Dual Readout Calorimetry with Heavy Glasses in T1015 Collaboration

Corrado Gatto

Outlines

- Applications of T1015 R&D
  - Hadronic calorimetry at HEF and high performance calorimetry at HIF
- Dual-readout calorimetry
  - Principles, rationale and techniques
- Status of T1015 R&D
  - ILCroot simulations
  - Test beam results
- 2012-2013 prospects
  - R&D on construction techniques
  - Construction and tests of new cells
- *Fermilab involvement*

T1015 Collaboration at FNAL (32 Members)

Institution	Collaborator
INFN Trieste/Udine and University of Udine	Diego Cauz
	Anna Driutti
	Giovanni Pauletta
	Lorenzo Santi
	Walter Bonvicini
	Aldo Penzo
Fermilab	Erik Ramberg
	Paul Rubinov
	Eileen Hahan Anna Pla Greg Sellberg Donatella Torretta
	Hans Wenzel
	Gene Fisk
	Aria Soha Anna Mazzacane Benedetto Di Ruzza (now at BNL)
INFN Lecce	Corrado Gatto
	Vito di Benedetto Antonio Licciulli Massimo Di Giulio Daniela Manno Antonio Serra
INFN and University Roma I	Maurizio Iori
University of Salerno	Michele Guida
	NEITZERT Heinrich Christoph
	SCAGLIONE Antonio
	CHIADINI Francesco

University of Modena	Cristina Siligardi
	Monia Montorsi
	Consuelo Mugoni
	Giulia Broglia

Fermilab
+
INFN
Collaboration

Applications of T1015 R&D

- Main focus is heavy glasses in several flavours (>5.5 g/cm^3, Bi based, scintillating, light capture techniques, SiPM readout, etc.)
- HE Frontier: hadronic calorimetry with $\sigma_E/E <$ 30%sqrt(E)
  - Required to disentangle W from Z jets
  - Dual readout calorimetry is one solution

Well established T1015 R&D since 2010

- HI Frontier: precision EM calorimetry
  - Needs sensitivity in the few meV – 100 MeV range
  - < 5 nsec detector response
  - Will benefit from dual readout technology

New R&D
Mostly driven from ORKA
Part of ORKA R&D after CD0

Performance Requirements at Future Colliders

Jet energy resolution (W/Z invariant mass reconstruction from jets)

→ 1/2 w.r.t. LHC

Impact parameter resolution for flavor tag (c/b-tagging in background rejection/signal selection)

→ 1/2 resolution term, 1/7 M.S. term w.r.t. LHC

Transverse momentum resolution for charged particles (e.g. Z mass reconstruction from charged leptons)

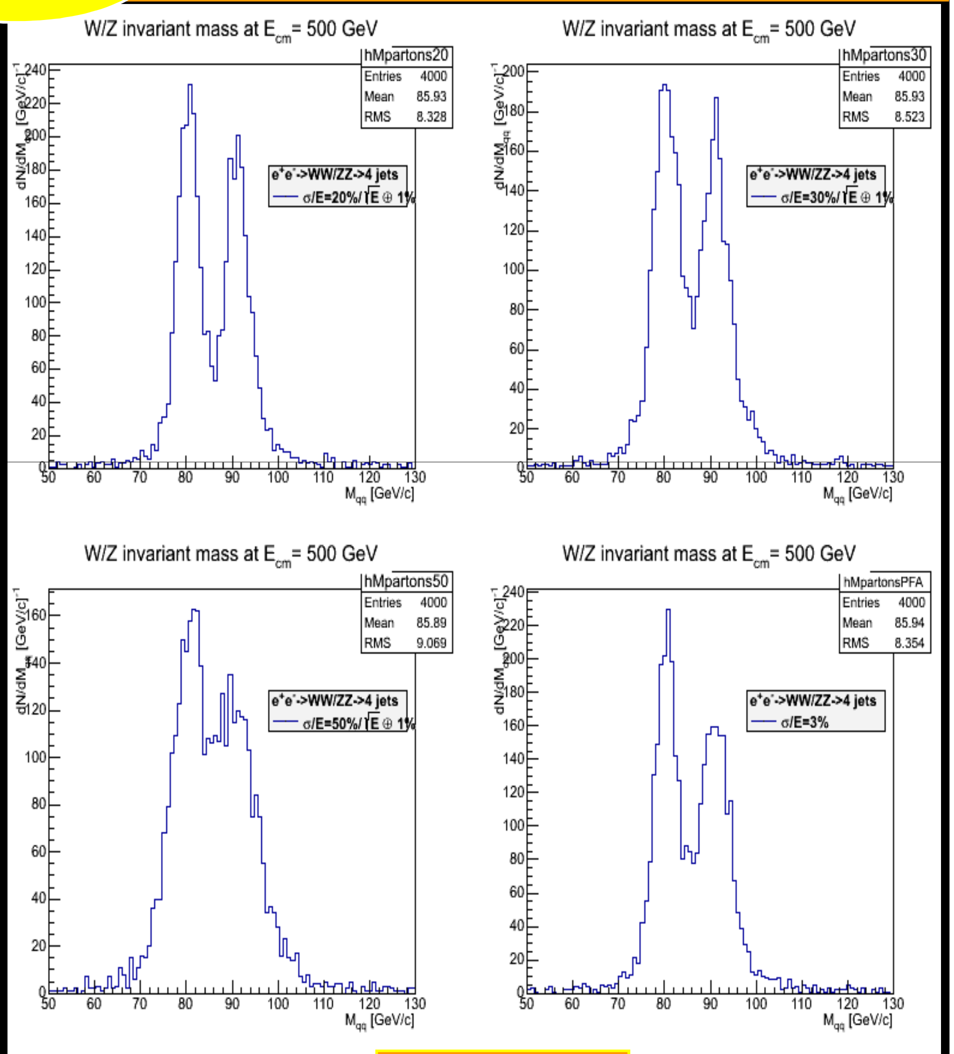
→ 1/10 momentum resolution w.r.t. LHC

Hermeticity (for missing energy signatures e.g. SUSY)

Sufficient timing resolution to separating events from different bunch-crossings or from beam background

Toy Montecarlo

W/Z separation at ILC

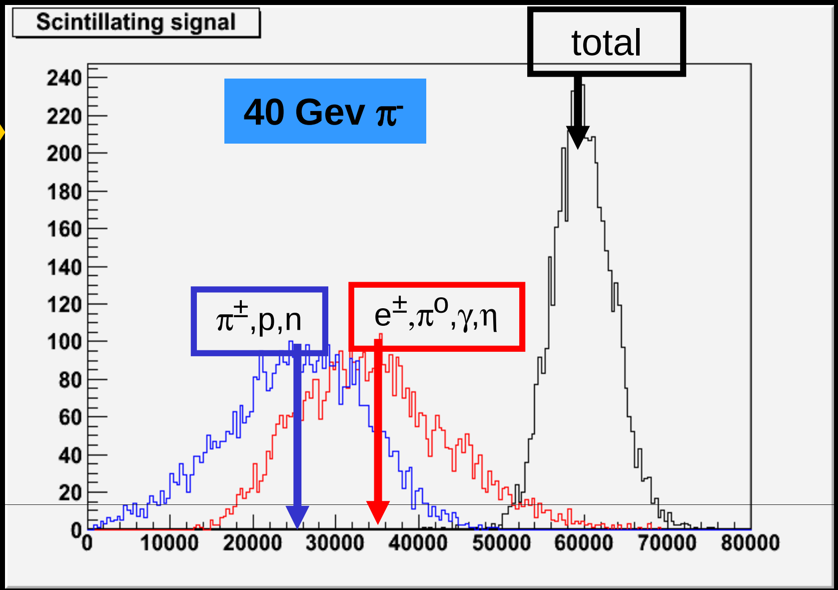


$$e^+e^- \to W^+W^-\nu\bar{\nu}, Z^0Z^0\nu\bar{\nu}$$
$$E_{cm} = 500 GeV$$

The Major Source of Fluctuations in Hadronic Showers: *fem*

ILCroot simulations

EM and non-EM Responses In scifi sampling calorimeter



***fem* is:**

1) Energy dependent -> the calorimeter is non linear
2) Fluctuating event-by-event -> the energy resolution is non gaussian if $\eta_s \sqrt{\neq} \eta_c$

- Different detector response to EM and non-EM is parameterized via $\eta=(e/h)$
- η depends heavily on the detector and on signal production mechanism

Ex.: $\eta_{scifi} \sim 1.2$ $\eta_{Cerenkov} \sim 3.5$

- If your calorimeter has only one readout, you cannot disentangle *e* and *h*

Dual readout: two calorimeters with different η's sharing the absorber

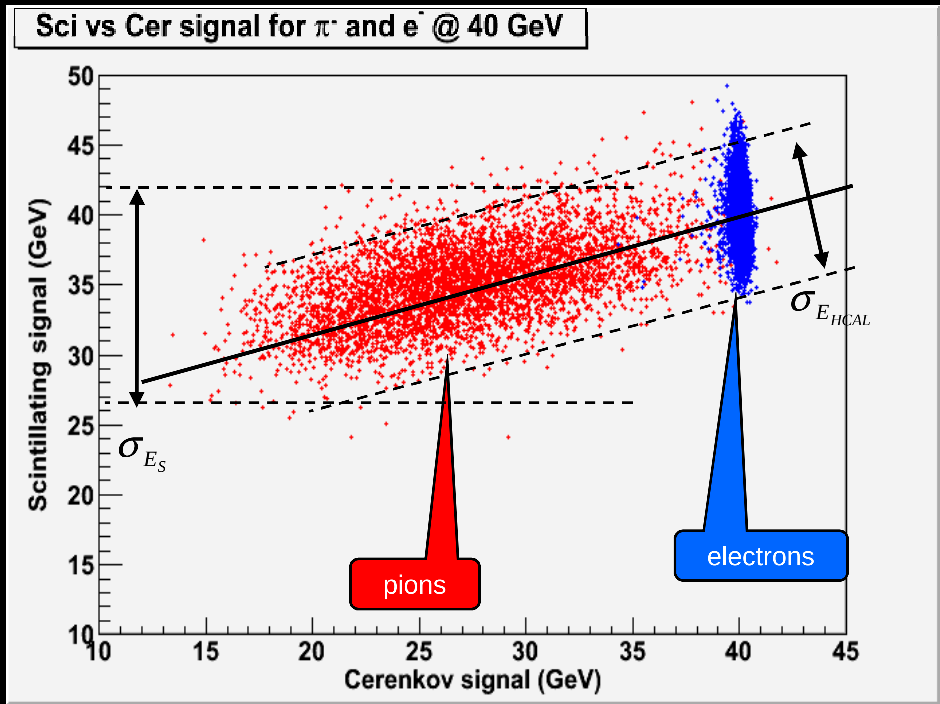
Must be sensitive in different ways to EM and HAD shower components (ex.: scintillation and Cerenkov signals)

