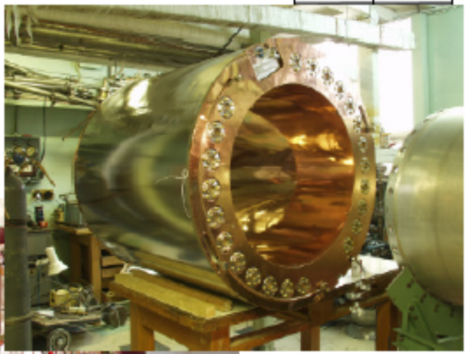
Homogeneous calorimeters

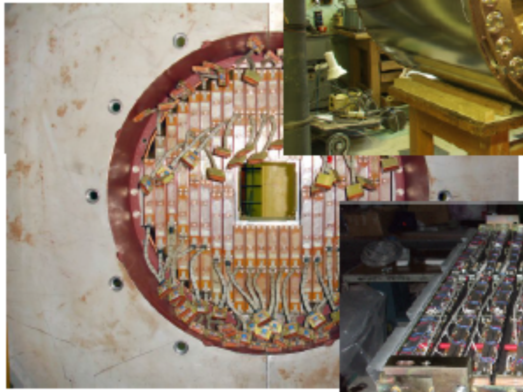
Calorimetry at the CMD-3 detector

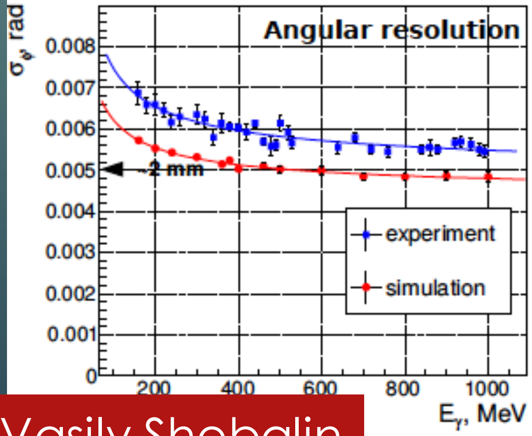
Vasily Shebalin on behalf of CMD-3 collaboration

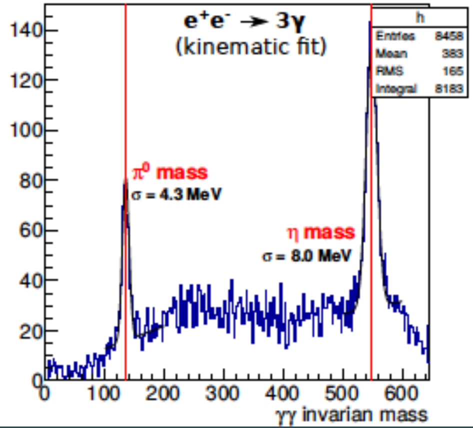
- VEPP-200 collider $E_{c.m.}$ = 150 – 2000 Mev
- Cryogenic magnetic detector (CMD)
- 3 calorimeter systems: calorimeter based on Liquid Xenon, CsI crystal calorimeter, endcap calorimeter based on BGO crystals
- Lxe + CsI – combined barrel calorimeter. Spacial resolution about 2 mm (angular 5 mrad). Energy resolution about 4% for 1 GeV photon.
- The structure and characteristics of calorimeter systems are described in the poster
- The energy calibration procedures are described











Vasily Shebalin

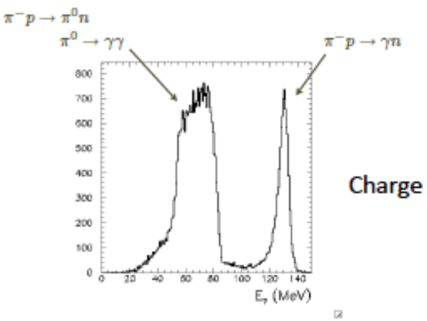
Calibration

A liquid hydrogen target for the calibration of the MEG and MEGII liquid xenon calorimeter

A.M.Baldini, C. Bemporad, F. Cei, D. Nicolò, L. Galli, G. Gallucci, M.Grassi, A. Papa, F. Sergiampietri, G. Signorelli, M. Venturini
INFN Sezione di Pisa, Università di Pisa, Scuola Normale Superiore, Paul Scherrer Institut

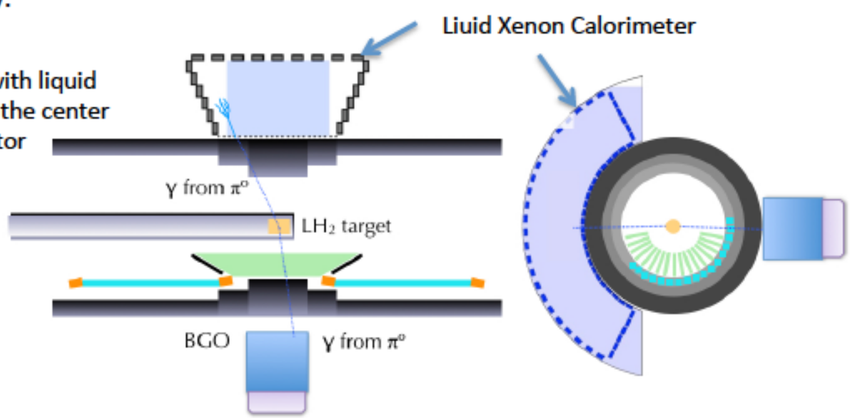
We designed, constructed and operated a liquid hydrogen target for the calibration of the liquid xenon calorimeter of the MEG experiment. The target was used throughout the entire data taking period, from 2008 to 2013 and it's being refurbished and partly re-designed to be integrated and used in the MEG-II experiment.

The charge exchange (CEX) reaction $\pi^- p \rightarrow \pi^0 n$ produces calibration photons from the neutral pion decay in the energy range 55 MeV < E_γ < 83 MeV very close to the $\mu \rightarrow e\,\gamma$ photon energy.



Charge exchange spectrum

MEG CEX set-up with liquid hydrogen target at the center f the detector

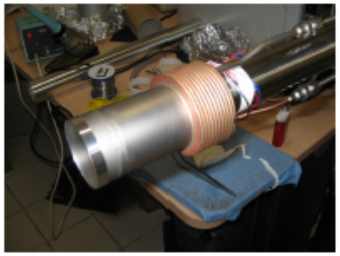


Need for a custom liquid hydrogen target with:

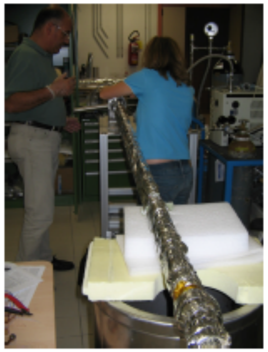
- Cell at the center of a solenoid magnet with high magnetic field (1.4 T)
- short data taking interruption (max beam time)
- Quick preparation: mounting, liquefaction, evaporation
- Accessibility to the operating position
- Minimal material towards the calorimeter
- Thin windows

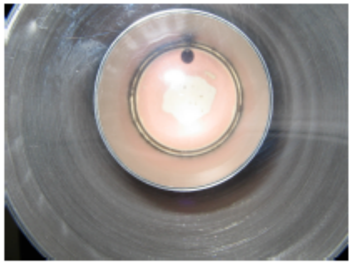
Donato Nicolò

The liquid hydrogen cell is a 500 um thick stainless steel cell 75 mm long and 50 cm diameter (150 cc liquid) cooled by a copper coil by a continuous flux of liquid helium. The entrance window is made of a 135 µm mylar foil glued to the target cylinder by a two components fast setting epoxy resin. The target cell is suspended by a 2 m long non-magnetic stainless steel pipe to be placed at the nominal center of the MEG-MEGII detector

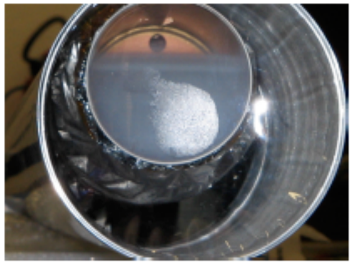


The liquid hydrogen cell



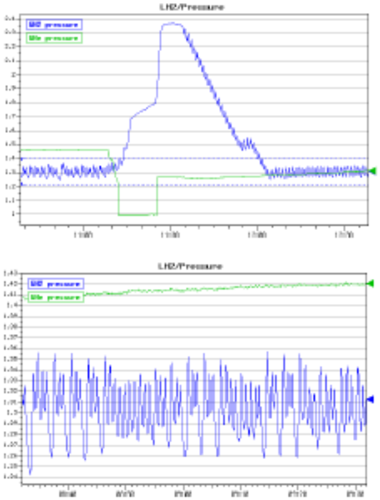


Empty cell before liquefaction. The hydrogen gas inlet is visible



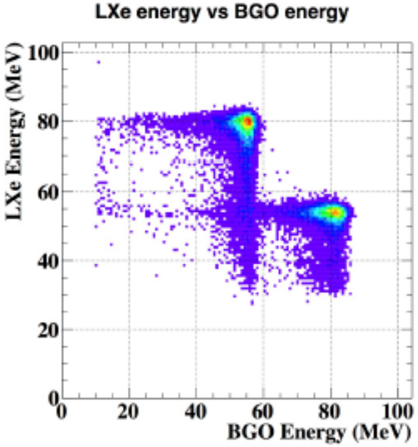
The cell in operating conditions is full of liquid hydrogen

In 50 minutes the target is ready for operation and its pressure/volume is stable at the percent level. Liquid He consumption is roughly 3 liters per hour



The liquid hydrogen was operated for the calibrations of the MEG experiment during years 2008-2013 against a BGO crystal and allowed the precise determination of the energy and timing response of the liquid xenon detector

Plot of the energy of back-to-back photons as observed by the MEG liquid xenon detector against a calibration BGO detector.