Dual Readout Calorimetry from a Different Perspective

If $\eta_s \neq \eta_c$ then the system can be solved for E_{HCAL}

Dual Readout is nothing but a rotation in E_S - E_C plane

ILCroot simulations

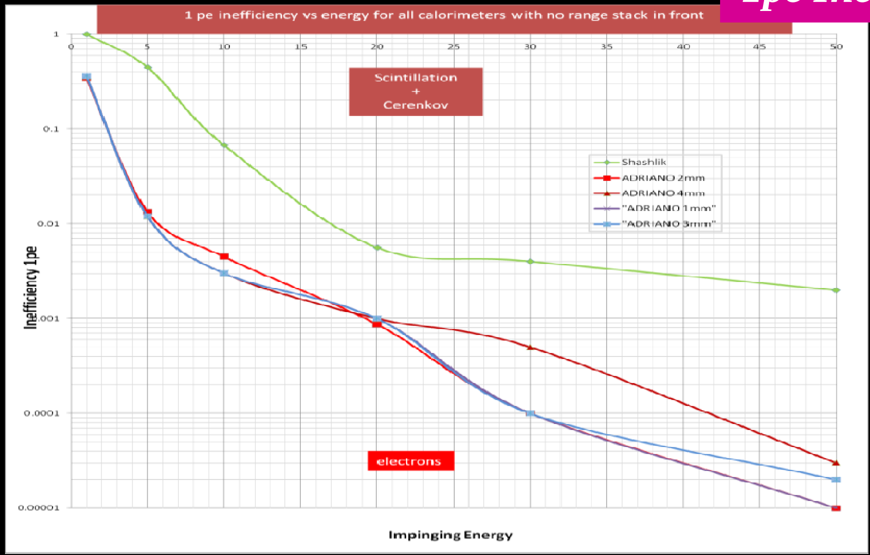


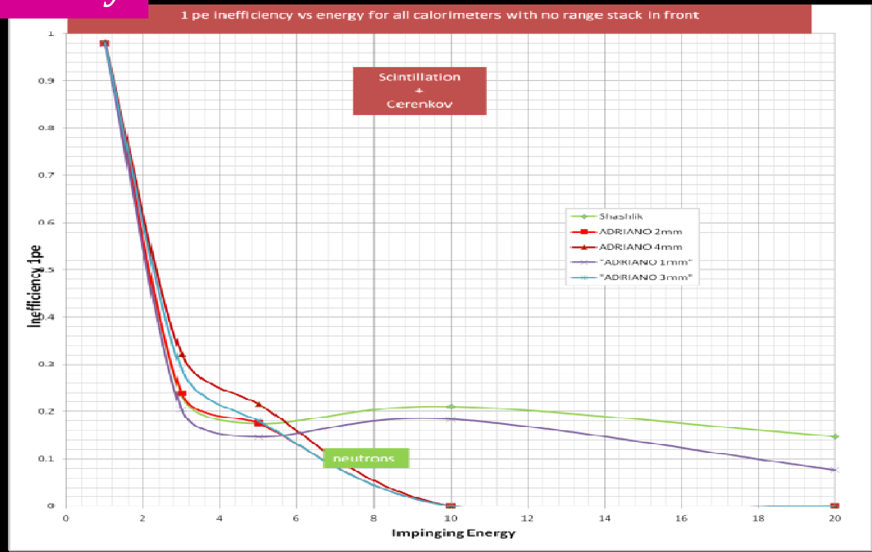
Anna Mazzacane
Vito Di Benedetto

ILCroot simulations

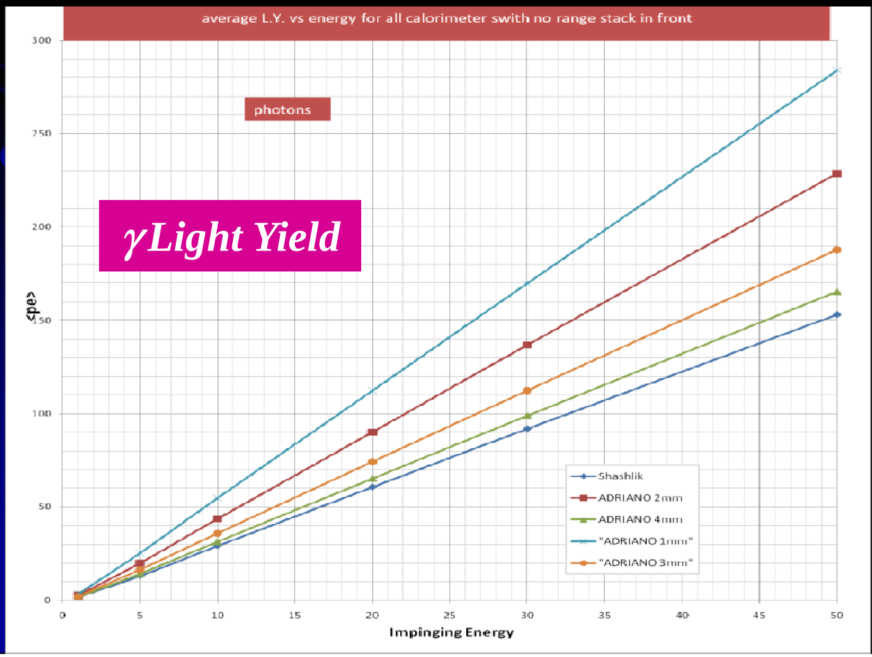
ADRIANO vs Shashlyk at ORKA

1pe Inefficiency

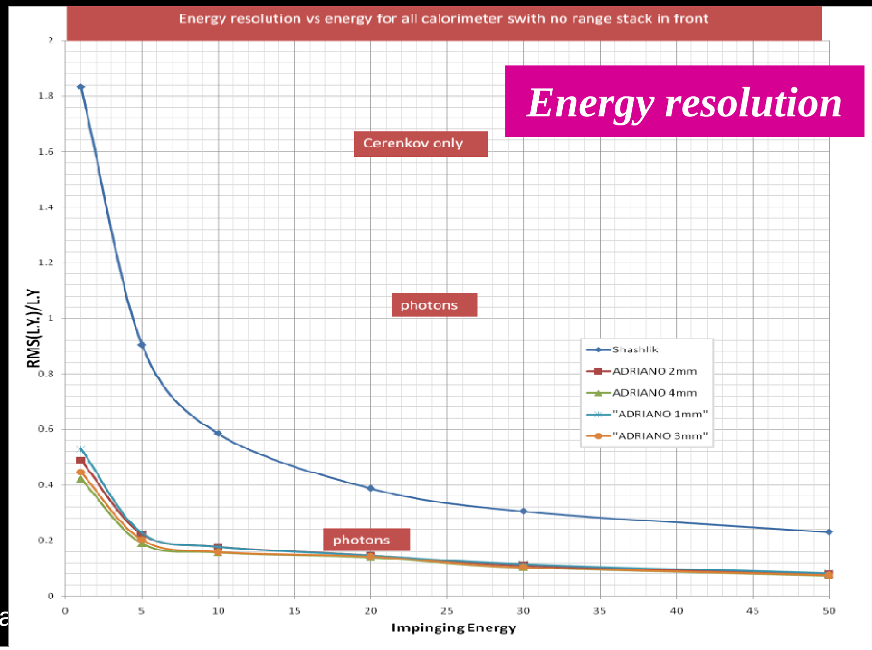




γLight Yield



Energy resolution



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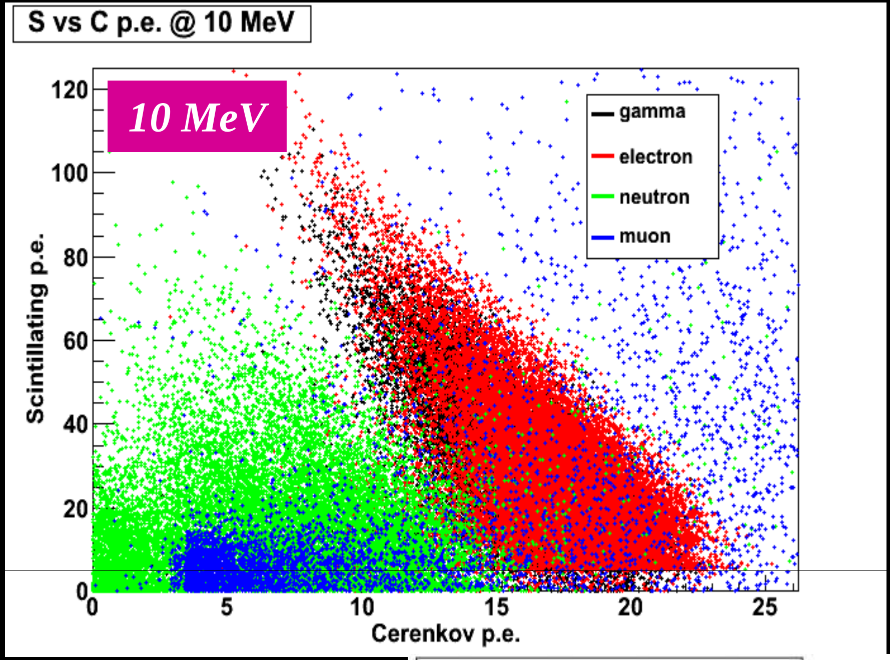
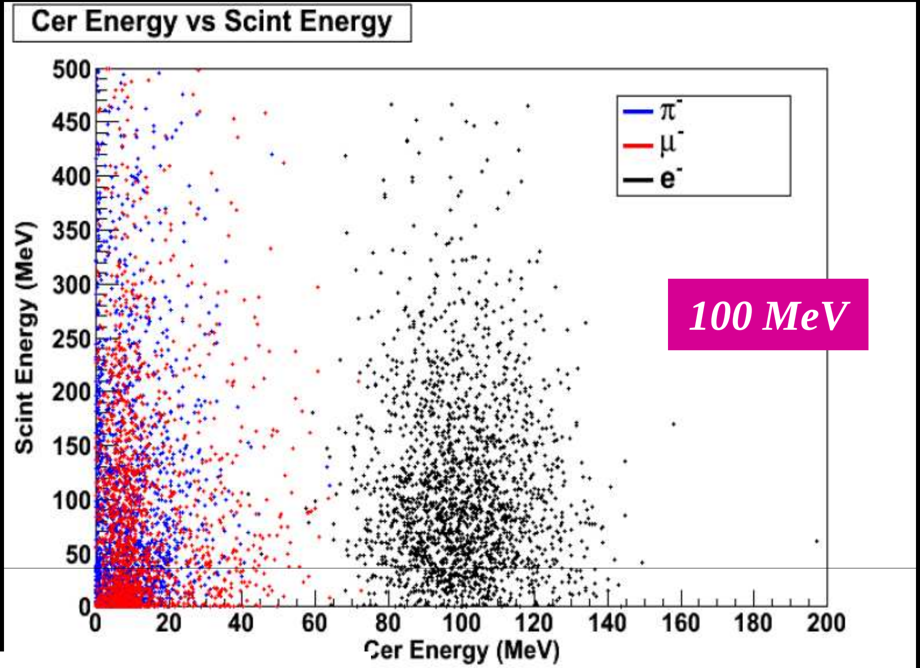
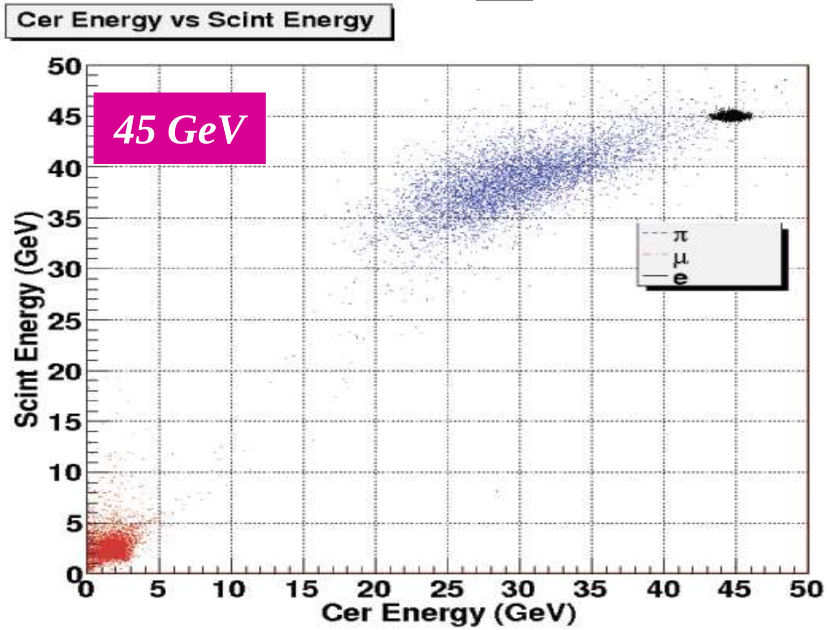
Vito Di Benedetto

ILCroot simulations

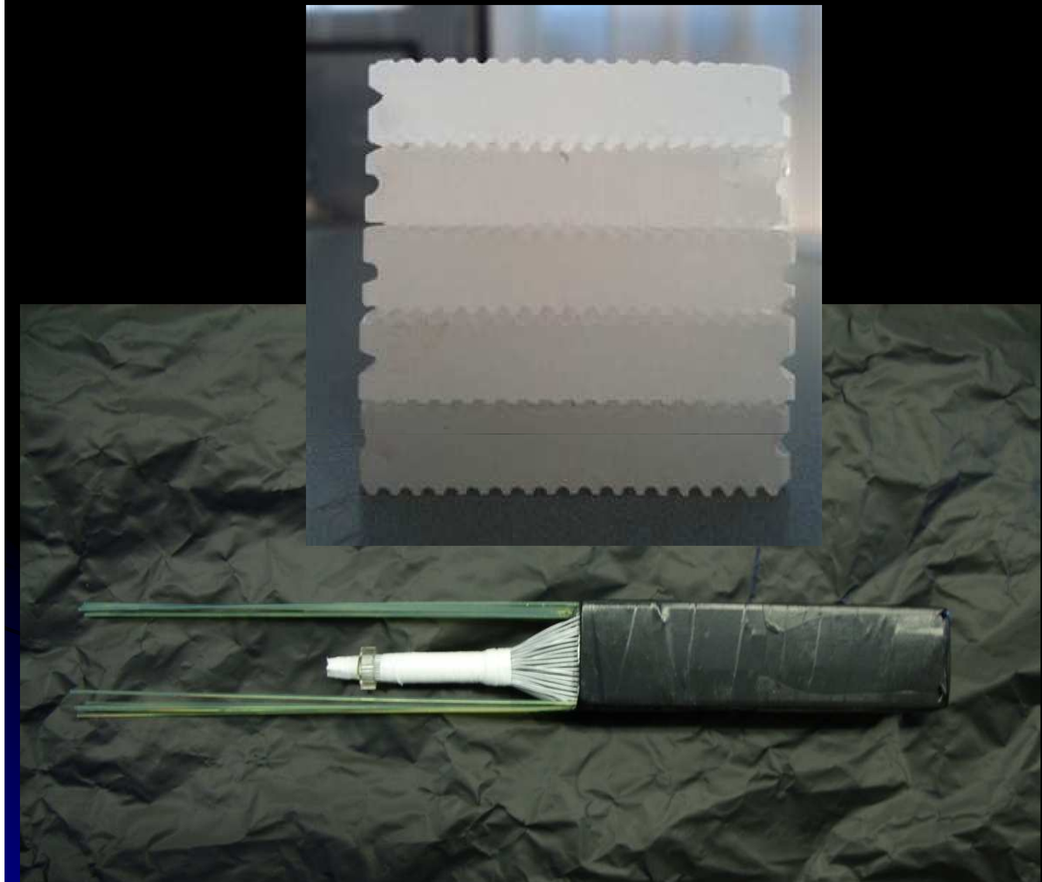
Particle ID with ADRIANO







ADRIANO: A Dual-Readout Integrally Active Non-segmented Option



- Fully modular structure
- 2-D with longitudinal shower CoG via light division techniques

- **Cells dimensions**: $4x4x180\ cm^3$
- **Absorber and Cerenkov radiator**: lead glass or bismuth glass ($\rho > 5.5\ gr/cm^3$)
- **Cerenkov light collection:** 10/20 WLS fiber/cell
- **Scintillation region**: scintillating fibers, dia. 1mm, pitch 4mm (total 100/cell) optically separated from absorber
- **Particle ID**: 4 WLS fiber/cell (black painted except for foremost 20 cm)
- **Readout**: front and back SiPM (Scifi only)
- **CoG z-measurement**: light division applied to SCSF81J fibers (same as CMS HF)
- **Small $tg(\theta_{S/Q})$**: due to WLS running longitudinally to cell axis ($\theta_{Cerenkov} < \theta_{Snell}$ for slower hadrons).

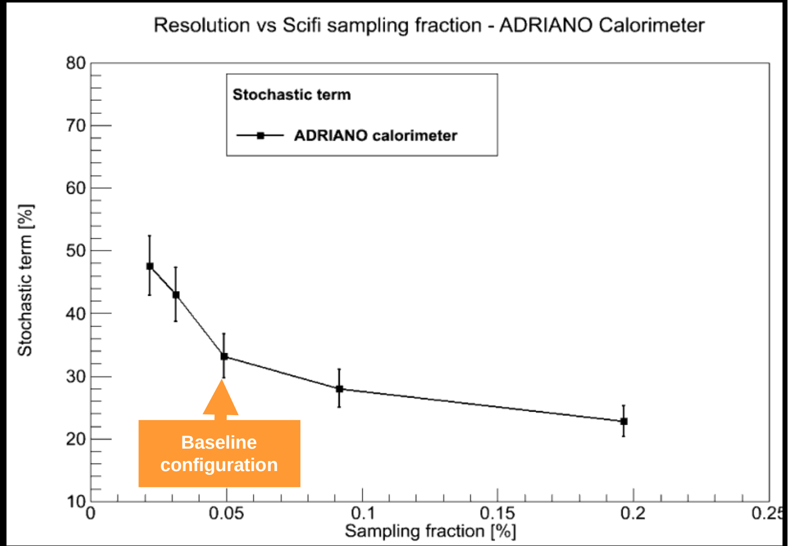
ILCroot simulations

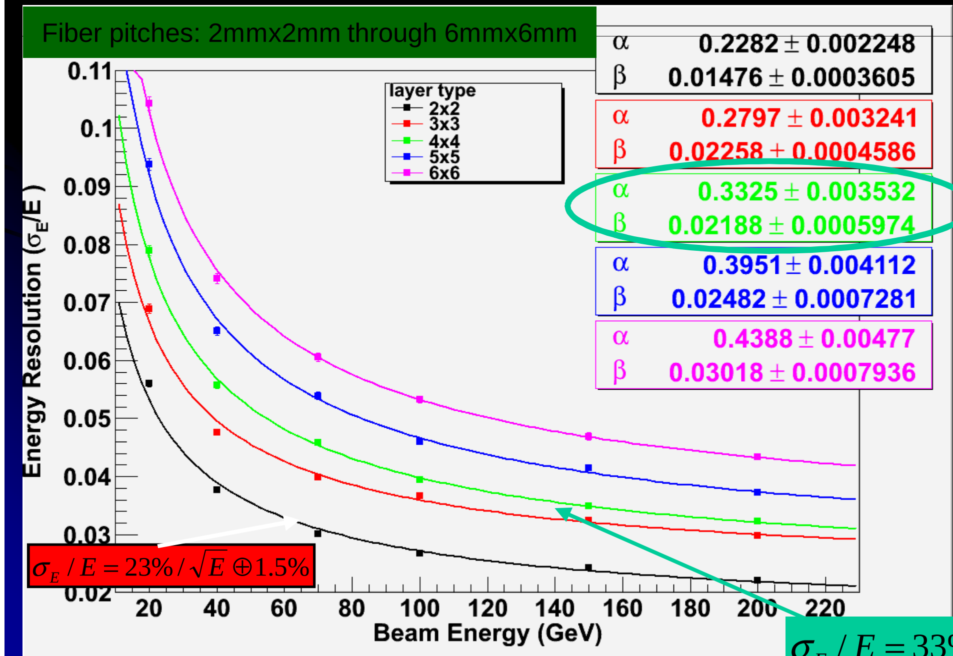
ADRIANO Light Yield and Resolution

Integrally Active with Double side readout (*ADRIANO*)									Sampling
Pitch [mm^2] Diameter	2x2 1mm	3x3 1mm	4x4 1mm	5x5 1mm	6x6 1mm	4x4 1.4mm	4x4 2mm	4x4 capillry	Sampling
<pe$_S$/GeV>	1053	430	254	163	124	500	110	250	200
<pe$_C$/GeV>	340	360	360	355	355	355	350	350	7.5

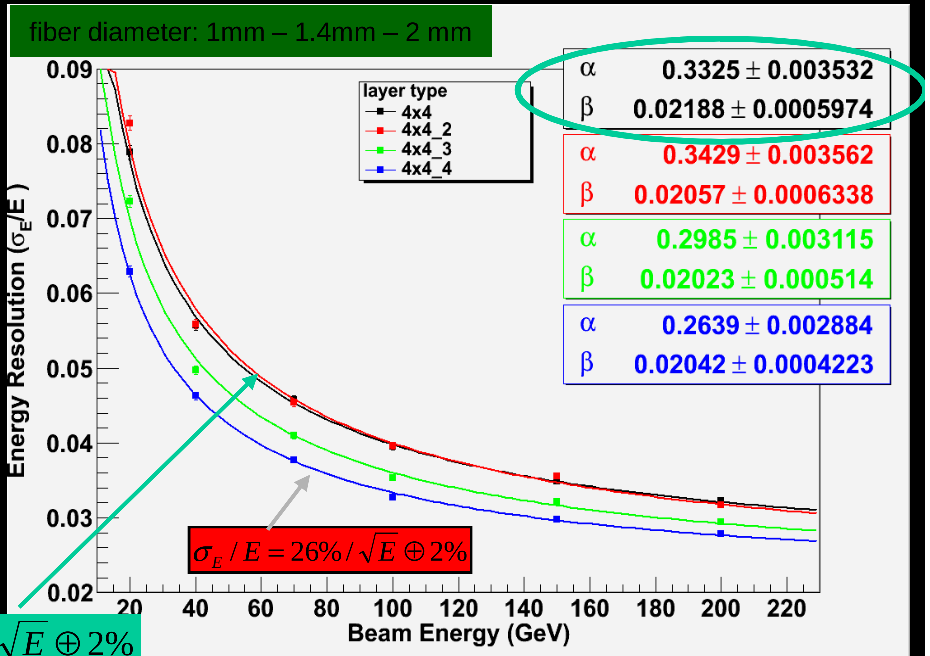
Baseline configuration

1-side readout





$\sigma_E / E = 33\% / \sqrt{E} \oplus 2\%$



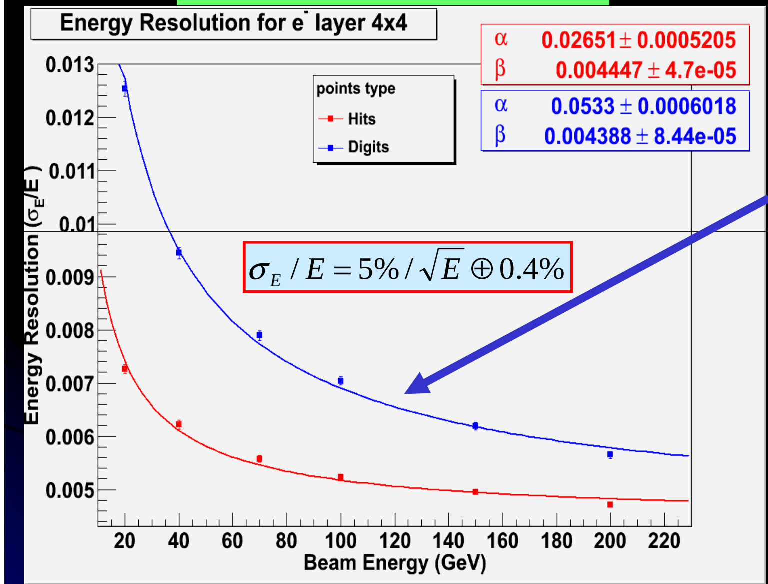
All numbers include the effect of photodetector QE

ILCroot simulations

ADRIANO EM Resolution (with and without instrumental effects)

- Compare standard Dual-readout method vs Cerenkov signal only (after electron-ID)
- Blue curve includes instrumental effects. Red curve is for perfect readout