Donato Nicolò

Sampling (Si/W) calorimeters

Performance results of a high-granularity electromagnetic calorimeter

Chunhui Zhang, Ton Van Den Brink, Marco Van Leeuwen, Gert-Jan Nooren, Thomas Peitzmann, Hongkai Wang
Utrecht University/NIKHEF

Summery

- **Forward Calorimeter** (FoCal) under discussion for Alice Upgrade (possible installation in LS3 (≈2024))
- A **high granularity** digital Si/W calorimeter **prototype** for FoCal has been built and tested.
- Very **small Molière radius** (11±0.5mm) has been measured.
- Unique **high resolution lateral shower profiles** have been obtained → two-shower separation.
- An additional **charge diffusion model** works well to improve the description in Geant 4 **simulations**.
- Sensor **sensitivities** and **dead area** have been **corrected** for.
- **Performance** of our prototype **agrees** reasonably well with the **simulation**.

Motivation

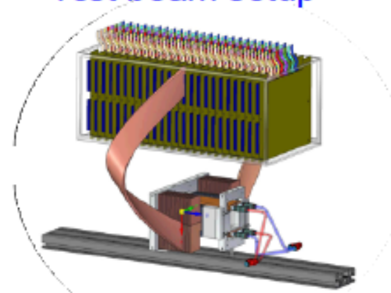
Measurement of direct photons at large rapidity as a signal of gluon saturation.

Requirements for the Focal detector
Gamma/π^0 discrimination

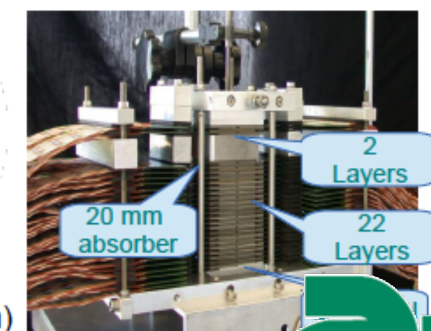
- 3D shower shape analysis
- Particle flow
- Energy measurement by particle counting: requires high granularity due to high density of shower particles (10^3 mm^{-2})

FoCal Prototype

Test beam setup



Stack of W and Si layers



A **unique** FoCal prototype:

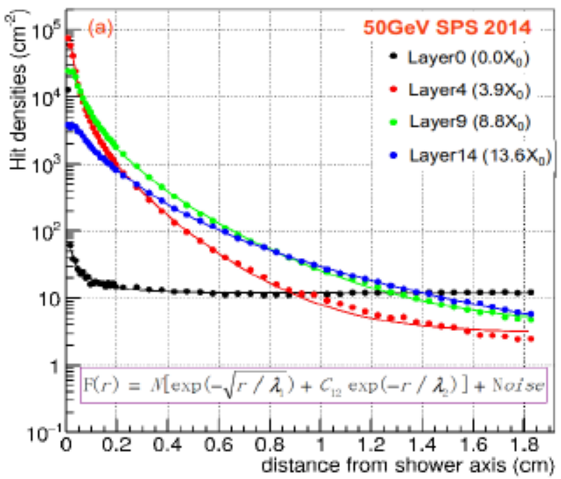
- ~39 M pixels (pitch: 30μm)
- Small R_M ~ 11mm

Chunhui Zhang

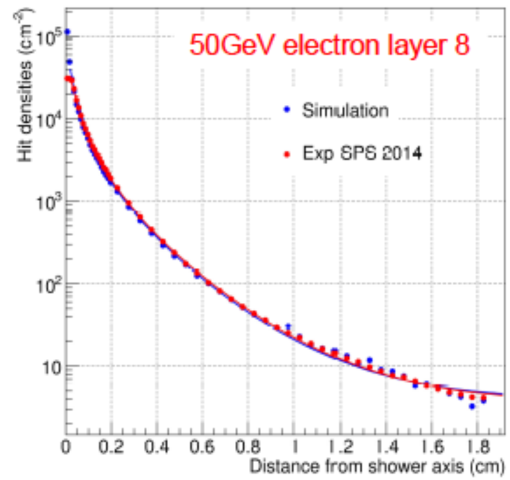
Results

Lateral profile

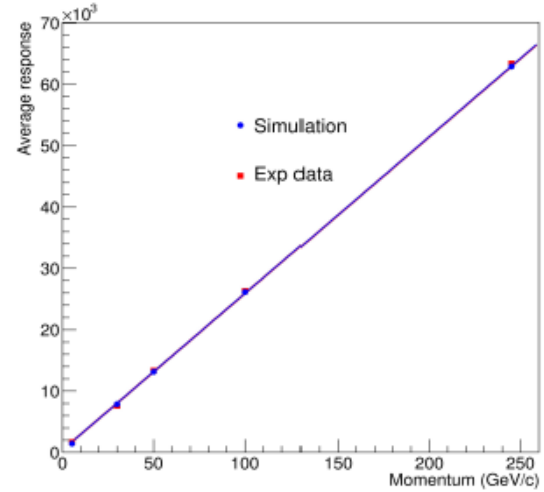
Experimental data



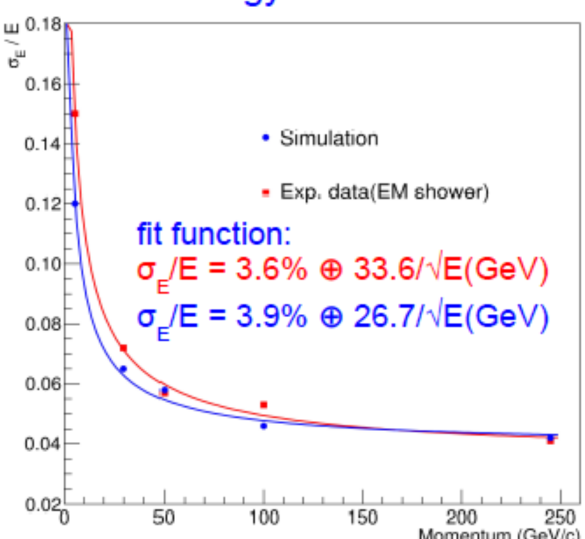
Comparison to simulation



linearity



Energy resolution



What was used in data analyses and simulation

Simulation	Experimental data
• A charge diffusion model was added to Geant 4 simulation	• Sensor sensitivity correction • Dead area correction

Upgrade of the ATLAS Tile Calorimeter for the High luminosity LHC

G. Usai
(U. of Texas at Arlington)
on behalf of the ATLAS Tile Calorimeter system

motivations

- a complete replacement of the Front-End and Back-End electronics of the ATLAS Tile (and LAr) calorimeter is foreseen for the Phase-II HL LHC:
  - components with improved radiation hardness are needed
  - better selectivity in the trigger selection is needed
    - digital data with full granularity and precision will replace the current "analog towers" signals. Pipelines are moved to the BE
  - improvement in the detector robustness:
    - design for reliability, add redundancy and minimise impact of SPF with smaller DAQ elements
  - improve access to the FE electronics for maintenance also reducing occupational radiation exposure

Giulio Usai

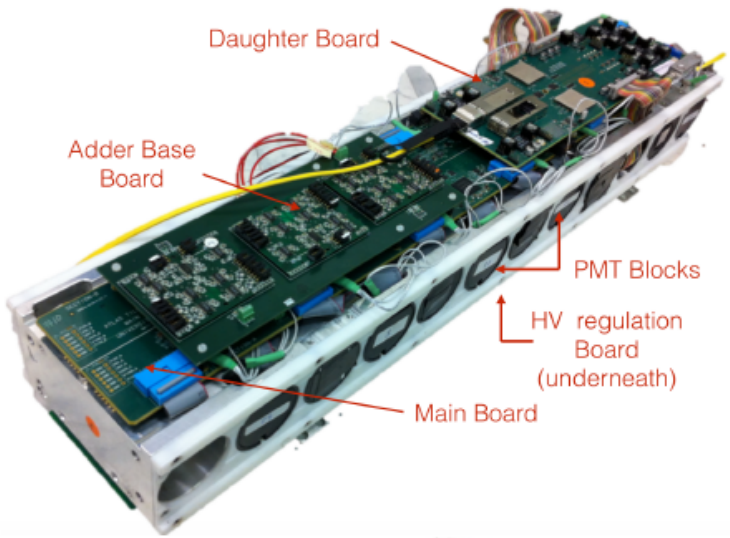
Sampling calorimeters

phase-II Tile demonstrator

- a demonstration slice to prove the new readout concepts will be built and operated within ATLAS during Run-2. Installation during the December 2016 shutdown

- the prototypes built in the current R&D efforts involving ~ten institutes and the current status of the integration will be illustrated

- one of the two Tile Upgrade project co-coordinators is Here to answer all your questions!