Use only Cerenkov light

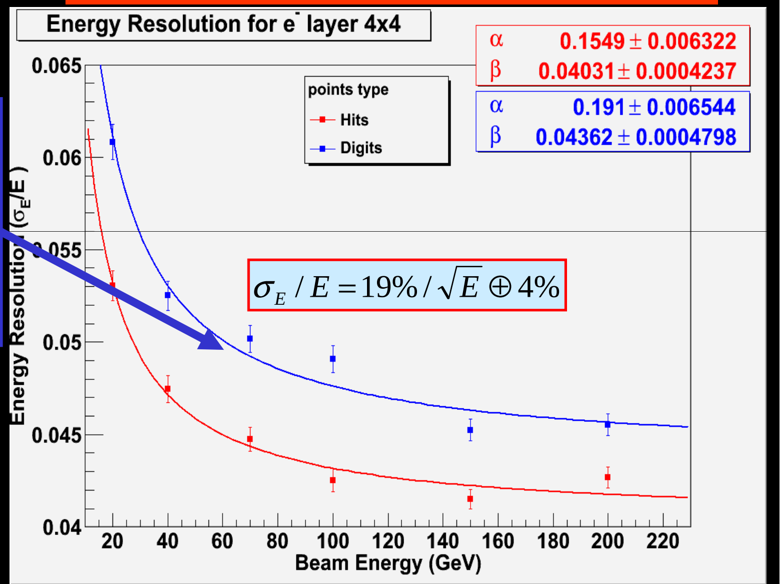


Blue curve includes:

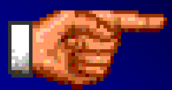
- **SiPM's ENF**
- **Constant noise**
- **Fiber non-uniformity**
- **14 bit ADC**
- **3pe threshold**

ILCroot simulations

Dual-readout (scintillating+Cerenkov)



- Using Cerenkov signal only for EM showers gives **5%/√E** energy resolution while full fledged dual-readout gives only **19%/√E** (including FEE effects)



ADRIANO does not need a front EM section

If Cerenkov ligth yield is large enough

Preliminary

11 Prototypes Performance Summary

Prototype	Glass	gr/cm^3	L. Y.	Notes
5 slices, machine grooved, unpolished, white	**Schott SF57HHT**	**5.6**	82	SiPM readout
5 slices, machine grooved, unpolished, white, v2	**Schott SF57HHT**	**5.6**	84	SiPM readout
5 slices, precision molded, unpolished, coated	**Schott SF57HHT**	**5.6**	55	15 cm long
2 slices, ungrooved, unpolished, white wrap	**Ohara BBH1**	**6.6**	65	
5 slices, scifi silver coated, grooved, clear, unpolished	**Schott SF57HHT**	**5.6**	64	15 cm long
5 slices, scifi white coated, grooved, clear, unpolished	**Schott SF57HHT**	**5.6**	120	
10 slices, white, ungrooved, polished	**Ohara PBH56**	**5.4**	30	DAQ problems
10 slices, white, ungrooved, polished	**Schott SF57HHT**	**5.6**	76	
5 slices, wifi Al sputter, grooved, clear, polished	**Schott SF57HHT**	**5.6**	30	2 wls/groove
5 slices, white wrap, ungrooved, polished	**Schott SF57HHT**	**5.6**	158	Small wls groove
2 slices, plain, white wrap	**Ohara experimental**	**7.5**	-	DAQ problem

- Analysis still ongoing
- Calibration problematic for DAQ issues and degrading of PMTs from He leaks
- Need further confirmation of the results

Summary of T1015 R&D Status

- ADRIANO for HEF
  - **11 prototypes built and tested**
  - ρ_{glass}= 5.3 - 7.5 g/cm3
  - L.Y= 30 pe/GeV – 158 pe/GeV

ADRIANO proof of principle succeeded

T1015 talks at IWL2010, LCWS11, TIPP2011, CALOR2012, LCWS2012

- ADRIANO for HIF
  - Simulations completed
  - Requires x5 – x10 compared to existing prototypes
  - Need to build and test a dedicated prototype
  - Also important to involve INFN in ORKA
  - Timing is important in this respect (given INFN funding scheme)

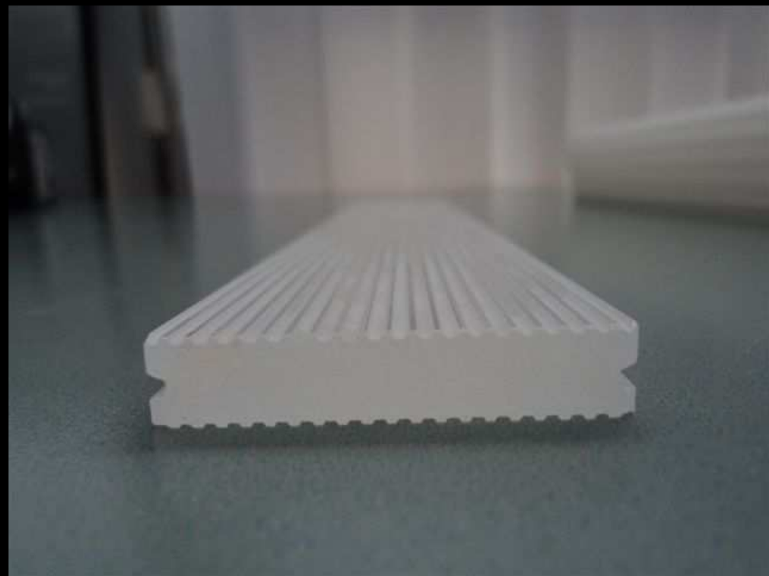
T1015 Research Program for SY2012-2013

- **Focus is on construction techniques: goal is finding a quick and cheap**
- One (of 5) is strongly privileged: precision glass molding
- Staged program: each stage will produce 1-4 cells (for FTBF) with a specific layout
- HIF development is a by-product of existing HEF R&D (with about 20-30% overhead)
- No plans to extend the program past SY13 (banned major disruptions)
- Next step will be the construction of a 1-2 ton prototype (or ORKA PV). Considerable bigger project (non expected to be off KA15)

Fabrication Technology #1: Diamond tools machining

- Pro
  - Minimal R&D required
  - Room temp (min effect on n_D)
  - It allows construction of longer cells

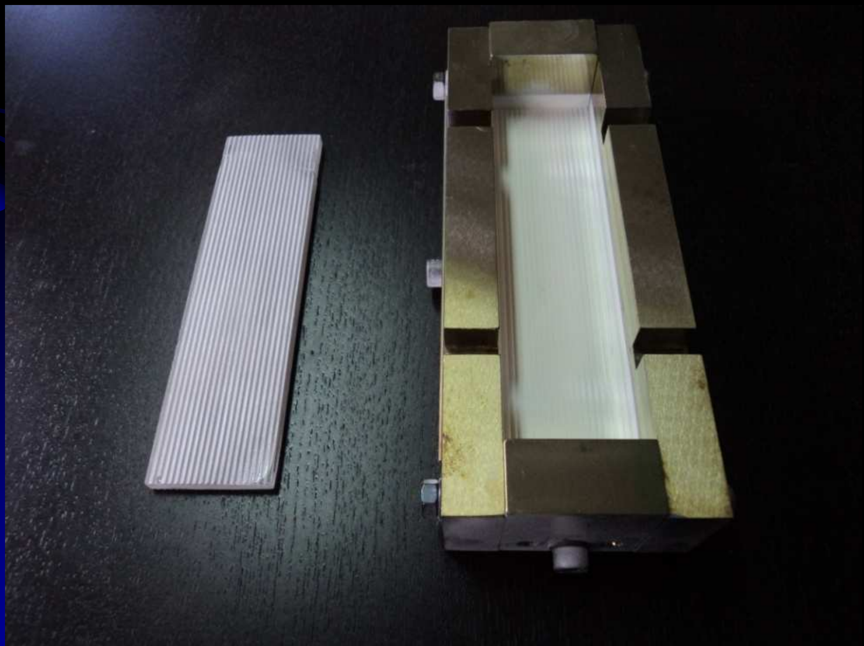
- Cons
  - Longer fabrication process
  - Large waste
  - Surface finish is ground

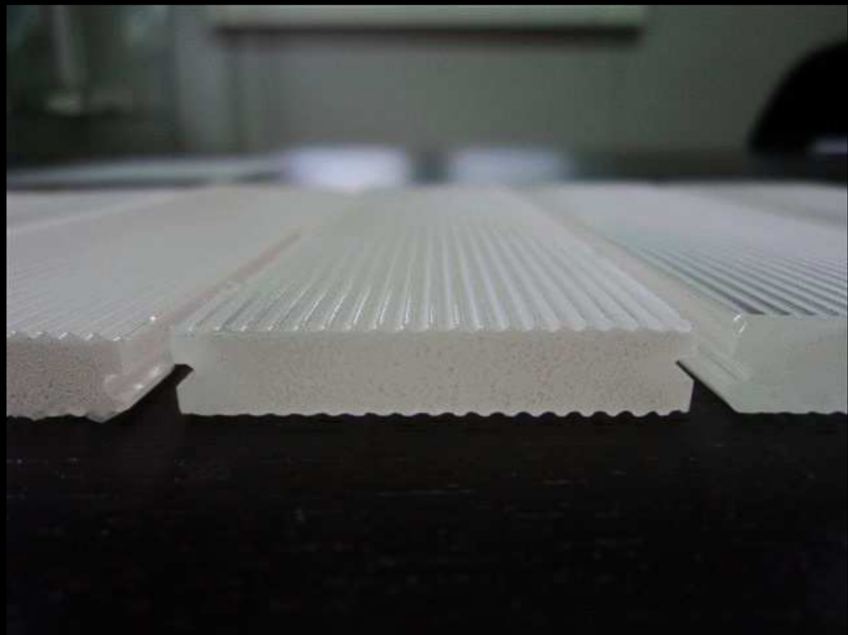


Fabrication Technology #2: Precision molding

- Pro
  - Cheapest and fastest (15 min)
  - Optical finishing with no extra steps
  - Low temp cycle (min effect on n_D)

- Cons
  - Molds are expensives
  - Lots of R&D

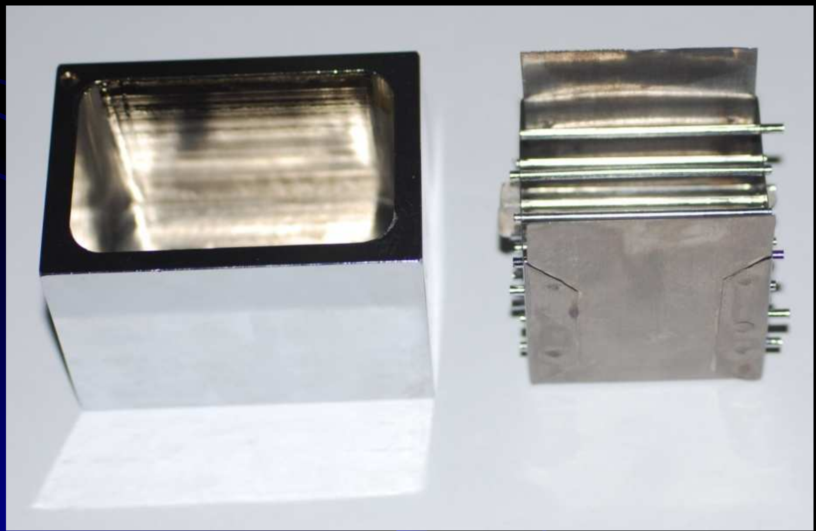




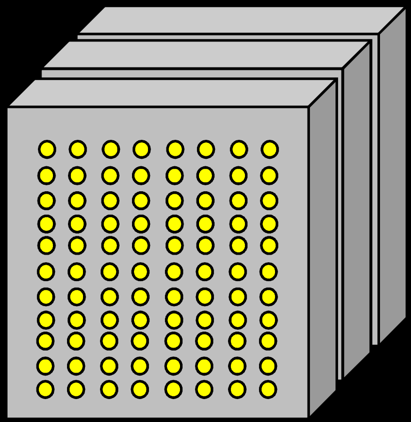
Fabrication Technology #3: Glass melting

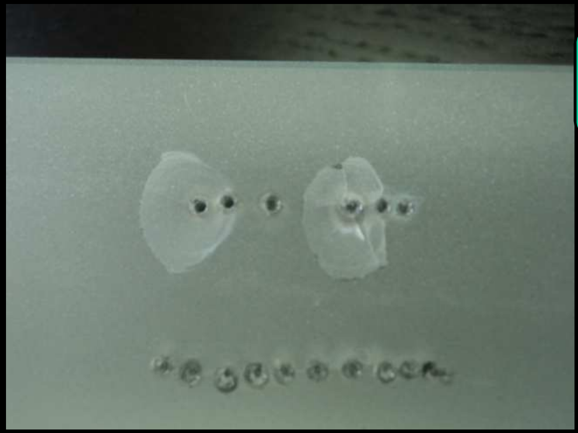
- Pro
  - Build entire cell in one step
  - Very robust mechanical structure

- Cons
  - High temperature cycle
  - Extra passive material
  - Easy to get glass defects



Fabrication Technology #4: Laser + diamond drilling

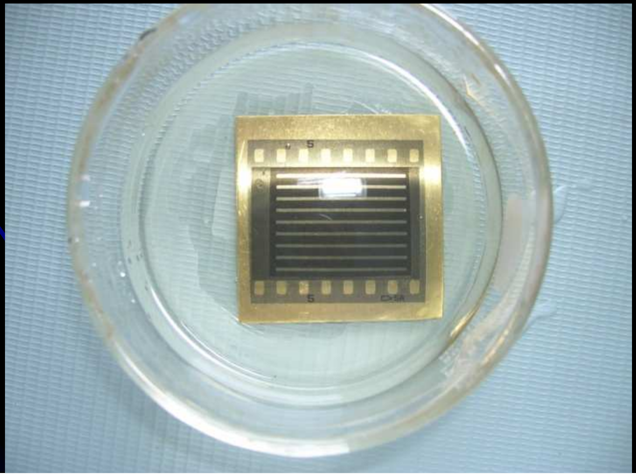




Nd-YAG laser

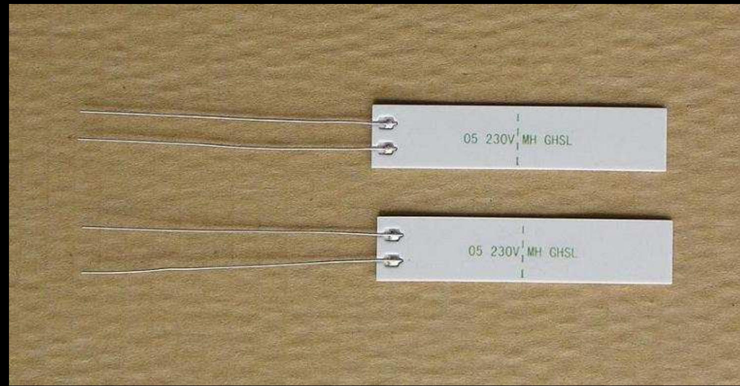
SALENTEC advanced technologies

Fabrication Technology #5: Photo-etching

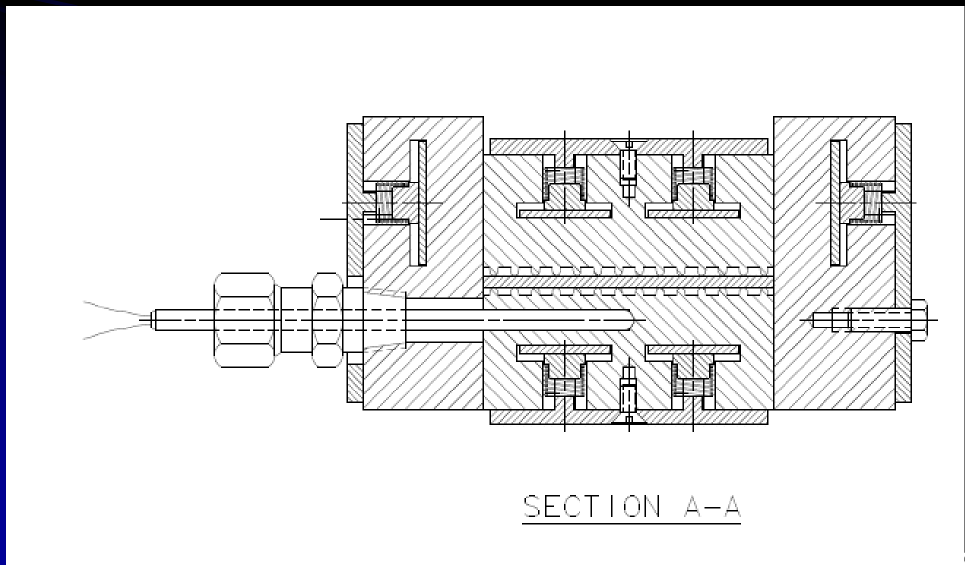


Apparatus For precision Glass Molding

- Steps involved in mold fabrications
  - Machining and grinding of raw inconel bars
  - Polishing of surfaces
  - Pt sputtering
  - Chamber for mold pressing (from FNAL excess)



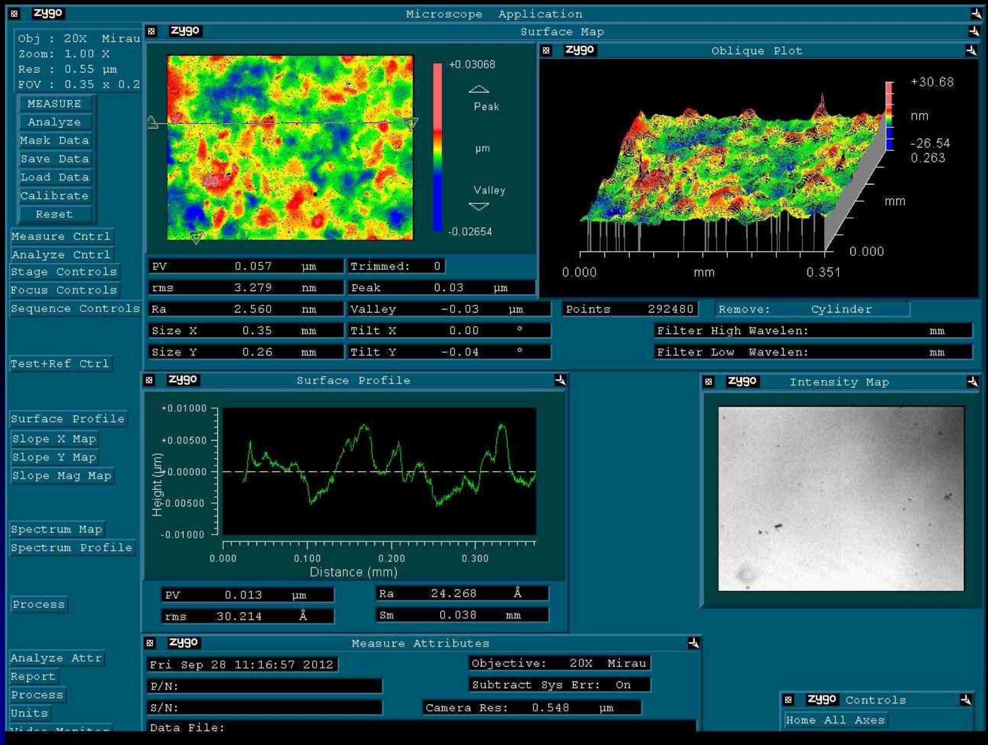
Large-Area Psec Photo-Detectors
Dean Walters Bob Wagner Argonne National Laboratory
Marc Kupfer University of Illinois of Chicago
Vacuum Vessel for Indium cold seal.