ATLAS Tile Calorimeter for the High luminosity LHC

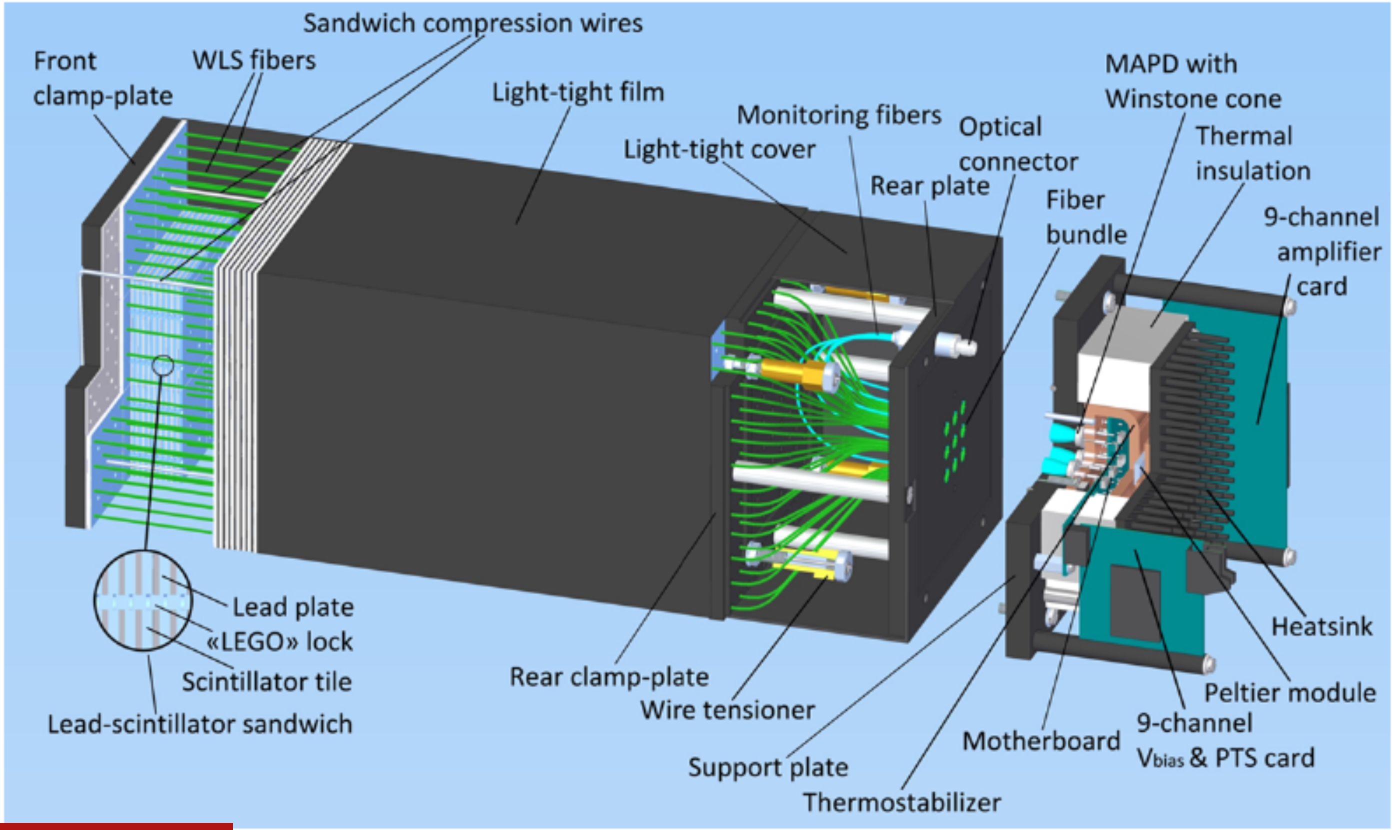
Giulio Usai U.of Texas at Arling

Giulio Usai

The design of a photodetector unit of a new Shashlyk EM calorimeter for COMPASS II

I. Chirikov-Zorin, Z. Krumshtein, A. Olchevski
Joint Institute for Nuclear Research, Dubna, Russia

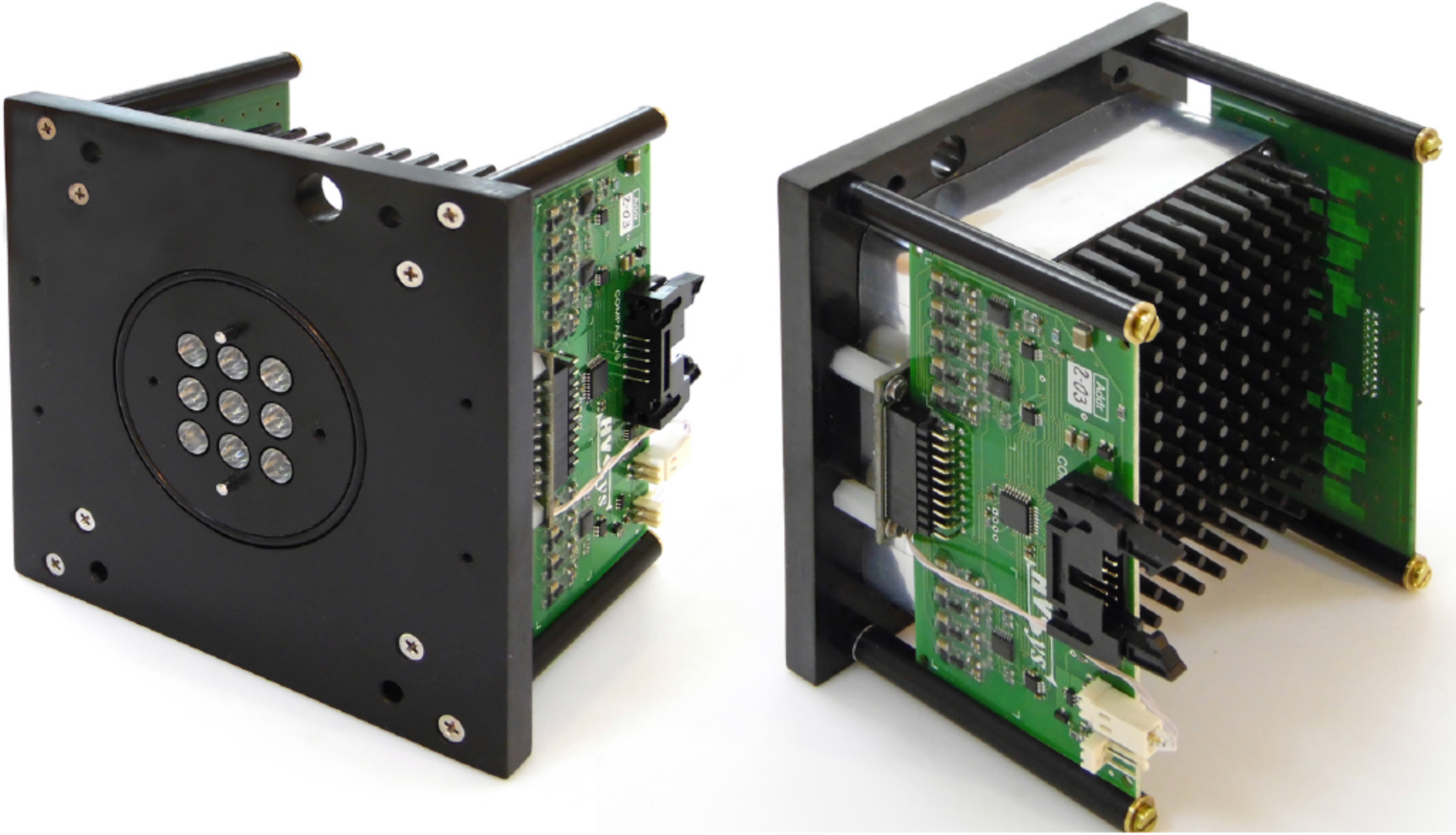
A new-generation high-granularity Shashlyk EM calorimeter read out by nine-channel photodetector unit with micropixel avalanche photodiodes (MAPD) and precision thermostabilization based on the compact Peltier module is designed and constructed. MAPD-3N with a high pixel density of 15000 per square mm and area 3×3 mm^2 produced by Zecotek were used.



Design of the Shashlyk calorimeter module

Igor Chirikov-Zorin

Shashlyk calorimeters



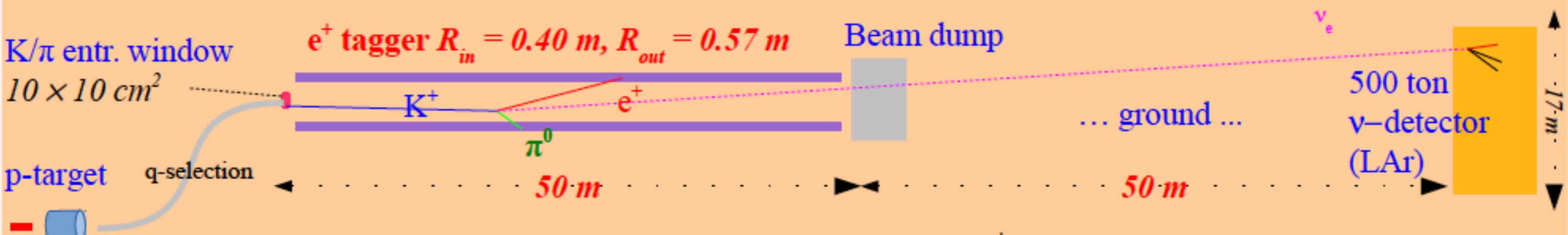
Igor Chirikov-Zorin

A new-concept calorimeter for future neutrino beams based on Kaon tagging

A. Longhin (INFN-LNF) L. Ludovici (INFN-RM1) F. Terranova (Univ INFN MIB) *Eur. Phys. J. C (2015) 75:155*

- **Knowing the ν_e cross section is crucial for Leptonic CP violation** (modulations of ν_e from $\nu_\mu \to \nu_e$)
- Present measurements w. **conventional ν beams limited by syst. in the flux** (~10% norm. error)

→ A new-generation ν source based on tagging of e^+ from K_{e3} decays $K^+ \to e^+ \pi^0 \nu_e$



Transport/focusing beamline ouput:

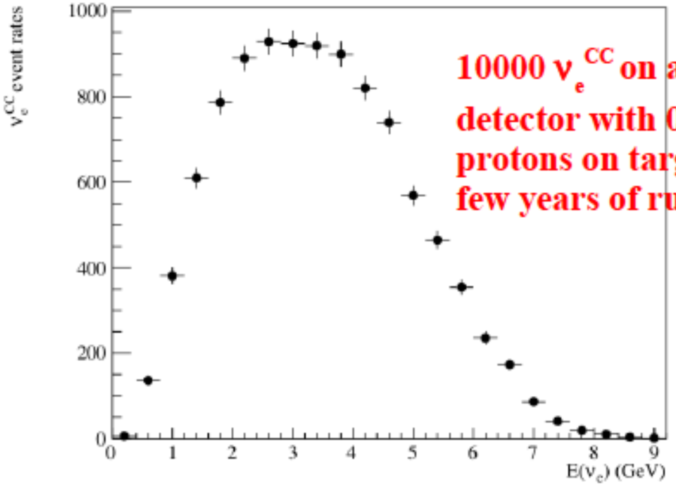
- K^+/π^+ 8.5 GeV/c ± 20% $\theta < 3$ mrad

- **85% of e^+ with a ν_e crossing the far detector**
- **1 ν_e^{CC} every 1.94×10^{13} K^+**