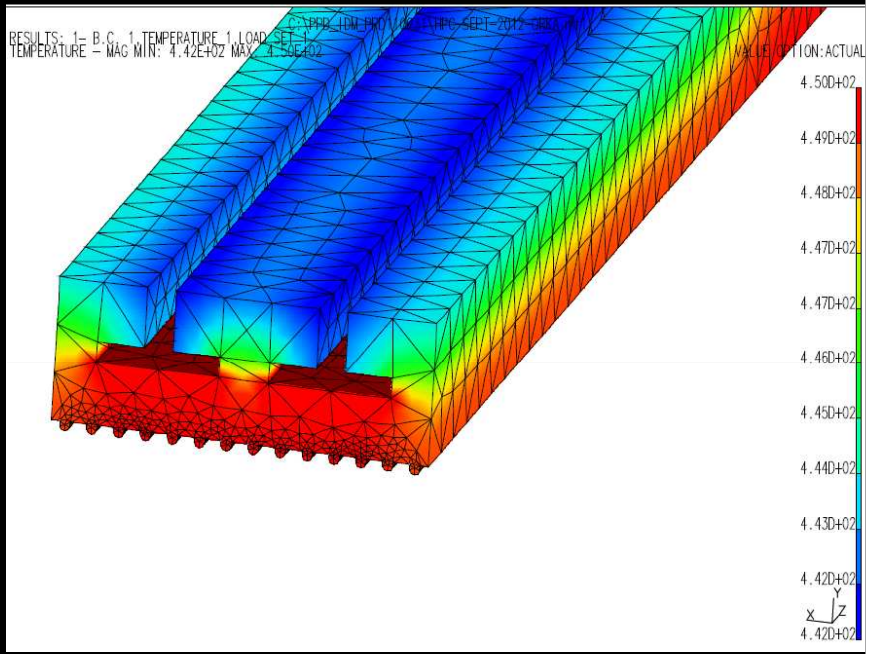


H. Cease
W. Cyko

Status of Mold R&D

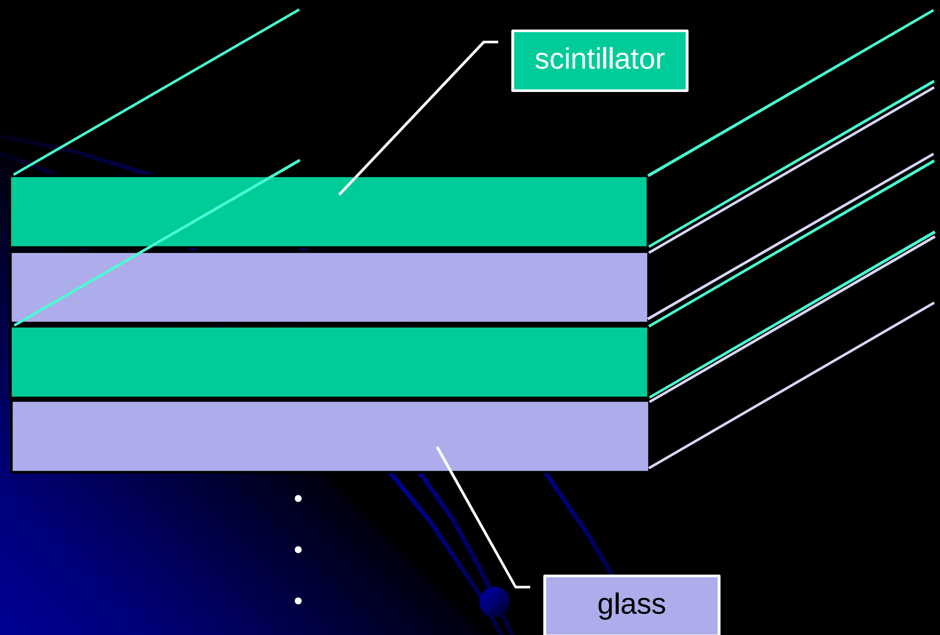
- Most critical steps are defined





Stage Ia: ORKA single-readout

- Goals:
  - Construction of simplest mold
  - Starting setup for stage II and III
  - Construction and test of two 4.6x4.6x27 cm^3 cells



Mold construction

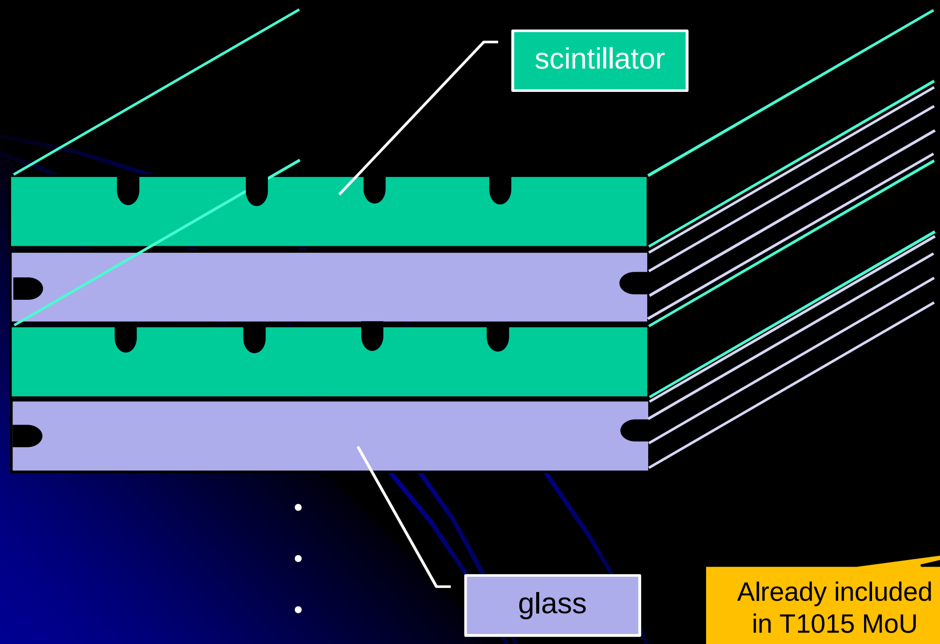
Items	Cost	Funds
Purchase of mold parts	$4000	INFN
Mold Machining & grounding	65-75 hrs x $75/hrs	FNAL
Polishing	$5000	INFN
Pt sputtering	See summary	FNAL
Setup of pressure chamber	See summary	FNAL

Cell construction

Items	Cost	Funds
Glass blocks (shipping)	$300	INFN
Cut and Blanchard	$400	INFN
Diamond saw setup	7 hrs	FNAL
Slicing 20+2 slabs	11 hrs	FNAL
Molding 20 slabs	20 hrs	FNAL/INFN
Scintillators purchase	$ 4000	INFN
Scintillators cutting & P4	28 hrs	FNAL
Cell assembly	15 hrs	INFN

Stage Ib: dual –readout with flat glass

- Goals:
  - Add WLS light capture
  - **Reuse existing mold**
  - Construction and test of two 4.6x4.6x27 cm^3 cells
  - Some of the costs could be avoided by reusing the glass from stage Ia



Mold construction

none

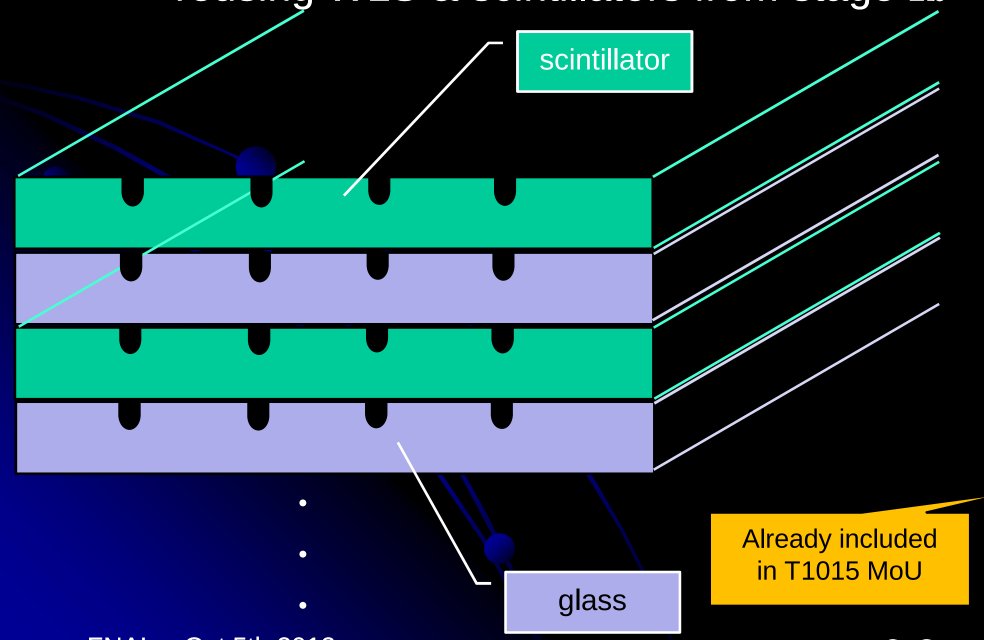
Cell construction

Items	Cost	Funds
Glass blocks (shipping)	$300	INFN
Cut and Blanchard	$400	INFN
Slicing 20+2 slabs	11 hrs	FNAL
Molding 20 slabs	20 hrs	FNAL/INFN
Grooving 20 slabs	$600	INFN
Scintillators purchase	$ 4000	INFN
Scintillators cutting & grooving	40 hrs	FNAL
140 WLS cut & polish	50 hrs	FNAL
Cell assembly	15 hrs	INFN

Already included in T1015 MoU

Stage II: dual-readout with grooved glass

- Goals:
  - Same as Ib but grooves are added during molding
  - **<u>It requires the replacement of mold plunger only</u>**
  - Construction and test of one 4.6x4.6x27 cm^3 cells
  - Some of the costs could be avoided by reusing WLS & scintillators from stage Ib



Mold construction

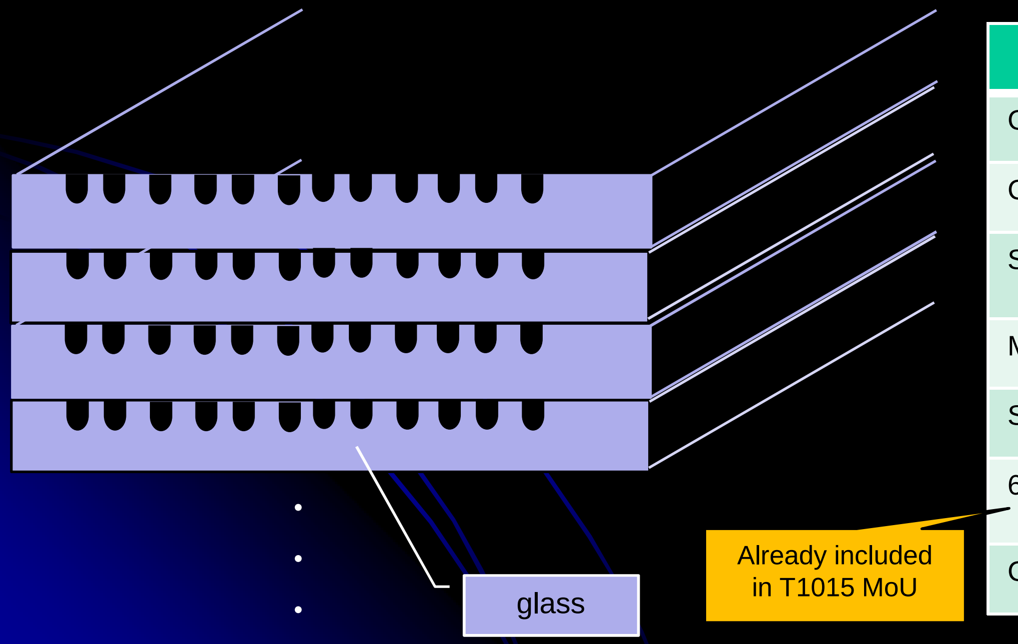
Items	Cost	Funds
Purchase of inconel	$400	INFN
Mold Machining & grounding	10 hrs x $75/hrs	FNAL
Polishing	Wait Cabot quote	INFN
Pt sputtering	See summary	FNAL
Add press to chamber	See summary	FNAL

Cell construction

Items	Cost	Funds
Glass blocks (shipping)	$150	INFN
Cut and Blanchard	$400	INFN
Slicing 10+1 slabs	6 hrs	FNAL
Molding 10 slabs	10 hrs	FNAL/INFN
Scintillators purchase	$ 4000	INFN
Scintil. cutting, grooving & P4	22 hrs	FNAL
100 WLS cut & polish	36 hrs	FNAL
Cell assembly	7 hrs	INFN

Stage III: ADRIANO for HEF

- Goals:
  - Construction of most complex mold
  - **It requires the replacement of mold plunger and bottom only**
  - Construction and test of four 4.6x4.6x27 cm^3 cells



Mold construction

Items	Cost	Funds
Purchase of inconel	$400	INFN
Mold Machining & grounding	20 hrs x $75/hrs	FNAL
Polishing	Wait Cabot quote	INFN
Pt sputtering	See summary	FNAL

Cell construction

Items	Cost	Funds
Glass blocks (shipping)	$600	INFN
Cut and Blanchard	$800	INFN
Slicing 40+4 slabs	22 hrs	FNAL
Molding 40 slabs	40 hrs	FNAL/INFN
Scifi purchase	$ 1000	INFN
600 WLS cut & polish	200 hrs	FNAL
Cell assembly	28 hrs	INFN

Summary of Expected FNAL Support for FY2013

- As per "PROPOSAL FOR PRECISION CALORIMETRY R&D BASED ON HEAVY GLASSES: FY2013 (Rev. 1.0 –July 2nd 2012)"

FNAL – 2013 Budget	Amount	Classification
Cutting 100 glass slices	1.5 weeks	Labor
Cutting and CNC grooving 100 scintillating tiles	1.5 weeks	Labor
Cutting and diamond polish100 WLS tiles	1 week	Labor
Cut, polish and aluminize scifi & wls fibers	300 hrs	Labor
Thin film lab support (E. Hahn)	150 hrs	Labor
Assembly of new ADRIANO cells	2 week	Labor
Lab3 support (D. Butler)	4 weeks	Labor
Spectrometer, Chem. Lab & Mech. Support (lab.6)	3 months	Labor
G. Sellberg support	4 months	Labor
DAQ support (P. Rubinov)	2 weeks	Labor
Machining and polishing inconel molds	Under eval.	M&S
Diamond wire saw (s.j.)	$50,000	M&S

Part of T1015 MoU

Contingent to construction of 1-2 ton ADRIANO prototype

- Quotes reflect Stages 1-4 plus generic labor support extrapoleted from FY2012.

Compare with Costs of Commercial Firms

- All 11 prototypes built so far have been cut, grooved and polished at external firms: (Ohara, Salentec Cat-I-Glass)

Process	Comm. cost	FNAL labor
Cut to size (Ohara)	$282	$15
Polishing (Cat-I-glass)	$30	$45
Grooving top (Salentec)	$250	
Total	$560	$60

- Cost of raw SF57/PBH56 is $50-$100/lb
- Surface finish of grooves from mechanical process is ground: no firms accepted to do the polishing

Scintillating Glass

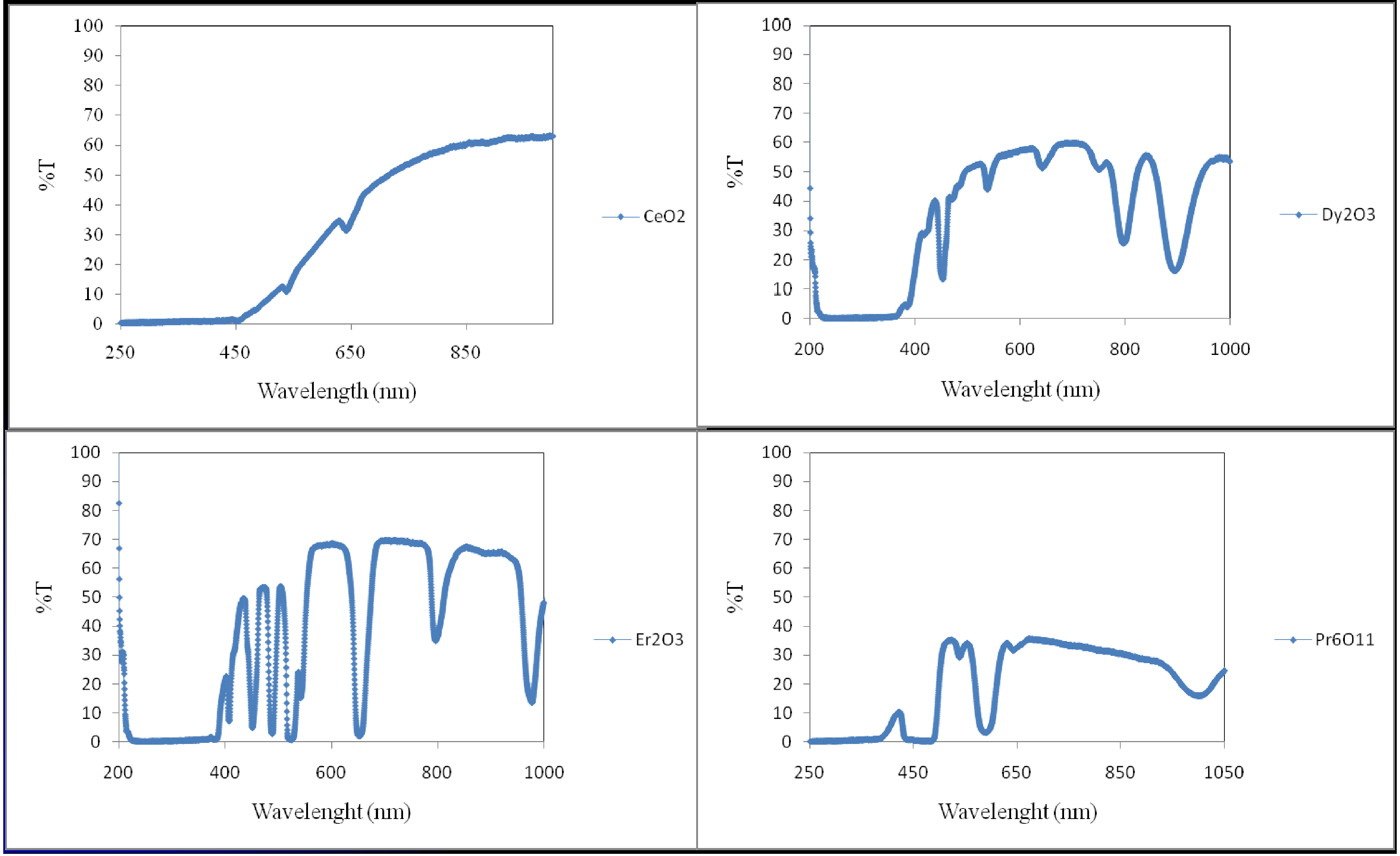
- Scintillation and Cerenkov at the same time in a totally homogeneous active absorber
- Major issues:
  - absorption lines in rare earths induce Č->S shift
  - Need high density glass
- Separate the two problems:
  - Fix the optical problem by finding the correct ratio of oxides
  - Increase the density with proper vetrous matrix (BiO and WO under consideration)
- Current status:
  - Several rare earth oxides tested: Dy_2O_3 promising (next slide)
  - BiO glass OK (6.6 gr/cm^3), WO unsuccesful (need a very high temp furnace)

Rare Earth Heavy Glasses

- Rare earths oxides + Ho_2O_3 + ZnO + P_2O_5+B_2O_3+SiO_2
- R.e. considered: CeO_2, Dy_2O_3, Nd_2O_3, Pr_6O_{11}, Er_2O_3

Composition	Density (g/cm^3)
CeO_2	3,3776
Pr_6O_{11}	3,7445
Dy_2O_3	3,8851
Er_2O_3	4,0690
Nd_2O_3	4,2441

Transmission Spectra



Department of Materials and Environmental Engineering

Conclusions

- *ADRIANO* dual-readout techniques is well established after four test beam at FTBF of 11 different cells
- Results from recent test beams prove that Cerenkov light readout from heavy glasses with WLS is feasible
- **Cerenkov ligth yield more than adequate for 30%/sqrt(E) calorimetry. Our goal is to make it even better for EM calorimetry**
- Next R&D will focus on construction techniques
- Besides calorimetry, novel techniques are exploited for capturing glass generated in heavy glasses

T1015 Collaboration and Fermilab

- Fermilab based T1015 collaboration was born in 2011
- It exploit new techniques based on heavy glass (no sampling calorimetry nor crystals)
- It covers R&D on a broad range of aspects related to high performance hadronic and EM calorimetry :
  - Production and characterization of large area SiPM
  - Custom FEE
  - Construction and tests of calorimeter prototypes
  - Total active multiple-readout calorimetry
  - Scintillating heavy glass for dual-readout homogeneous calorimetry
  - *ADRIANO* calorimetry
- It gathers 9 INFN institutions + Fermilab
- Support from Fermilab Detetector R&D Program has been of paramount importance during the initial (and risky) proof of principle phase
- Focus has shifted from scientific aspects to technical ones (no risk any more).Fermilab is even more important in this phase because of:
  - Excellent tech. staff for solving mechanical related problems
  - Thin film lab for WLS preparetion, sputtering, etc.
  - Spectroscopy lab for study of light detectors (Cerenkov, scintillating glass and scintillation)

Backup Slides

FNAL – Oct 5th 2012
C. Gatto
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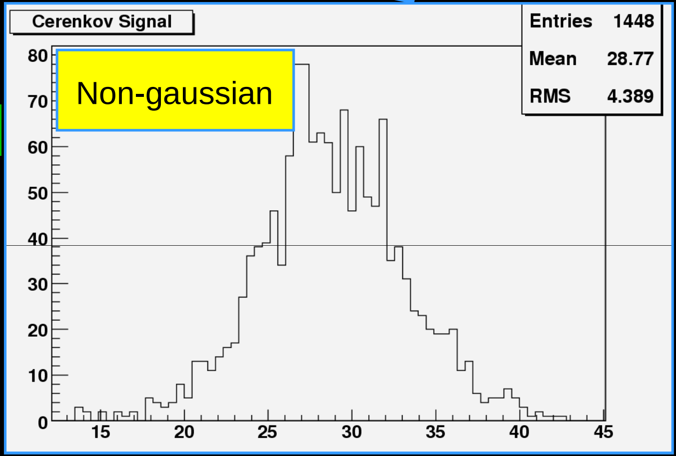
Dual Readout Calorimetry

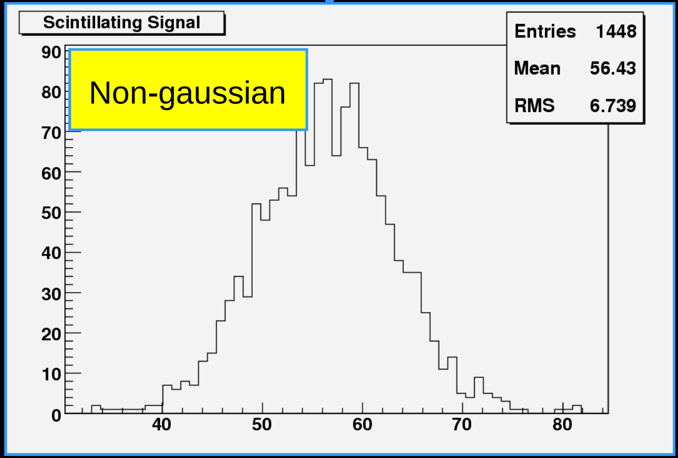
Total calorimeter energy: use two measured signals and two, energy-independent, calibration constants.

Dual Readout Calorimetry

Total calorimeter energy: use two measured signals and two, energy-independent, calibration constants.

ILCroot simulations

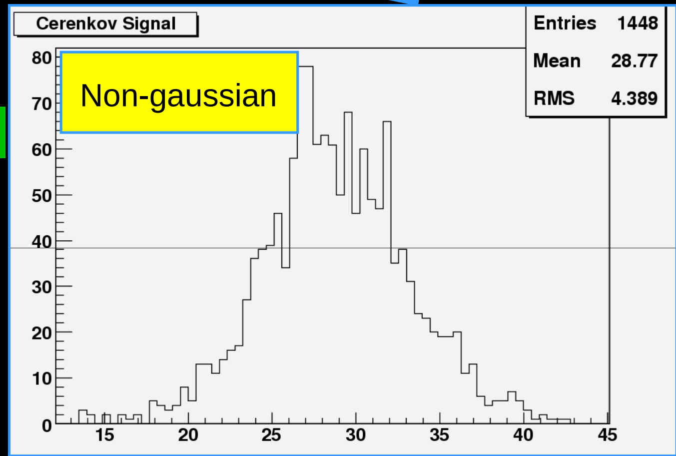


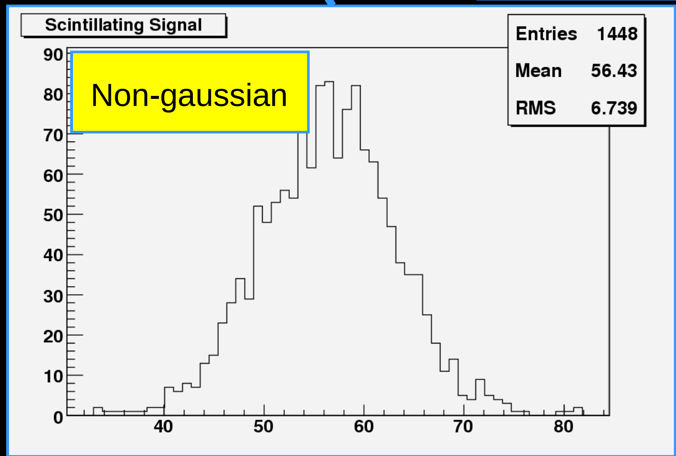


Dual Readout Calorimetry

Total calorimeter energy: use two measured signals and two, energy-independent, calibration constants.

ILCroot simulations





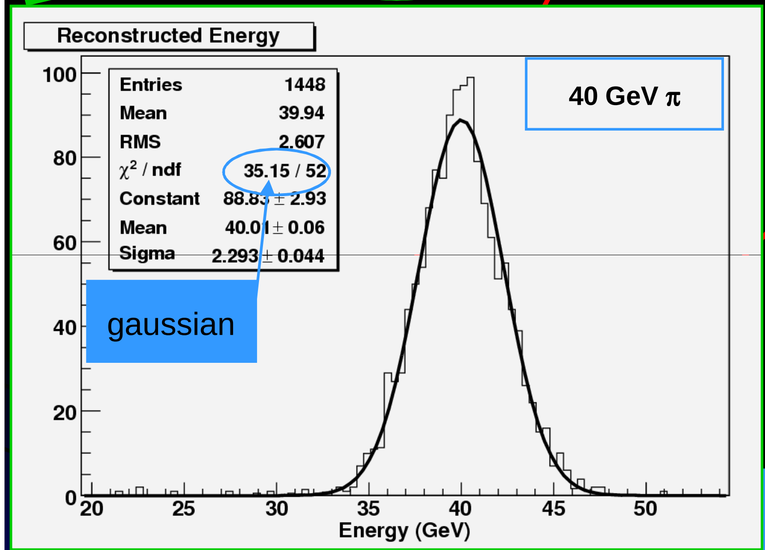
From calibration

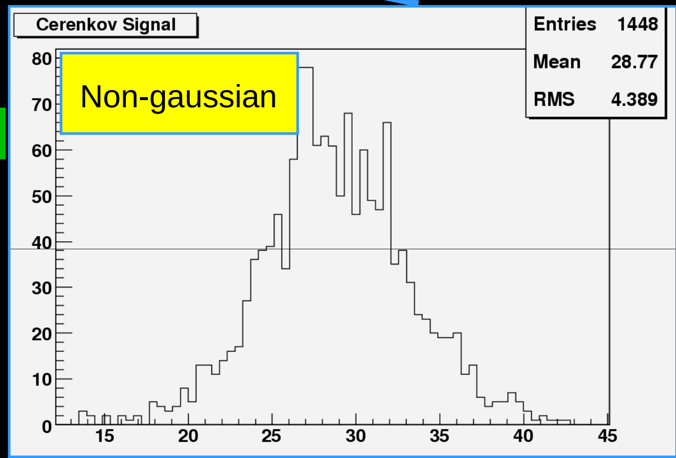
@ 1 Energy only

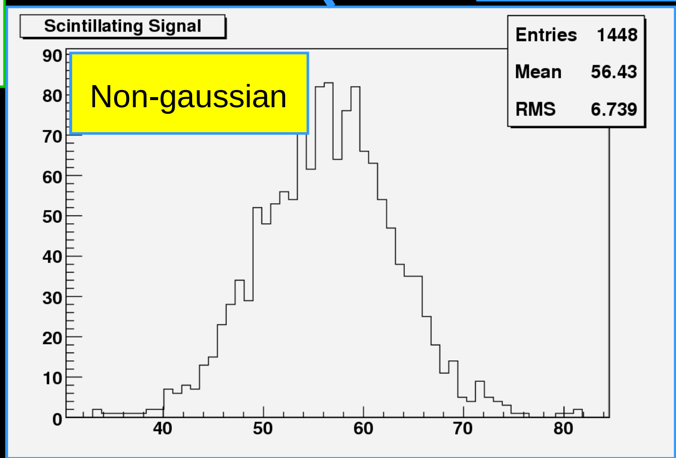
Dual Readout Calorimetry

Total calorimeter energy: use two measured signals and two, energy-independent, calibration constants.

ILCroot simulations







$\eta_c = \left(\frac{e}{h}\right)_c$

From calibration

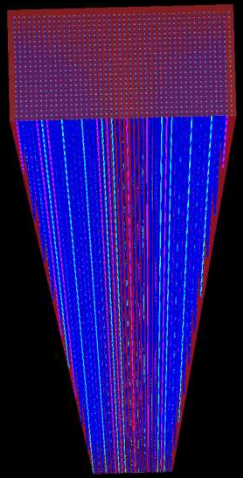
@ 1 Energy only

Dual readout calorimeter is two distinct calorimeters sharing the same absorber. Measured energy is gaussian because of compensation event by event.

THE ORIGINAL APPROACH

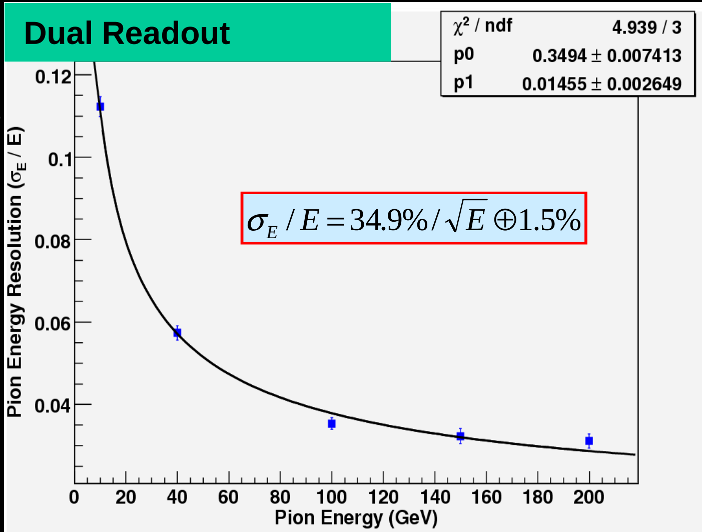
Sampling Dual-readout (DREAM and 4th Concept)

After extendd simulations and studies with ILCroot we have learnt that Sampling Dual-readout (i.e. with PASSIVE absorber) has:



- **Pro**
  - First working example of dual-readout calorimeter
  - Scintillation and Cerenkov light are produced in distinct and optically separated volumes
  - Simulations confirm test beam data (more or less) and improvement in energy resolution up to **30%/sqrt(E)**
  - Cheap to build (brass and plastic fibers)

ILCroot simulations



- **Cons**
  - Sampling is far too coarse shower generated by EM particles
  - Cerenkov light in fibers is very dim (7.5 pe/Gev for 4th)
  - Large unbalance between Scintillation signal (200 pe/Gev)

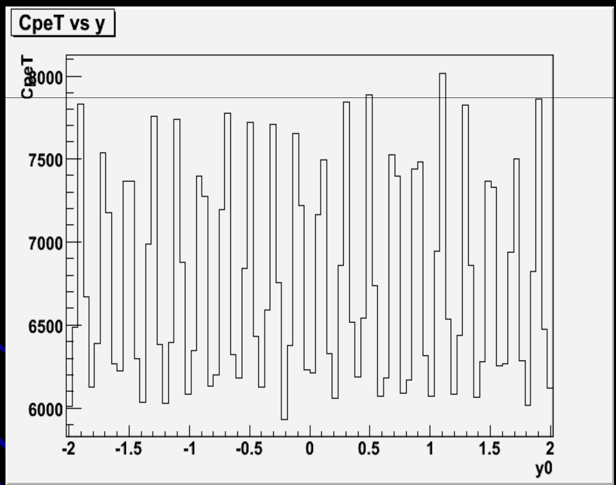
    vs Cerenkov (7.5 pe/GeV for 4th)
  - Too many fibers to be routed to FEE for a 4π calorimeters