ν_e flux proportional to the e^+ rate in the tagger

ν_e flux will NOT depend on hadro-production, K/π production ratio, Protons on Target (PoT), 2ry beamline efficiency **but only on:** the **geometrical acceptance** of the e^+-tagger/ν-detector, the **e^+ tagger efficiency** and the **mastering of residual backgrounds. O(1%) systematic error achievable**

→ ν_e^{CC} precision measurement

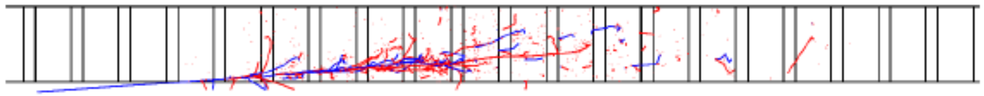


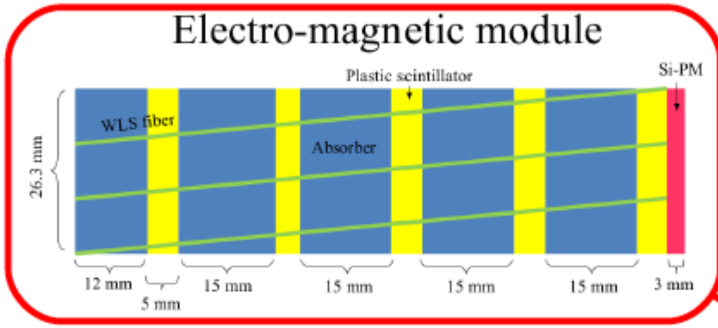
10000 ν_e^{CC} on a 500 t detector with 0.5-5 10^{20} protons on target (~ few years of run)

Andrea Longhin

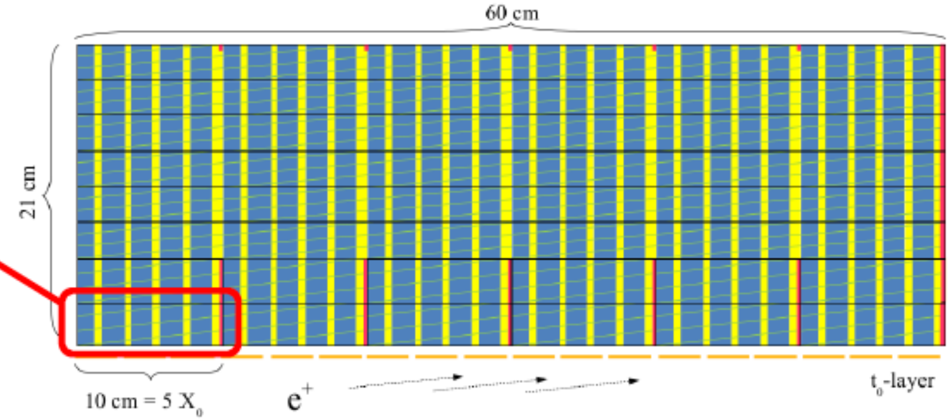
Shashlyk calorimeters

Proposed technology: Shashlik calorimeter (0.5 cm scintillator tiles + 1.5 cm Copper slabs)
Wave **L**ength **S**hifting **fibers** running along the average e^+ direction (i.e. almost perpendicular to the tiles) with ~1 cm pitch, read-out by small area **Si**licon **P**hoto-**M**ultipliers

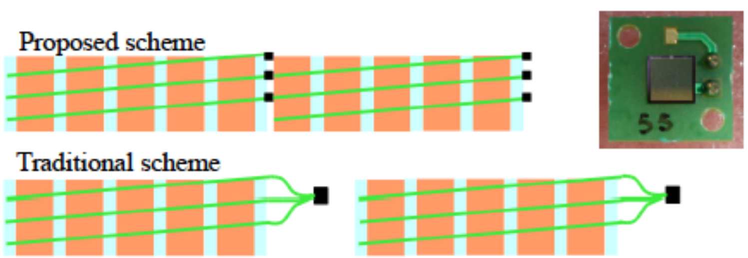




Radial views (the 2π geometry is obtained with 76 azimuthal modules)



1 Si-PM per fiber, avoid bundling to improve the longitudinal sampling uniformity

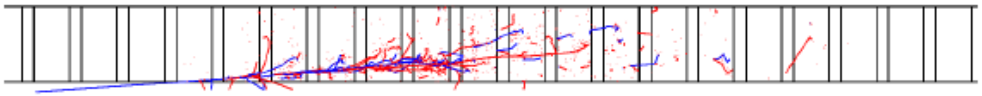


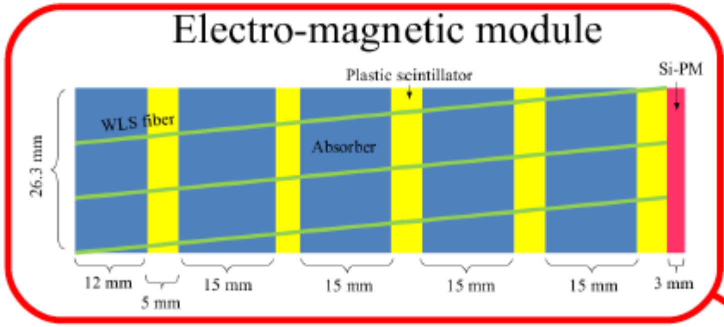
- **Full GEANT4 simulation** in progress.
- **test-beam with π/e beams** planned for e.m. module.
- A **3 m long demonstrator** (**ENUBET**, **E**nhanced **N**e**U**trino **BE**ams with kaon **T**agging) possibly at the **CERN ν platform** is envisaged.
- A **working group** is forming. Open to interested parties!

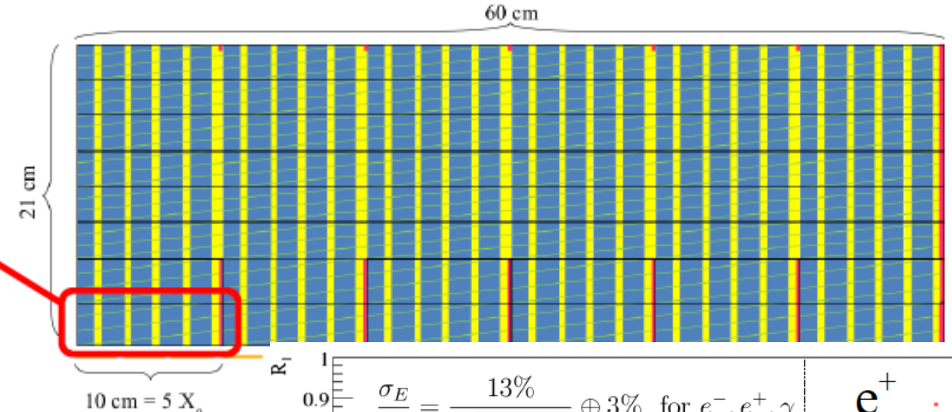
Andrea Longhin

Shashlyk calorimeters

Proposed technology: Shashlik calorimeter (0.5 cm scintillator tiles + 1.5 cm Copper slabs) **W**ave **L**ength **S**hifting **fibers** running along the average e^+ direction (i.e. almost perpendicular to the tiles) with ~1 cm pitch, read-out by small area **Si**licon **P**hoto-**M**ultipliers

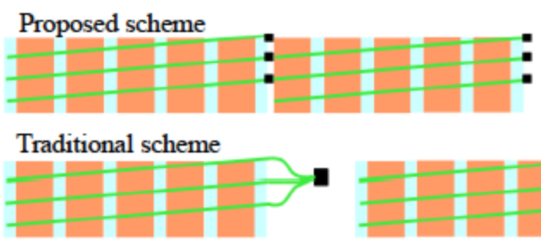




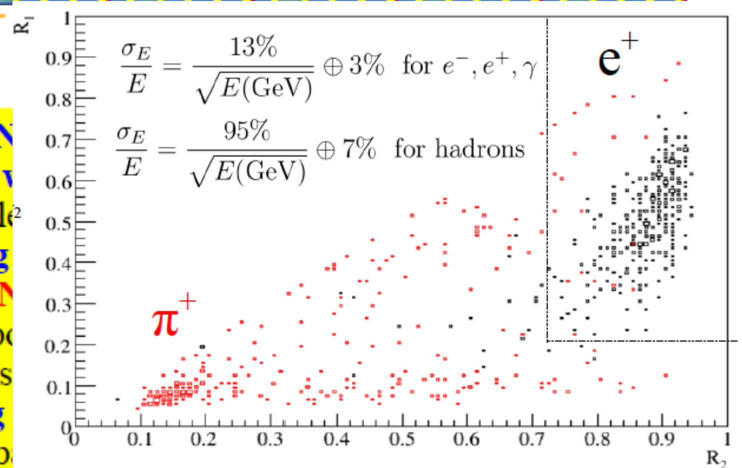


Radial views (the 2π geometry is obtained with 76 azimuthal modules)

1 Si-PM per fiber, avoid bundling to improve the longitudinal sampling uniformity



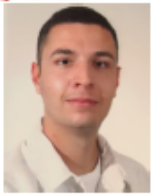
- **Full GEAN**
- **test-beam v**
  e.m. module
- A **3 m long**
  Enhanced **N**
  Tagging) p
  platform is
- A **working**
  interested p



Andrea Longhin

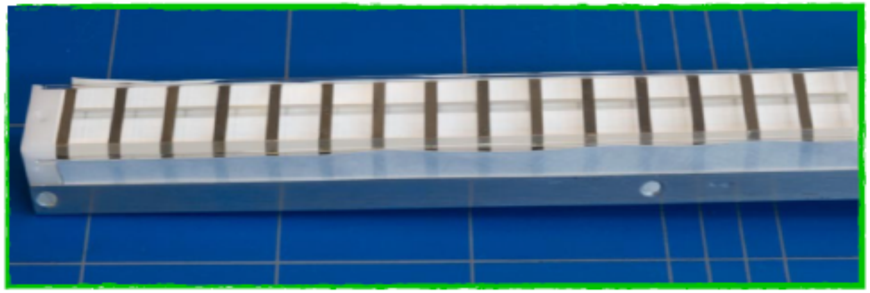
Test beam results with a sampling calorimeter of cerium fluoride scintillating crystals and tungsten absorber plates for calorimetry at the HL-LHC