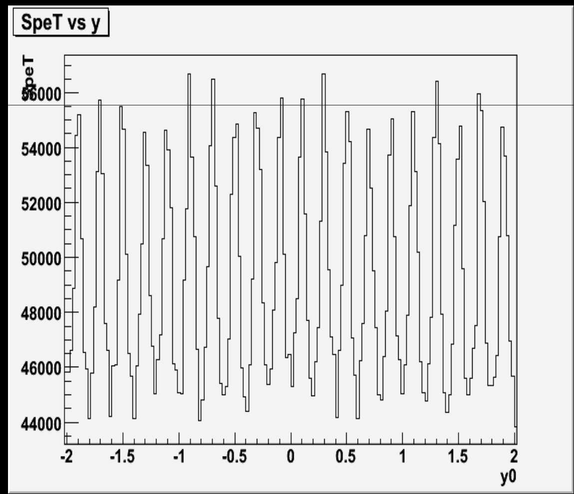
Cons N. 1: Sampling is far too coarse for shower generated by *EM* particles

- Calorimeter sampling frequency must be compared to absorption length of bulk of the particles composing the shower (not X_o nor λ_I): **<u>i.e 1 mm for e^-</u>** (typical shower particle in em showers is a 1 MeV electron)

See R. Wigmans book

<u>Consequences: large signal fluctuations depending on impact point of impinging electron</u>





40 Gev electrons Simulated in ILCroot

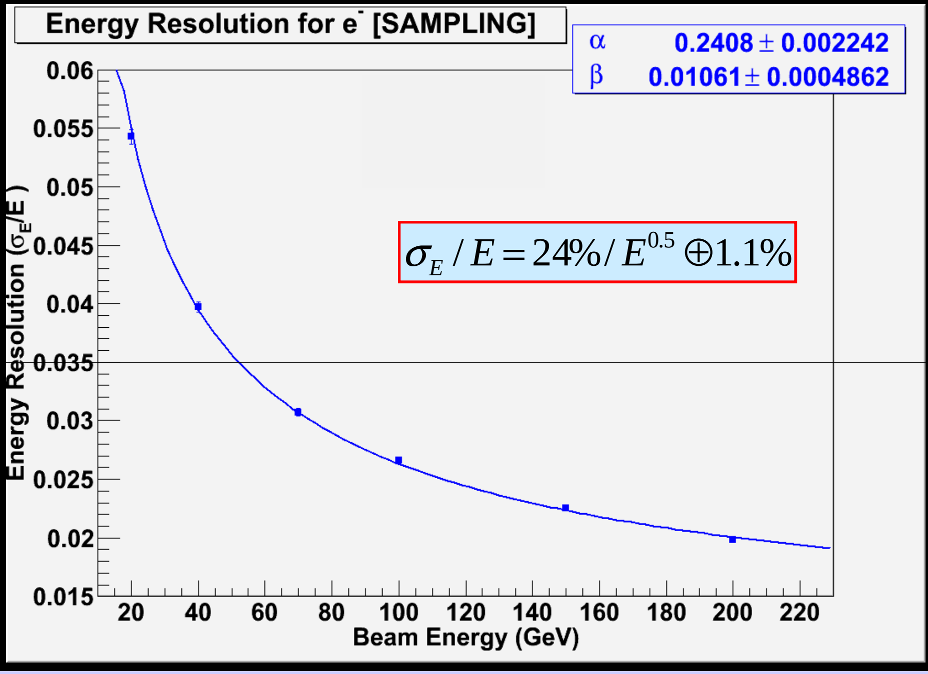
Cerenkov and Scintillating signal produced by e^- @ 45 GeV beam in 4th calorimeter (1mm pitch between fibers) as function of e^- impact point.

Cons N. 1 (cont'd)

Effects on energy resolution:

energy resolution curve for electrons in **4th Concept** the hadronic calorimeter

Single electrons



ILCroot simulations

No instrumental effects Included in this simulation

- **Very poor EM energy resolution.**
- **Hadronic sampling calorimeters require a front, EM section.**

In real life this is a bad idea as:

1. More complex calibration.
2. Introduce extra fluctuations with hadronic showers.

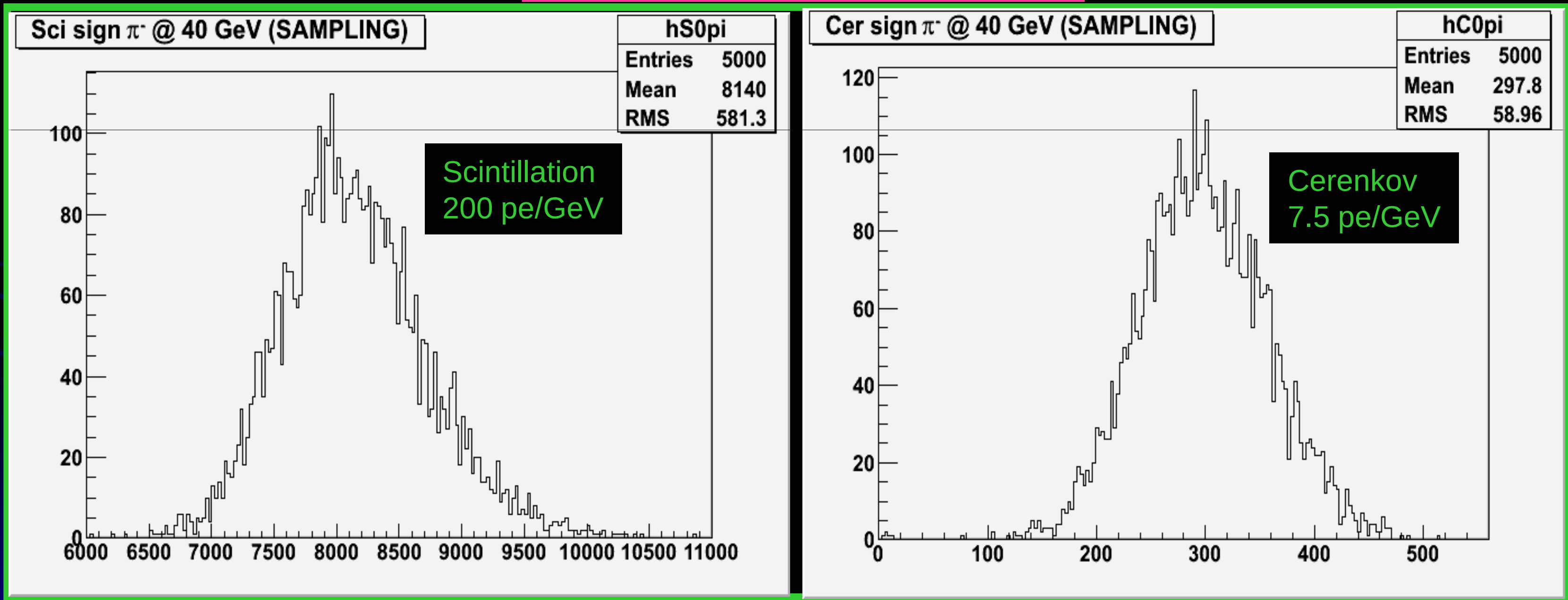
Cons N. 2: Cerenkov light in fibers is very dim

Consequences: large unbalance between scintillation and Cerenkov signals

40 Gev pions

4th Concept Calorimeter

ILCroot simulations



Cerenkov and Scintillating signal produced by π^- @ 40 GeV beam in 4th calorimeter (1mm pitch between fibers) including FEE effects

Cons N.3: Too many fibers for a 4π calorimeter

- Define Γ =(total area of photodetector/total external calorimeter area).
- Γ takes into account:
  - The needed photodetector area to read circular fibers with optimum packing
  - The crowdiness of your FEE
- At present:
  - Γ_{DREAM} = ~24%. $\Gamma_{4th\ Concept}$ = ~ 21%.
- This issue is honestly recognized by DREAM Collaboration:

Very large

"…The grouping of the
fibers was labor intensive and required the fibers to extend about 50 cm beyond the end of the calorimeter. While this worked very well in the beam tests, it probably would not scale well with the lateral size of the calorimeter…."

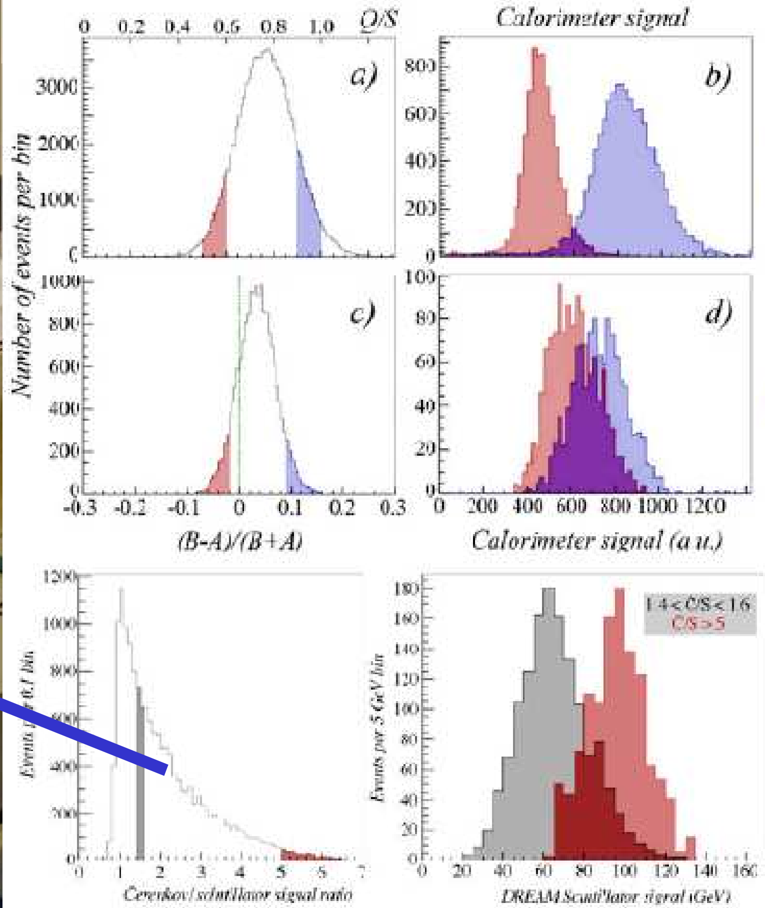
- **Goal is Γ < 10%**

Excerpt from:
R.Wigmans, et al., Dual-Readout Calorimetry for the ILC -
A University Program of Accelerator and Detector Research for the International Linear Collider (vol. III) FY 2005 - FY 2007
Available at: http://www.hep.uiuc.edu/LCRD/LCRD_UCLC_proposal_FY05/6_16_Wigmans_LCRD1.pdf

Difficulties of Total Active Homogeneous Dual Readout

Report form DREAM Collaboration studies.

Separation efficiency between S & C components



DREAM stand-alone (2 separate media)

$PbWO_4$ matrix (directionality)

BGO_{UV} (1 crystal)

(time structure + spectrum)

Combine the advantages of sampling and total active techniques

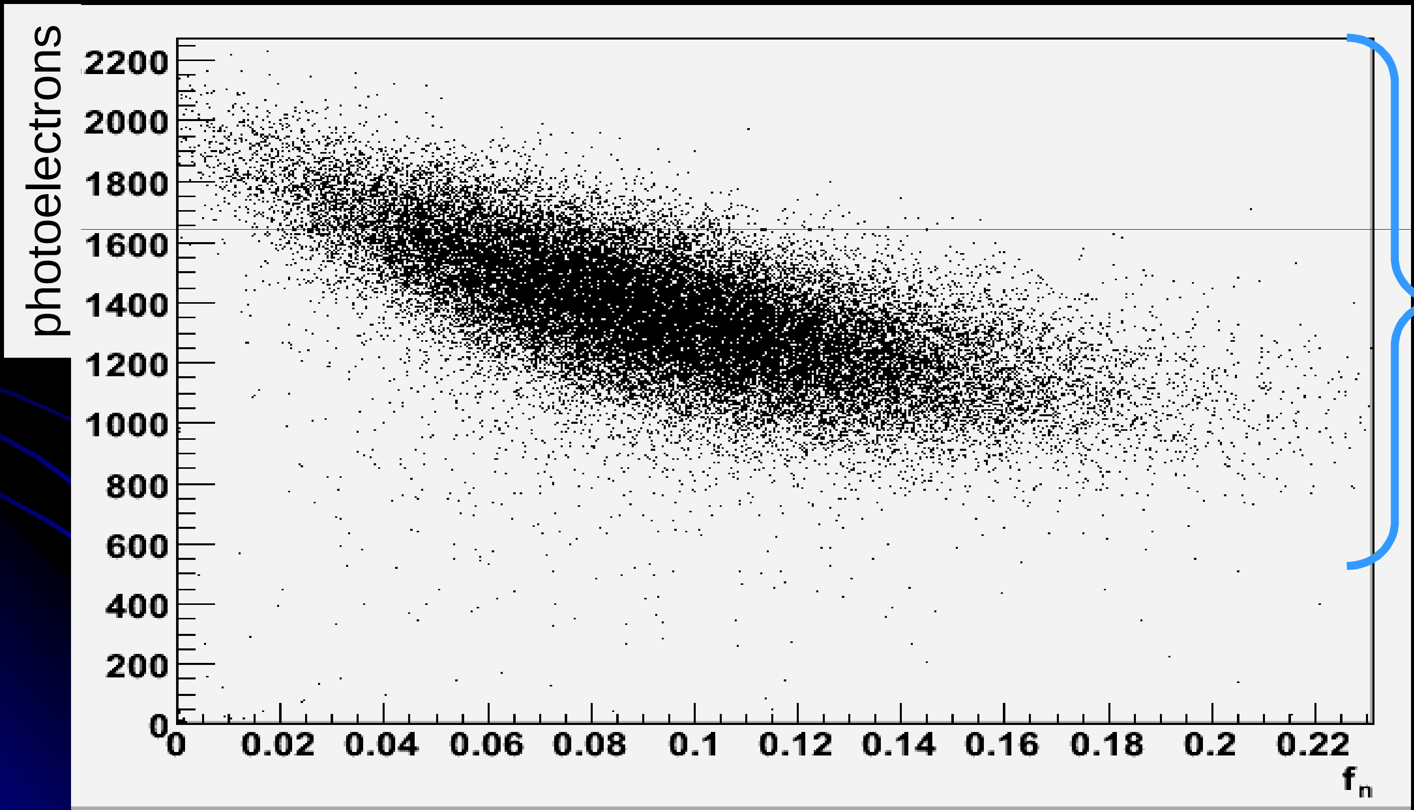
*E*mbedd scintillating fibers into heavy glass

- **Active Cerenkov component: Optical Heavy Glass**
  - It functions as an **active absorber**
  - No scintillation light
  - Lots of Cerenkov photons thanks to n_l=1.95 (for λ ~ 510 nm)
- **Scintillating component: scintillating fibers**
  - **Optically separated** from Cerenkov absorber
  - Control the scintillation/Cerenkov signal with appropriate pitch between fibers
  - $\Gamma_{ADRIANO}$ = 8% (baseline version)