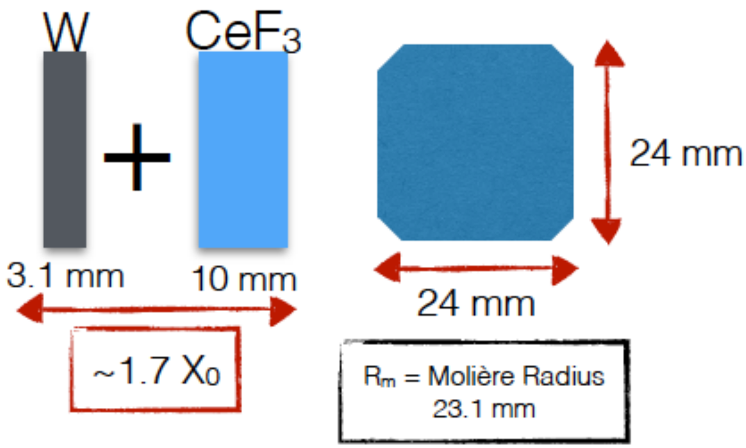
Simone Gelli

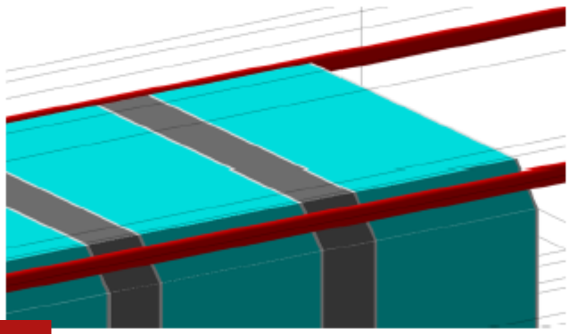


HL-LHC

Endcap: high rad. damage (30 Gy/h) → Radiation-hard material







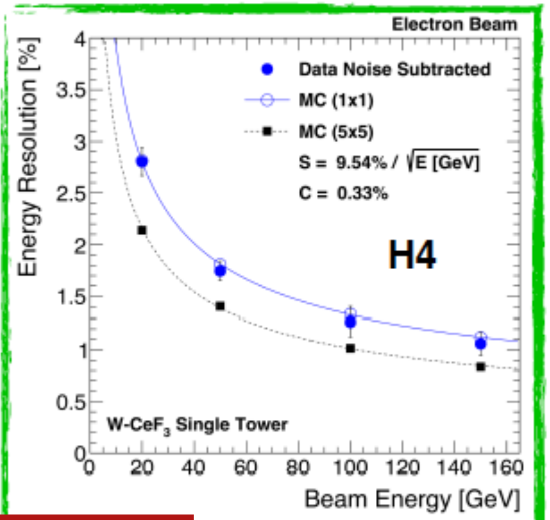
Signal read through WLS scintillating fibres housed in the chamfered edges of the crystal

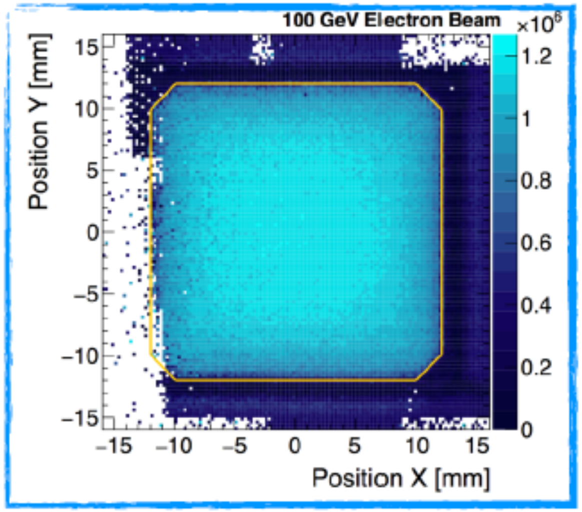
Beam Test Results

2 Beam Test
- Frascati BTF ($E(e^-)$=491 MeV - 17 X_0)
- CERN-SPS H4 ($E(e^-)$ up to 150 GeV - 25 X_0)

General Beam Line schema

e^-
- Scintillators (trigger)
- Hodoscope/Wire Chambers (Positioning)
- CeF_3 tower





Response map of the W-CeF_3 channel as a function of the impact point with the channel dimension superimposed

Energy Resolution

$$\frac{\Delta E}{E} = \frac{N}{E} \oplus \frac{S}{\sqrt{E}} \oplus C$$

S= **9.7** %	Stochastic Term	Frascati
S= **9.54** % C= 0.33 %	Stochastic and Constant Term	H4

Good Resolution: suitable for HL-LHC

Simone Gelli

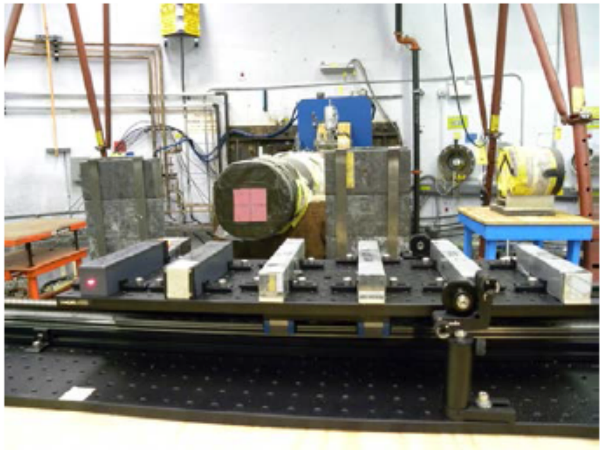
Radiation Damage Induced by 800 MeV Protons in Fast Crystal Scintillators

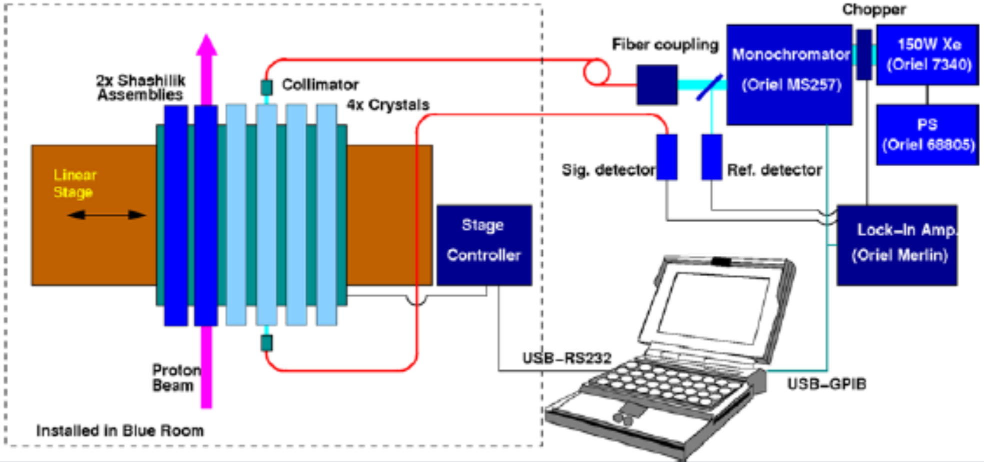
Fan Yang, Liyuan Zhang and Ren-Yuan Zhu

Crystal Laboratory, HEP, California Institute of Technology, Pasadena, CA 91125, USA

Jon Kapustinsky, Ron Nelson and Zhehui Wang

Los Alamos National Laboratory, Los Alamos, NM 87545, USA





- Six samples were loaded on a remote controlled linear stage: one LYSO/W/Y-11 Shashlik cell, one box containing four 6 cm long sealed capillaries and three Y-11 WLS fibers and four large size crystals (LYSO, LFS, BGO and CeF_3).
- An optical fiber and lock-in amplifier based spectrophotometer used to measure longitudinal transmittance (LT) of crystal samples before, during and after irradiations.
- Because of a power blackout, only the box, LYSO and CeF_3 were irradiated with fluence of 2.7, 3.3 and 1.4×10^{14} p/cm² respectively.

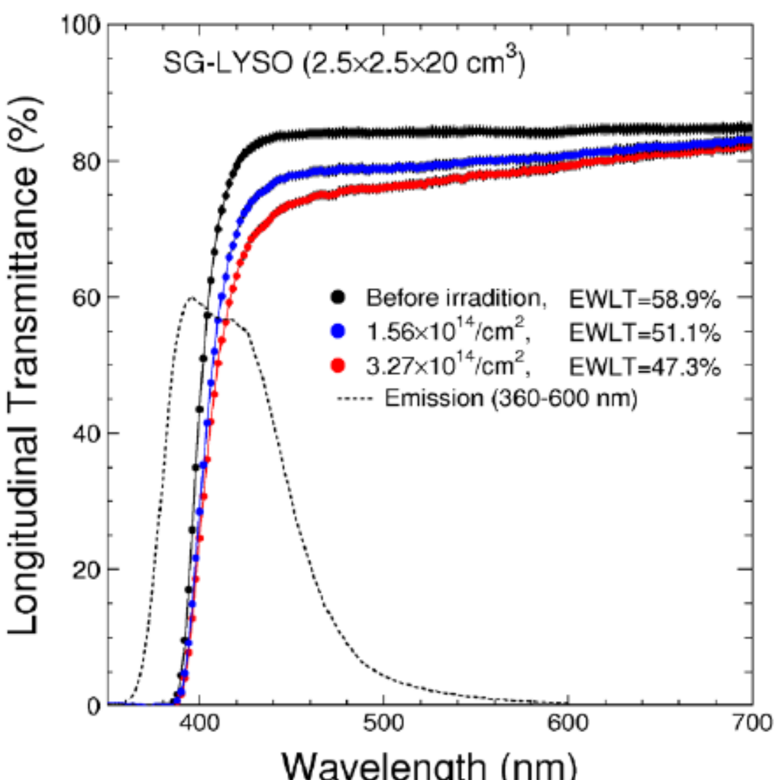
13th Pisa Meeting on Advanced Detectors, by Liyuan Zhang, Caltech.

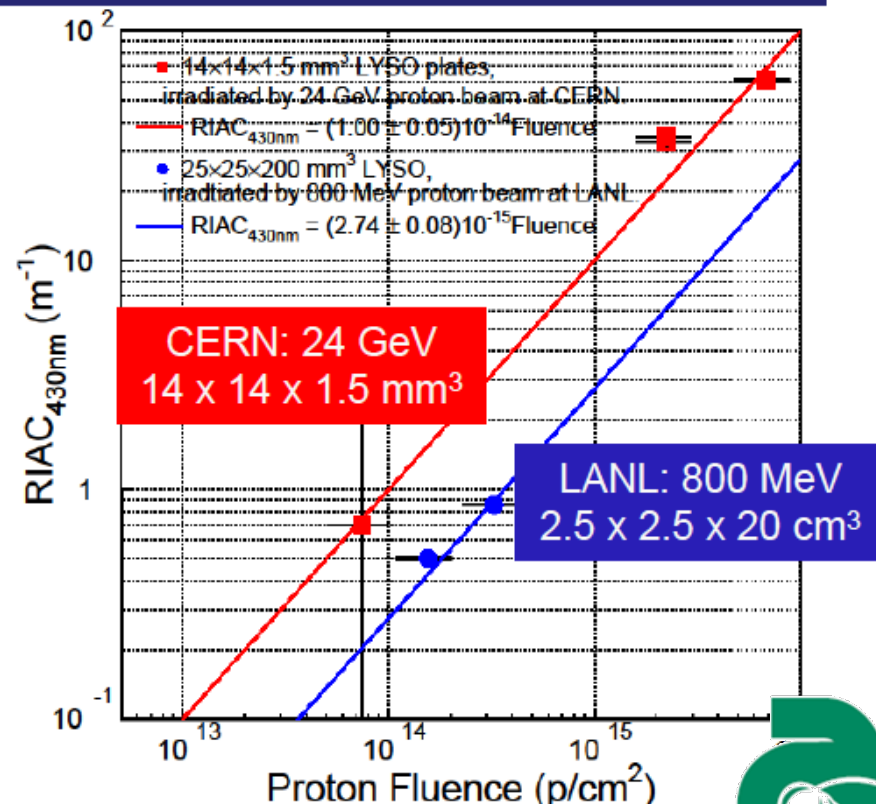
Radiation damage

Liyuan Zhang

Radiation Damage in Fast Crystal Scintillators Induced by 800 MeV Protons

- The LYSO of 2.5×2.5×20 cm³ was irradiated to 3.3×10¹⁴ p/cm².
- The emission weighted radiation induced absorption (EWRIAC) is about 1 m⁻¹, indicating excellent radiation hardness of LYSO against charged hadrons.
- The result is consistent within a factor of 3 with 14×14×1.5 mm³ LYSO plates irradiated up to 7×10¹⁵ p/cm² by 24 GeV protons at CERN.





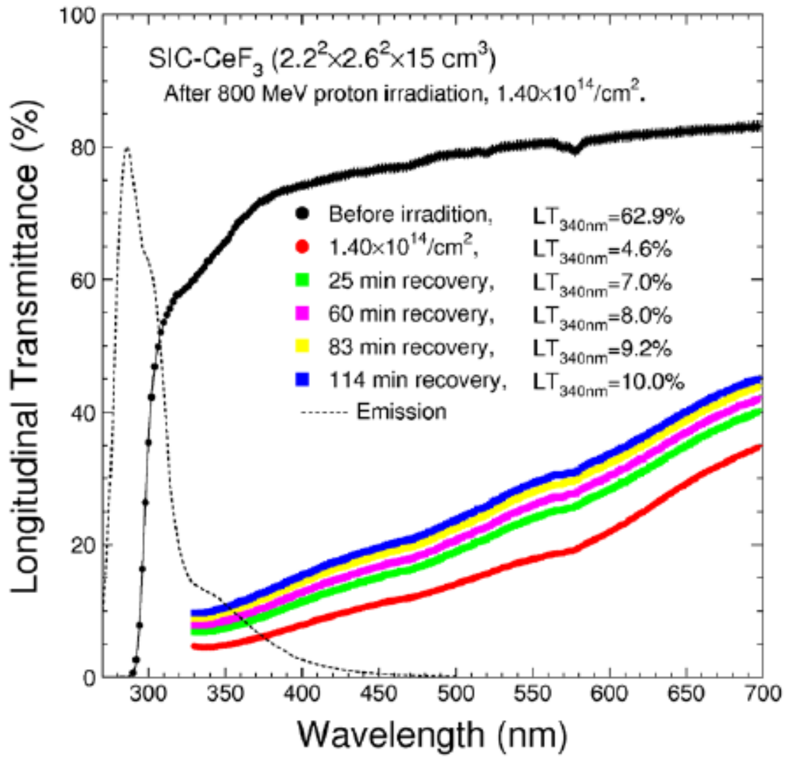
13th Pisa Meeting on Advanced Detectors, by Liyuan Zhang, Caltech.

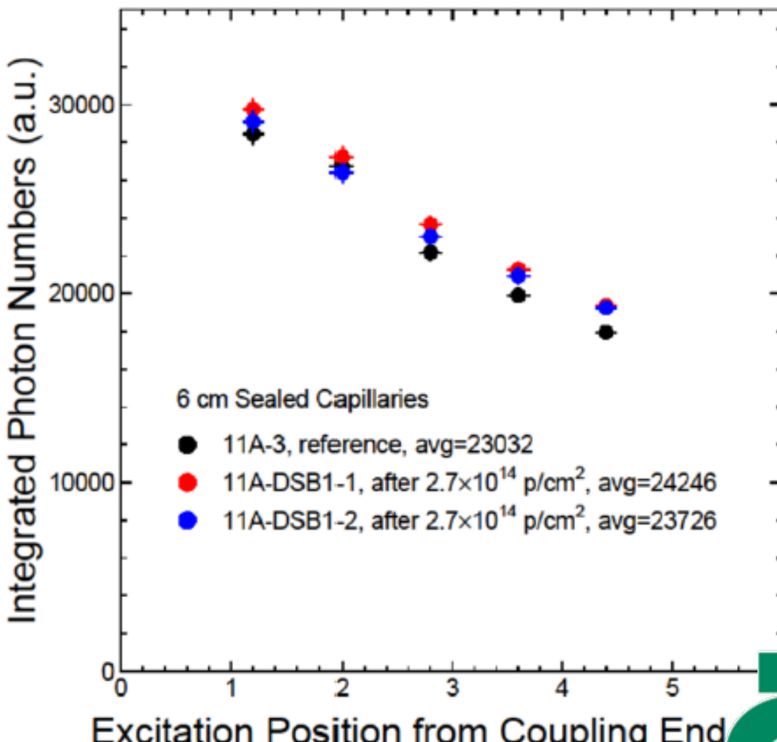
Liyuan Zhang

Radiation Damage in Fast Crystal Scintillators Induced by 800 MeV Protons

Radiation damage

- An order of magnitude larger absorption was observed in the CeF_3 of $2.2^2 \times 2.6^2 \times 15$ cm³, after 1.4×10^{14} p/cm² irradiation, partly due to its poor quality since it was grown 20 years ago. More test with optimized samples is needed.
- Two quartz capillaries filled with DSB based liquid scintillator show consistent emission spectra, measured 76 days after an irradiation of 2.7×10^{14} p/cm² as compared to un-irradiated one.





Liyuan Zhang

13th Pisa Meeting on Advanced Detectors, by Liyuan Zhang, Caltech.

Test beam results of MCP in "ionisation mode" for detection of single charged particles and EM showers

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L. Brianza, R. Gerosa, A. Ghezzi, C. Gotti, P. Govoni, A. Martelli, B. Marzocchi, S. Pigazzini, T. Tabarelli de Fatis
BINP (Novosibirsk)
Mikhail Yu. Barnyakov, Alexander Yu. Barnyakov

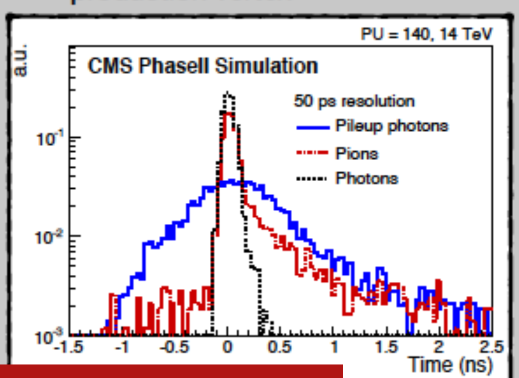
Pile-up @ future hadron colliders

High instantaneous luminosity >10^{34} $cm^{-2}s^{-1}$ in pp colliders is achieved at a cost of large number of collisions for BX.
e.g.: **HL-LHC (2024): 140 PU. Time spread ~200ps**

Idea: use time-of-flight information in calorimeters to aid the full event reconstruction

➡ **pile-up mitigation:** remove energy deposits in calorimeters not associated to the hard interaction (e.g. pile-up jets identification, improve MET resolution…)

➡ **triangulate high energy photons** from Higgs decay to production vertex



<50ps TOF resolution is needed to get rejection in forward EM calorimeter of pile-up photons