Neutron fluctuations

45 GeV π^-

Cerenkov signal vs Neutron fraction in 4th Concept calorimeter



neutron fluctuations

ILCRoot simulation

C. Gatto

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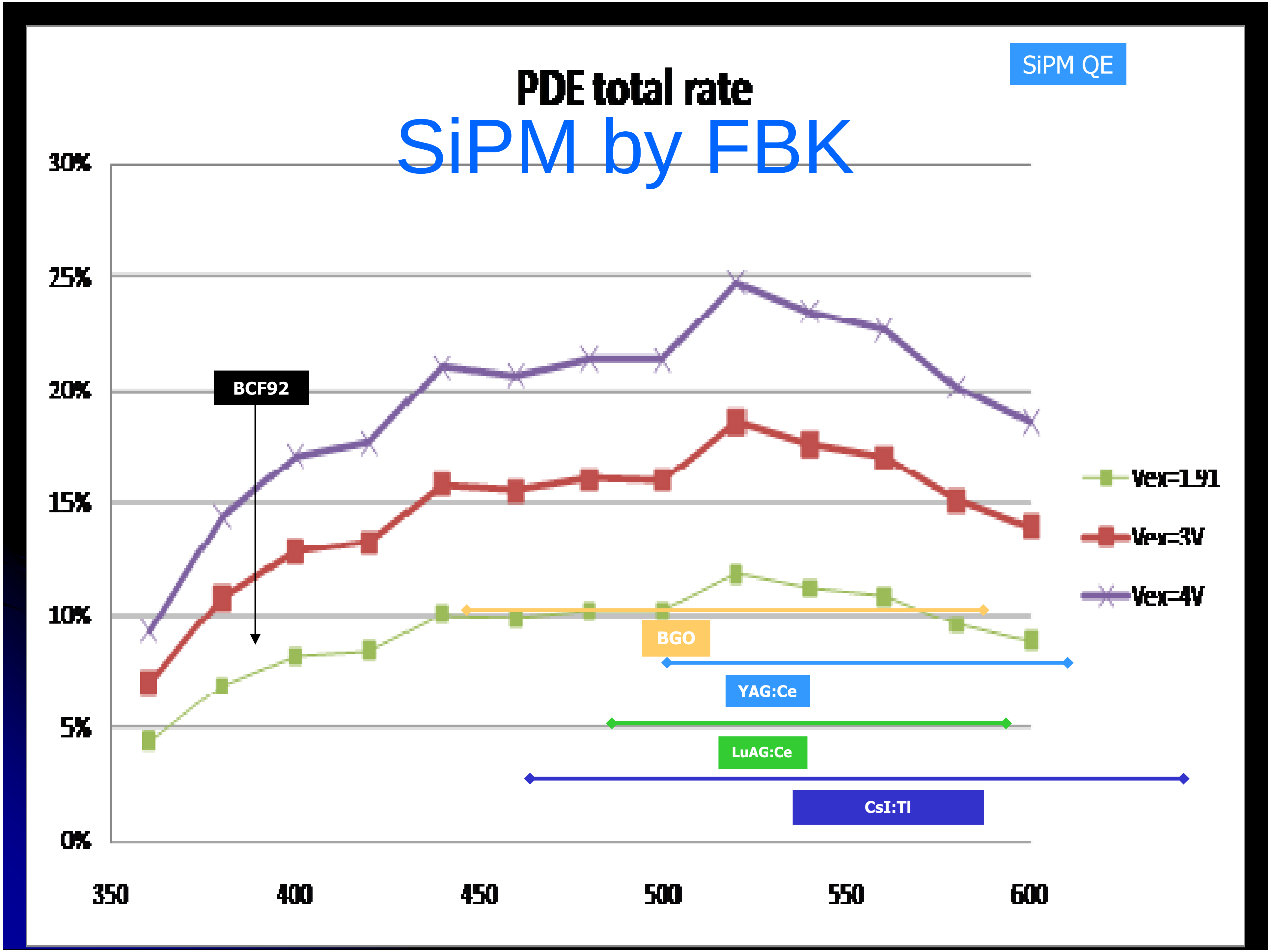
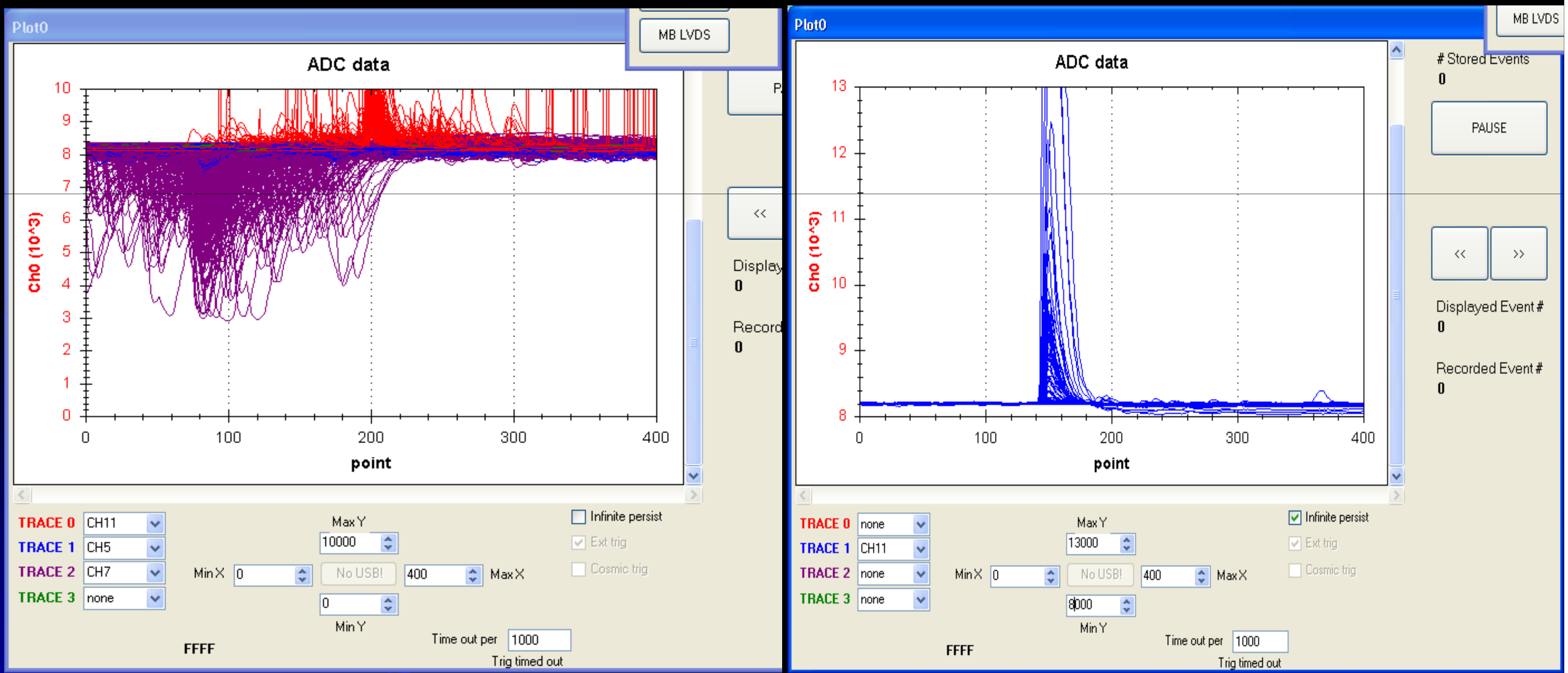

SiPM QE
PDE total rate
SiPM by FBK
30%
25%
20%
15%
10%
5%
0%
350
400
450
500
550
600
BCF92
BGO
YAG:Ce
LuAG:Ce
CsI:Tl
Vex=1.91
Vex=3V
Vex=4V

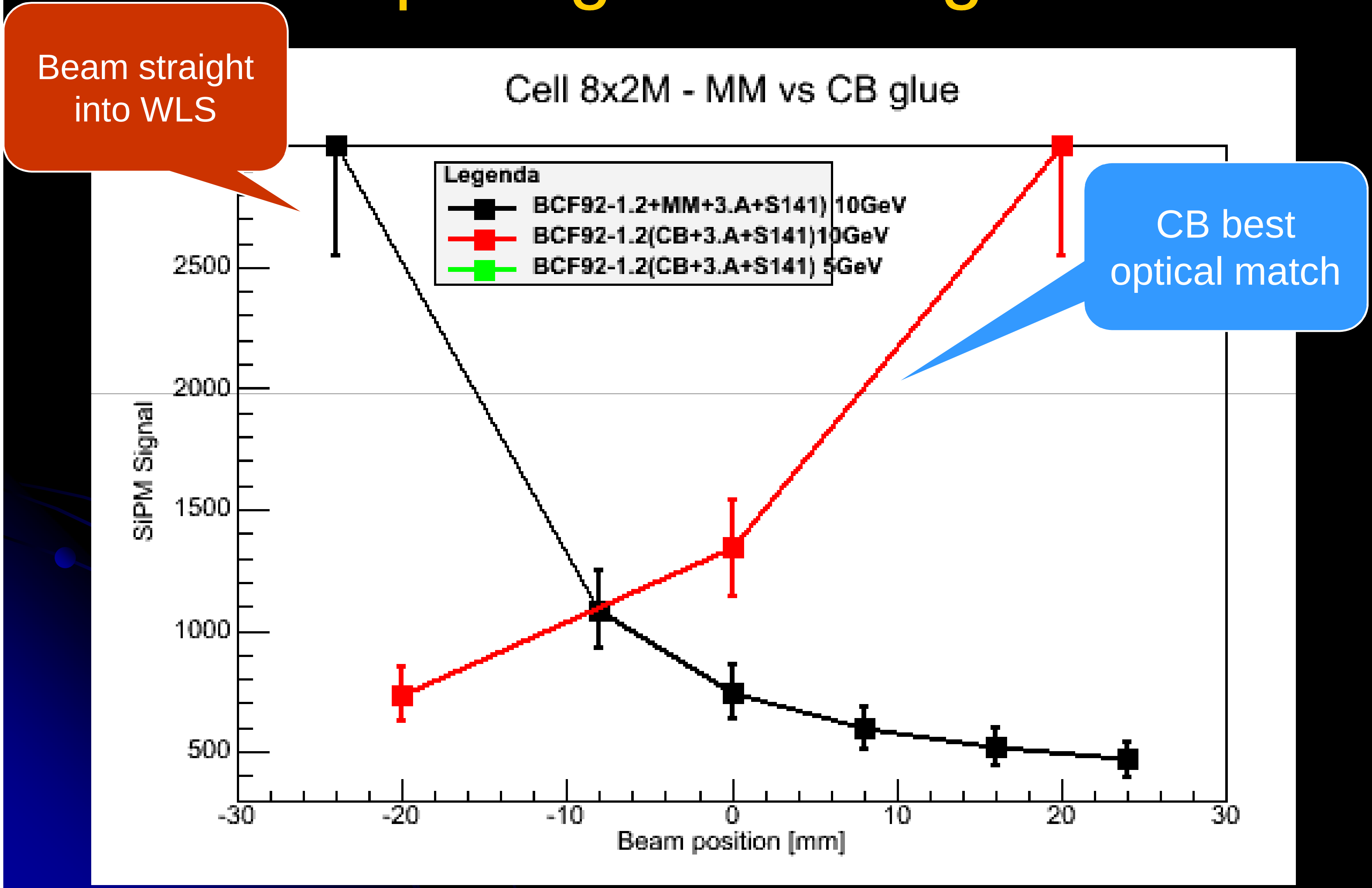
Waveforms from TB4 DAQ:

SiPM with W.C. light concentrator (by G. Sellberg) vs PMT

5 Gev e/π beam



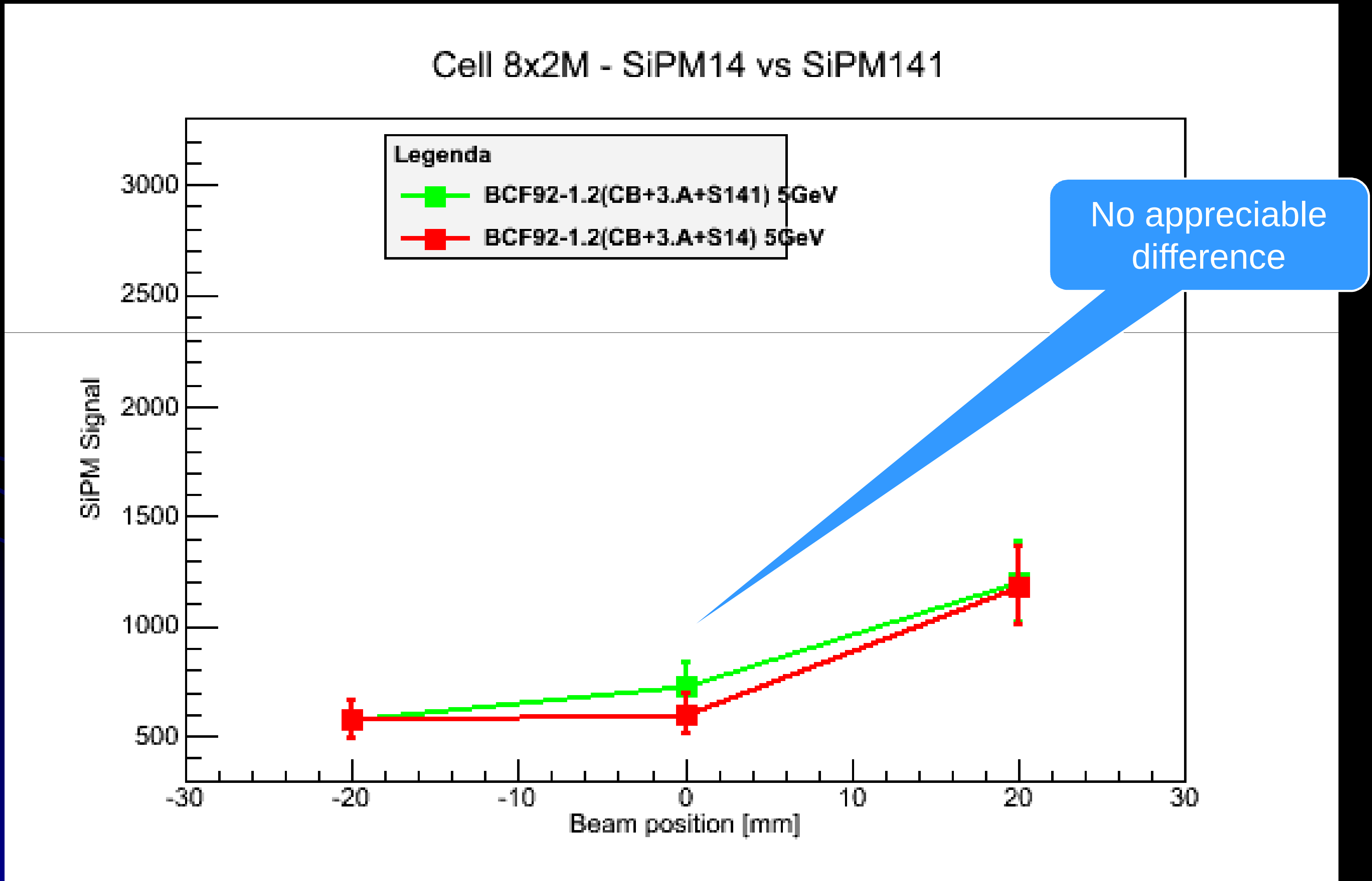
Comparing different glues



Preliminary results

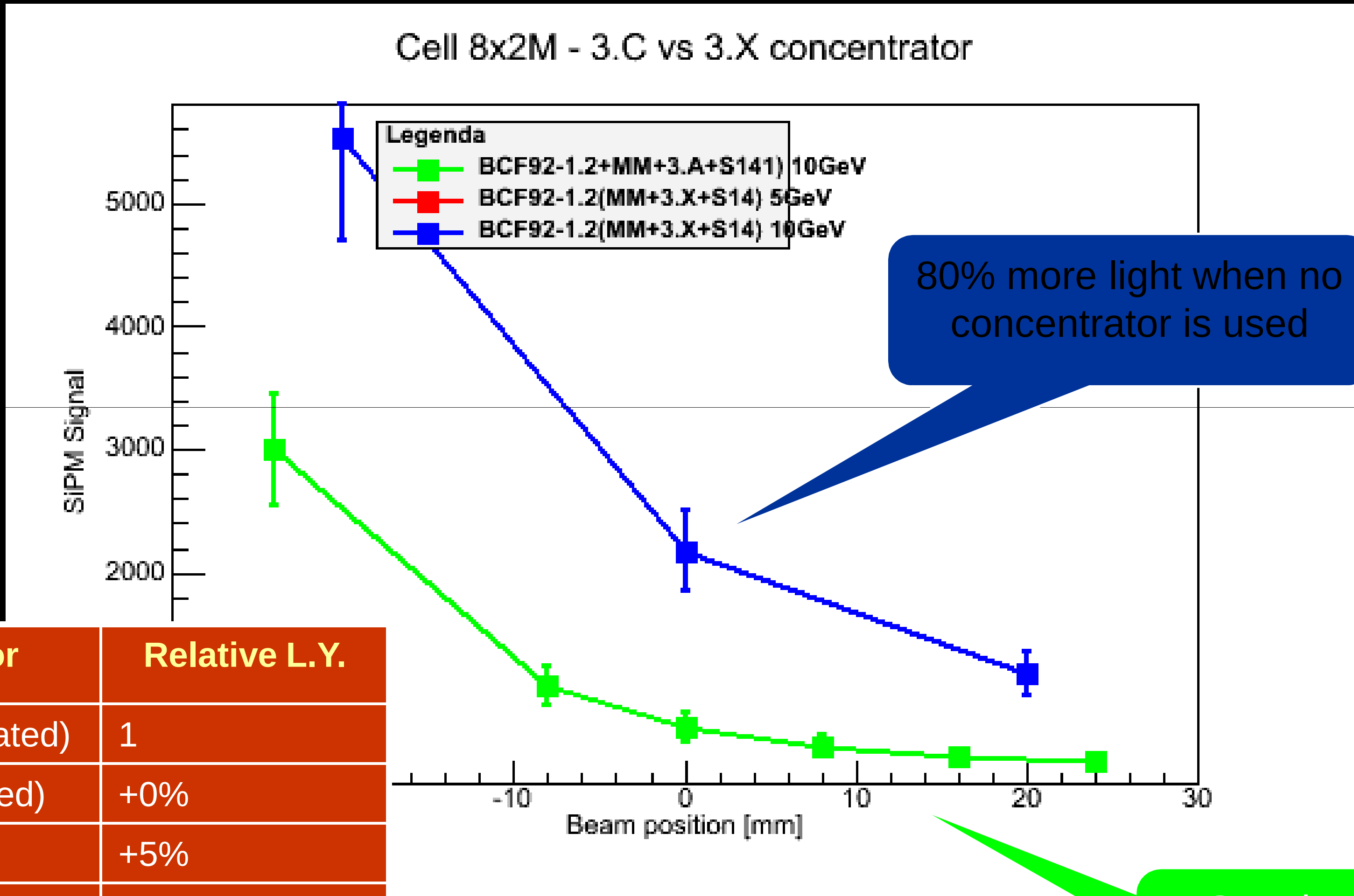
Comparing different SiPM

2.8 mm round vs 4x4mm^2 square



Preliminary results

Comparing different Light Concentrators



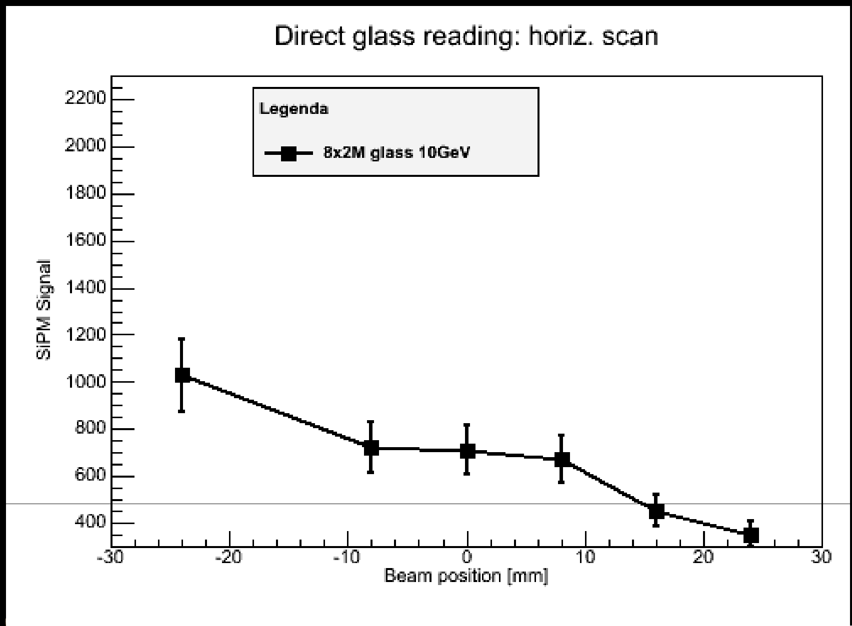
80% more light when no concentrator is used