MCP as MIP/EM shower TOF detector

PMT-MCP mode

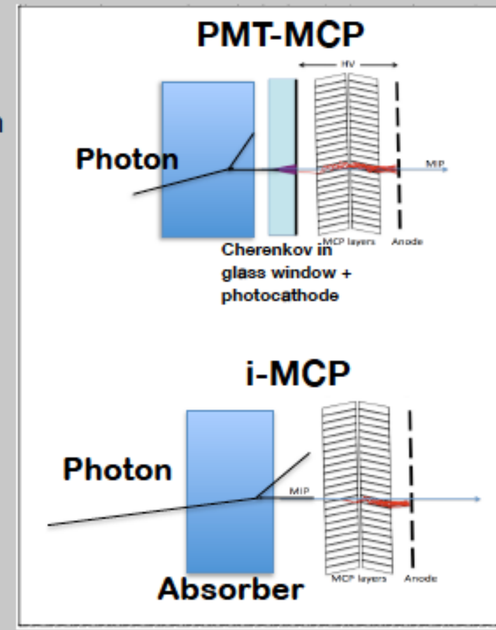
➡ High efficiency & excellent time resolution (<20ps)

➡ Issues for colliders: lifetime & radiation hardness (photocatode)

i-MCP mode

➡ Secondary emission in the MCP, no photocathode

➡ more radiation hard, improved lifetime, robust/easier assembly



i-MCP test beam setup

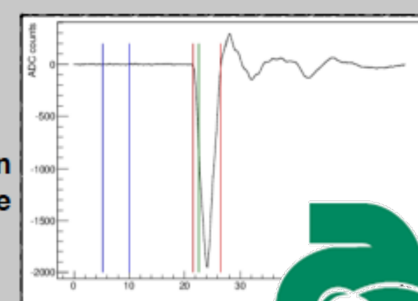
1 PMT-MCP: trigger and time reference (15ps resolution)

Different configurations tested in **i-MCP mode:**

➡ **2 MCP layers (d/L=1:40) chevron**

➡ **2 MCP layers (d/L=1:40), surface chemically treated to enhance SEE, chevron**

➡ **3 MCP layers (d/L=1:40) Z-stack**

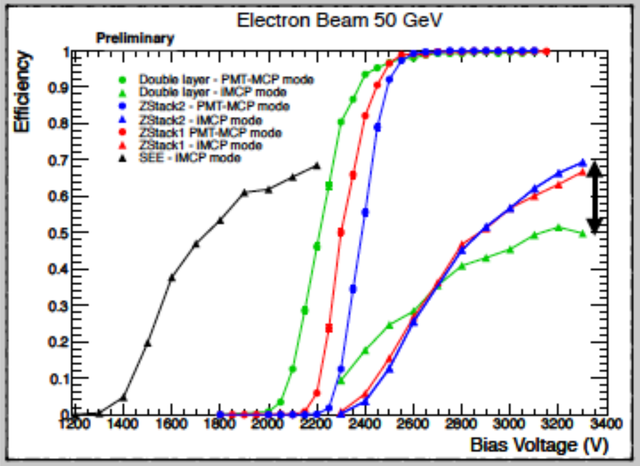


i-MCP

Test beam results of MCP in "ionisation mode" for detection of single charged particles and EM showers

INFN Istituto Nazionale di Fisica Nucleare
Università degli Studi di Milano Bicocca
Sapienza Università di Roma
НГУ

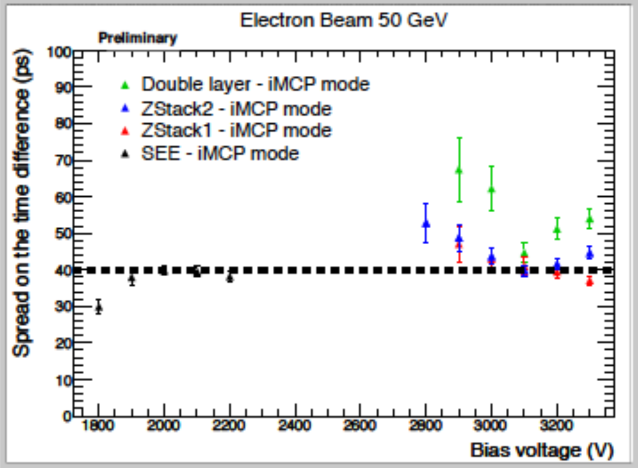
Single charged particle results



PMT-MCP mode:
100% efficiency

Z-stack & enhanced SEE i-MCP mode:
~ 70% efficiency

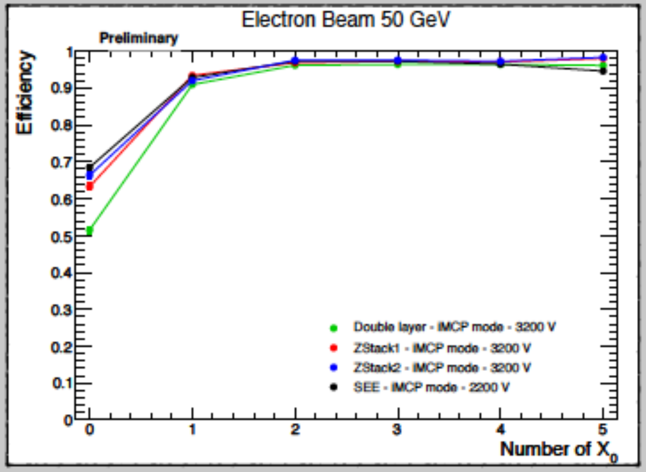
20% improvement over standard chevron configuration



$\sigma(t_{TRIG}-t_{MCP})$ ~ 40 ps for Z-stack & enhanced SEE:

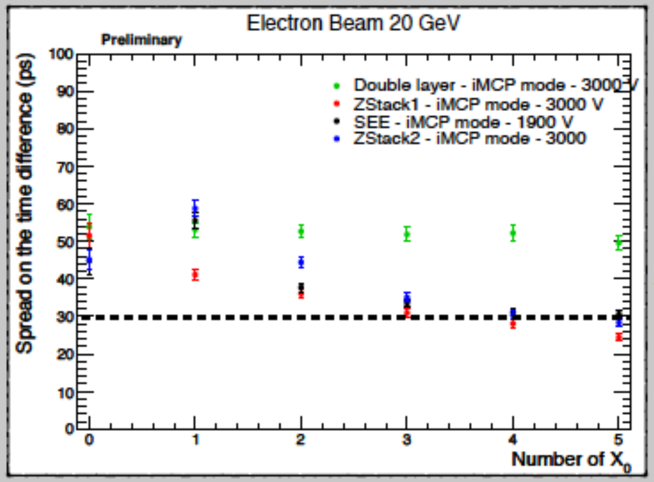
35ps resolution on single charged particle for a single detector

EM shower results



0-5X_0 in front of i-MCP with configurable lead absorber

100% efficiency for EM showers after 2-3 X_0



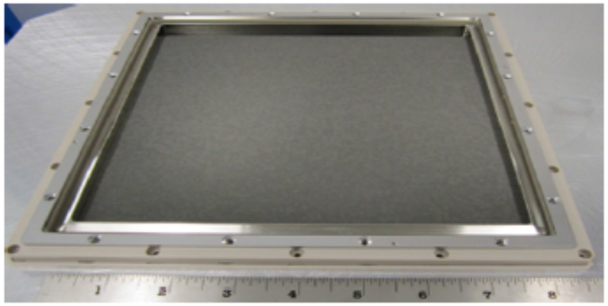
$\sigma(t_{TRIG}-t_{MCP})$ ~ 30 ps for showers:

25ps resolution for a single EM shower

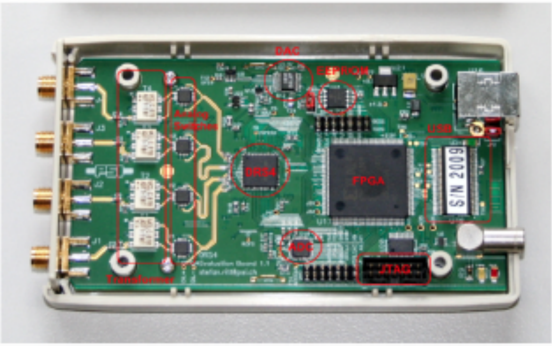
Fast timing for calorimeters

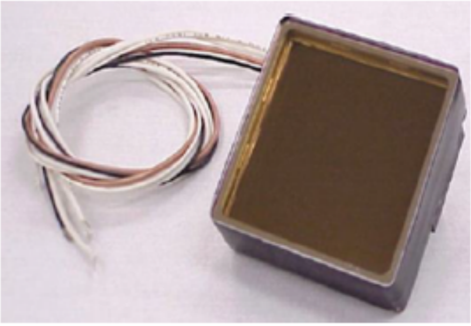
Micro-channel Plate Phototubes used as a Fast EM Shower Max Detector

Fermilab: Anatoly Ronzhin, Sergey Los, **Erik Ramberg**
CalTech: Artur Apresyan, Si Xie, Maria Spiropulu
U. Of Chicago: Heejong Kim



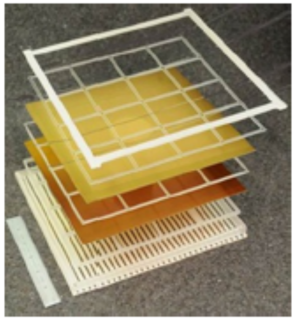
Largest microchannel plates from INCOM: 20 cm per side

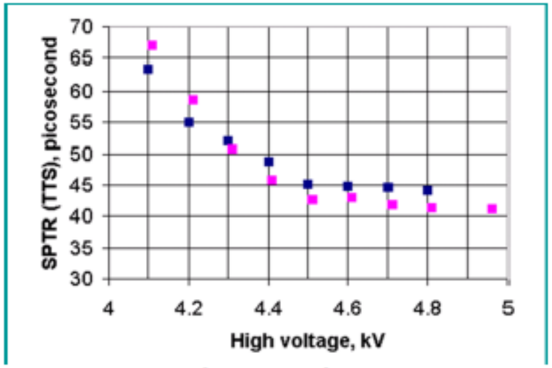




Use the DRS4 digitizer from PSI and Photonis 85011 MCPMT

The MCP are activated by atomic layer deposition





MCP phototubes give excellent single photon
ution

The LAPPD effort, hosted at Argonne National Lab, is working towards a simple strip-line readout for the 20 cm MCP plates, with an expectation of 5 psec timing resolution.

Nanolayer MCP Construction

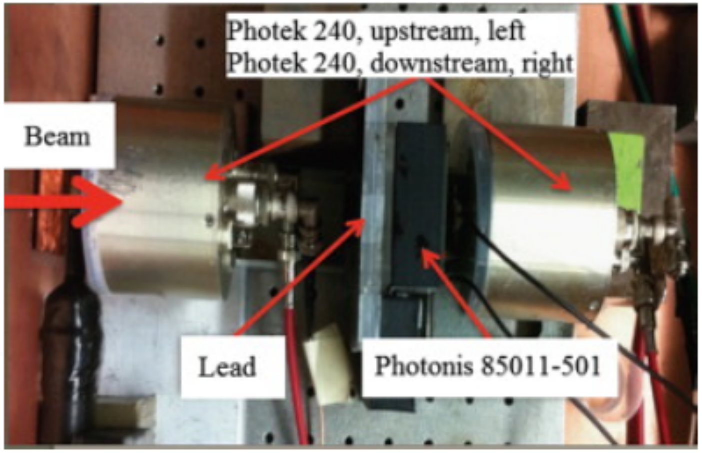
Chemically produced and treated Pb-glass does 3-functions:

1. Etched clad fiber substrate provides pores,
2. Hydrogen – reduced glass layer establishes MCP resistance,
3. Alkali/Pb - reduced glass layer provides secondary electron emission,

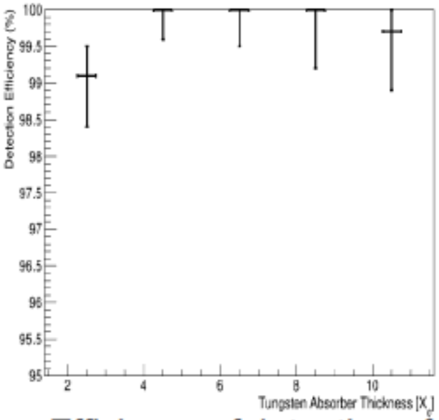
Separate the three functions:

1. Hard glass microcapillary array substrate provides pores,
2. Tuned Resistive Layer (ALD) provides current for electric field,
3. Specific Emitti layer provides SEE,

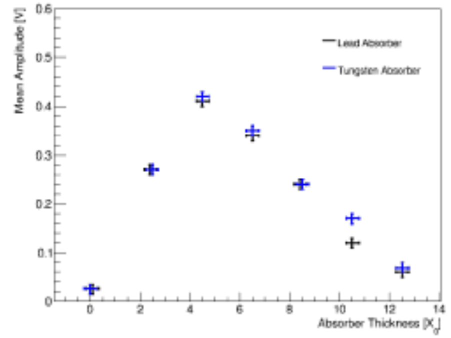
Erik Ramberg



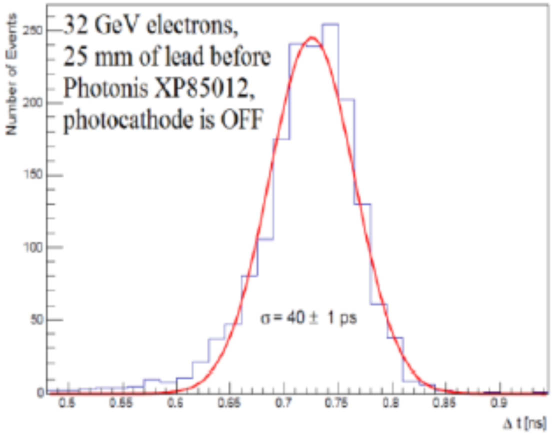
An example of the setup at Fermilab 32 Gev test beam, with Photek 240 and Photonis 85011 detectors and lead absorbers between them



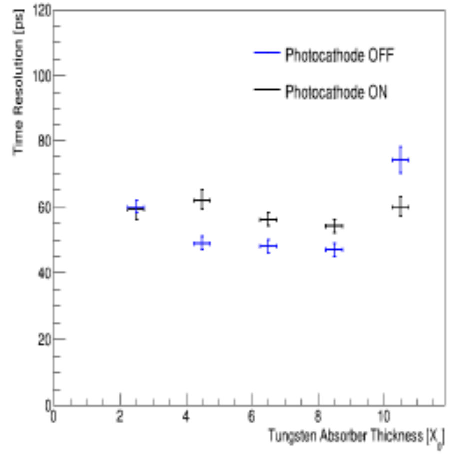
Efficiency of detection of a shower is 100% after first few layers



Shower profile is the same for lead and tungsten



Gaussian time response with photocathode turned off by 9 Volt reverse bias. Resolution=40 psec



Time resolution at shower max is not dependent on presence of photocathode

Our studies indicate that a standard microchannel plate can act as a calorimeter element without a radiator or scintillator or photocathode. The timing resolution for a bare MCP inside an electromagnetic shower is on the order of 40 psec.

Erik Ramberg

Real calorimeters

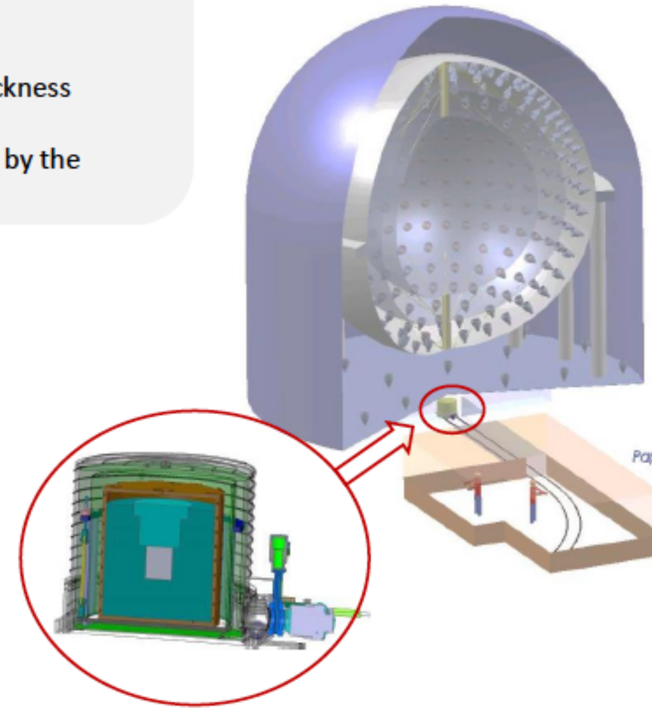
Physik-Department und Excellence Cluster Universe, Technische Universität München, Germany
Dipartimento di Fisica, Università degli Studi e INFN Genova, Italy

A high precision calorimeter for the SOX experiment

Laszlo Papp on behalf of TUM/Genoa SOX calorimeter collaboration

The SOX (Short distance neutrino Oscillations with BoreXino) aims at unambiguously discover or refute eV-scale sterile neutrinos by observing short baseline oscillations of active-to-sterile neutrinos.

- 100 kCi ^{144}Ce-^{144}Pr antineutrino generator (CeSOX), shielded by a 19 cm wall thickness tungstate container, will be placed under the BOREXINO detector.
- To reach the maximal sensitivity, we aim to determine the neutrino flux emitted by the antineutrino generator with a <1% accuracy.



The source-generated heat will be measured by a vacuum calorimeter

- Mass flow with 0.1% stability of high purity water is guarantied by a fixed height water reservoir and high precision flow regulating valve (accuracy 0.05%)
- Ideal $\dot{m}\approx 10$g/s at 1kW power, $\Delta T=25^{0}$C and 5mm pipe diameter to keep the relative error low and provide turbulent flow.
- Coriolis flow meters 0.05%, and temperature sensors with 5mK accuracy.
- Systematic error for one heat power measurement

$$\sigma_P{}^2[W]=\sqrt{0.35[W^2]+0.02[W^2/K^2]\cdot\Delta T^2}$$

  is between 1 and 3 W (~0.4%)
- Calibration will be performed with an electric heater

Physik-Department und Excellence Cluster Universe, Technische Universität München, Germany
Dipartimento di Fisica, Università degli Studi e INFN Genova, Italy

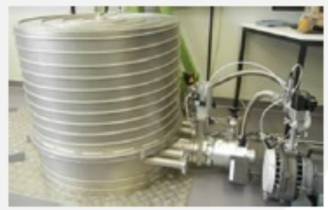
Real calorimeters

A high precision calorimeter for the SOX experiment

Laszlo Papp on behalf of TUM/Genoa SOX calorimeter collaboration

Convection

- Vacuum tank. 10^{-4} mbar or lower pressure.
- Screws are vented and Silver coated.
- Robust flange with elastic O-ring.
- Powerful, big inlet size (100mm) turbomolecular pump mounted directly on tank.
- Gate valve gives a possibility to isolate the vacuum tank.
- Oil free scroll pump for pre-vacuum



Conduction

- The heat exchanger located on a stainless steel plate held by three Kevlar ropes (breaking test 7t/each).
- Conduction $\dot{Q} = \lambda \cdot A/d \cdot \Delta T < 0.4\ \mathrm{mW}$ with λ=0.04W/m, A=6·2cm², d=0.3m

Radiation

- 20mm thick Copper – Guaranties a homogenous heat distribution.
- Stainless steel pipe is brazed into the Copper. Resistant for the coolant high purity water, and brazing gives good heat contact.
- The outer surface of the tank is equipped with a stainless steel spiral pipe for temperature compensation.
- Two stages of heat radiation shields. They are made of 10 layers super insulator each.
- Radiative heat loss is lower than 30 mW:

$$P \approx \frac{\sigma \cdot A_1 (T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_S} - 1 + (N-1)\cdot(\frac{2}{\varepsilon_S} - 1) + \frac{A_1}{A_2}\cdot(\frac{1}{\varepsilon_S} + \frac{1}{\varepsilon_2} - 1)}$$

A: surface area; ε: emissivity; N: number of shields

Thermal simulations
Copper temperature with water cooling (left)
Cutaway of the tungstate showing the heat distribution (right)