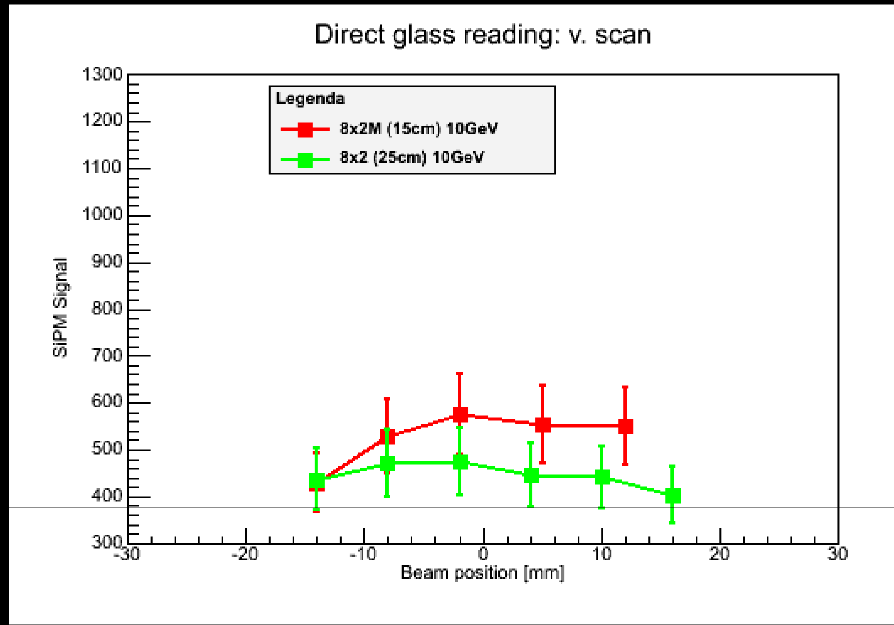
Standard concentrator

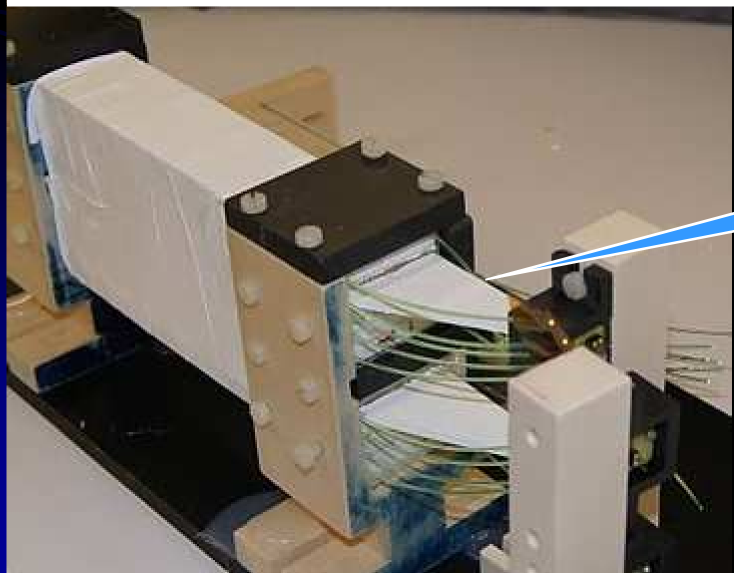
Concentrator	Relative L.Y.
Original (TiO_2 coated)	1
Original (Ag coated)	+0%
super polished	+5%
Winstone cone	+60%
none	+80%

Preliminary results

Fiber Readout vs Direct Glass Readout





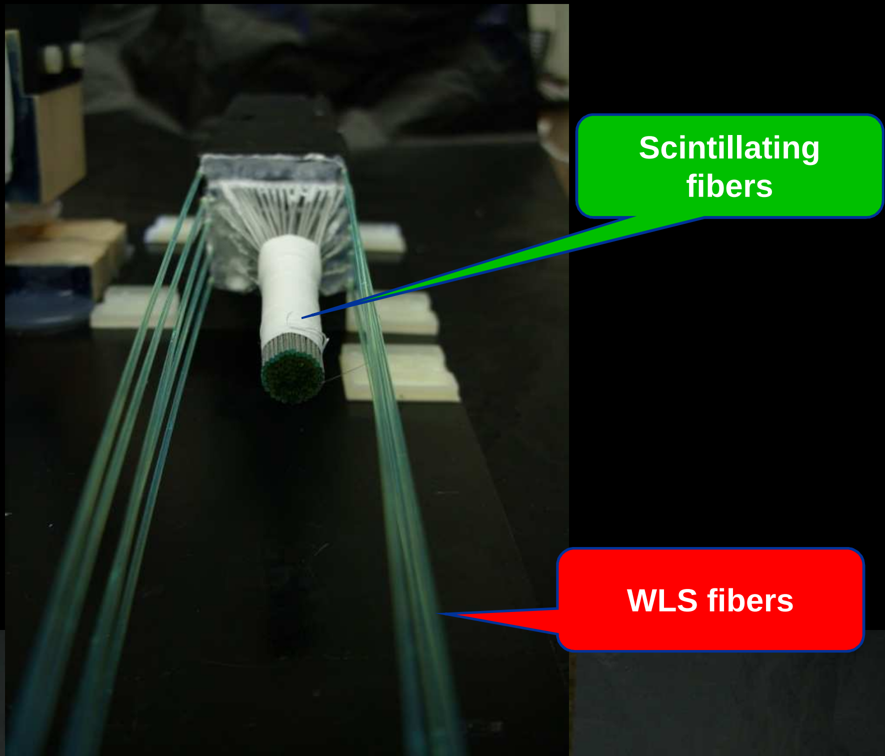


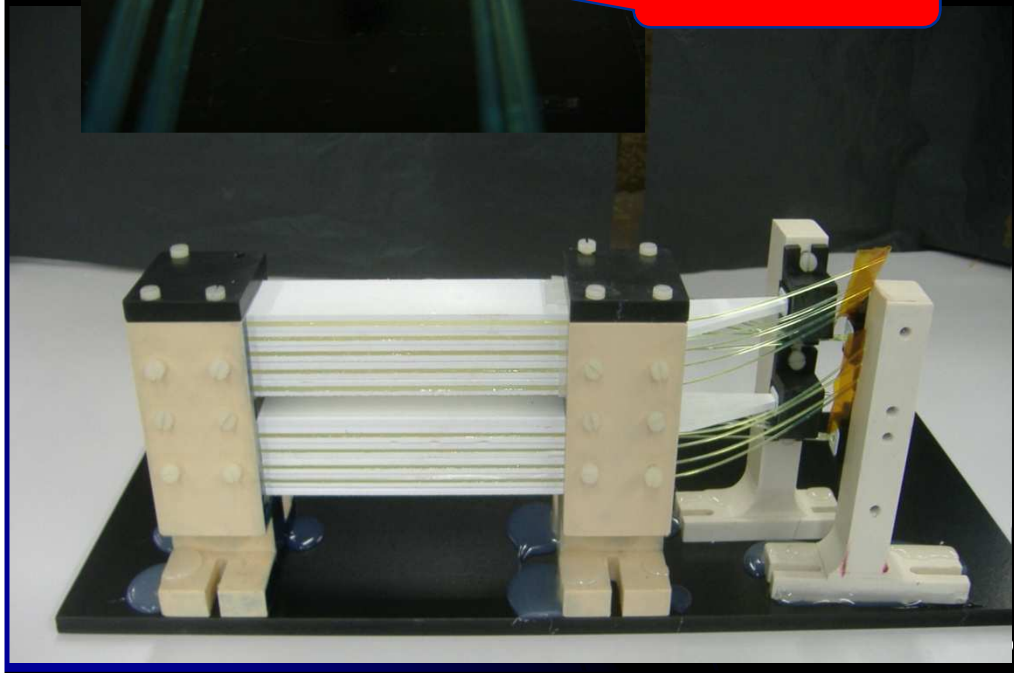
Only ~16% of Cerenkov light is collected

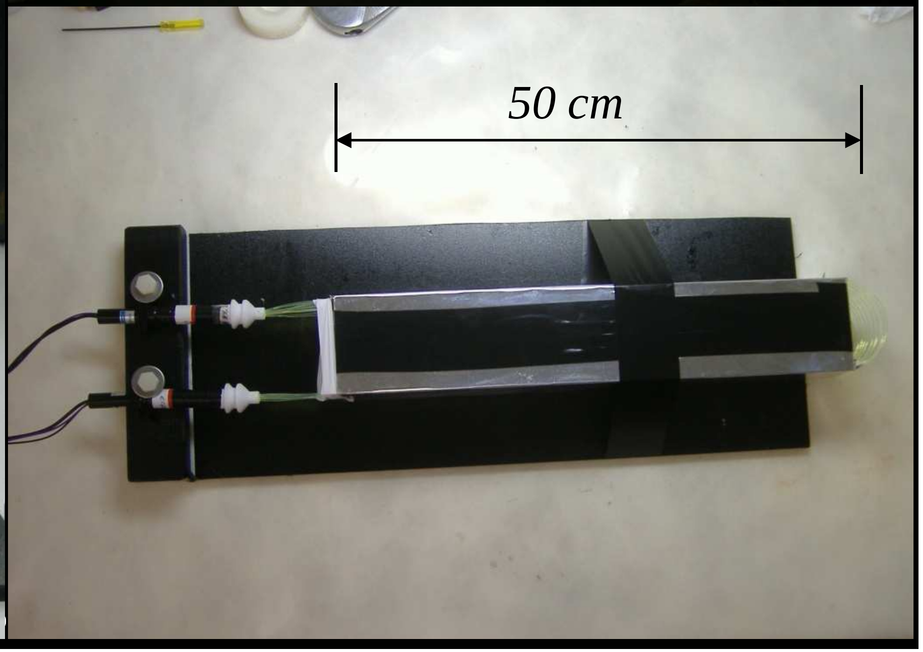
~73% more light collected by directly reading the glass

~2 cm longitudinal attenuation length

Pictures from 2011 Test Beam

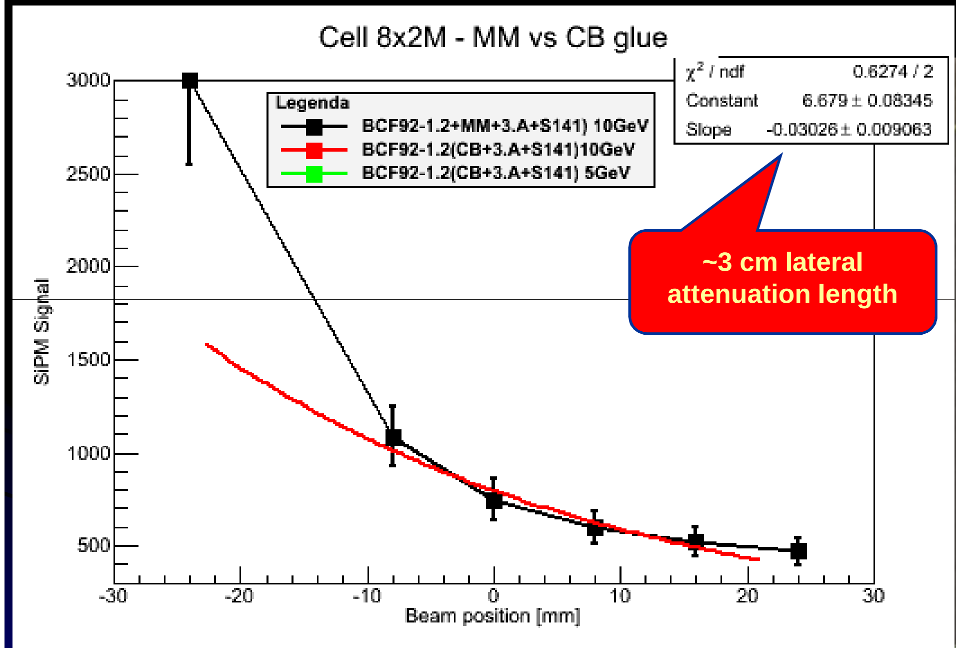


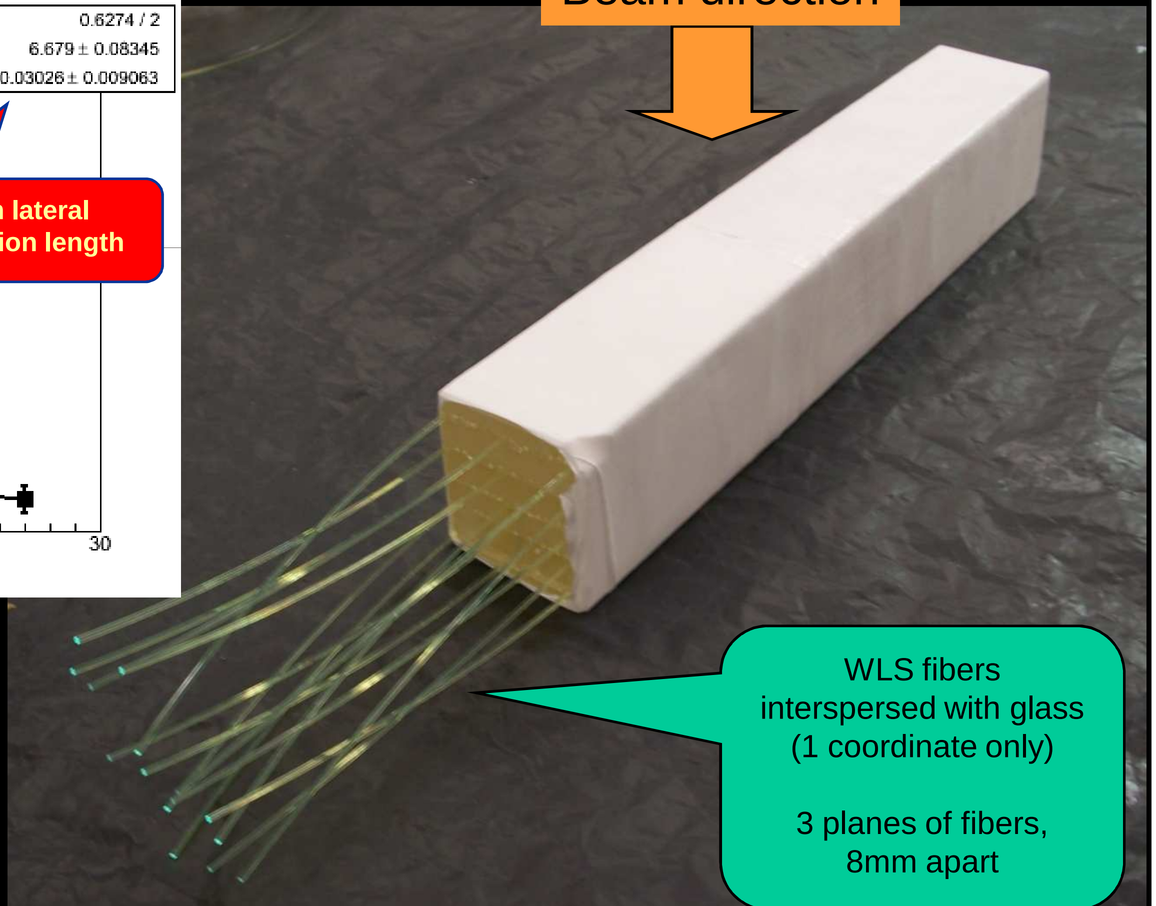




ADRIANO Variant for Imaging Calorimetry

- R&D targeting γ400 experiment
- Special coating to limit Cerenkov light spread

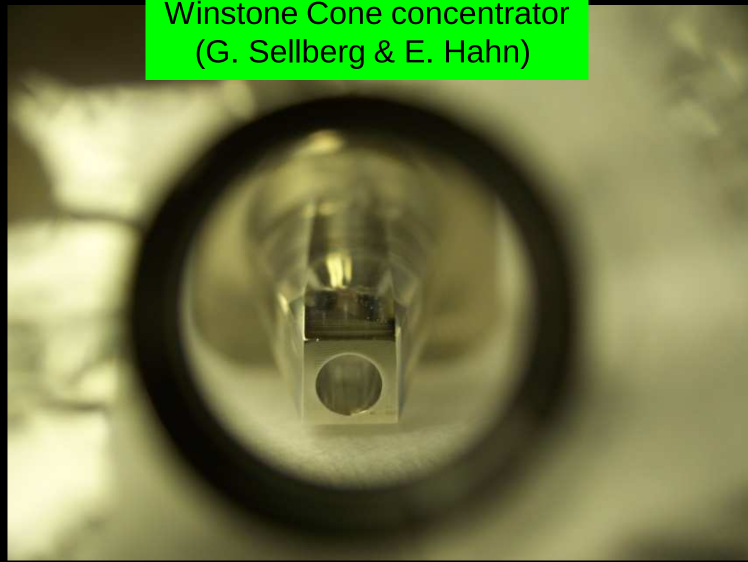


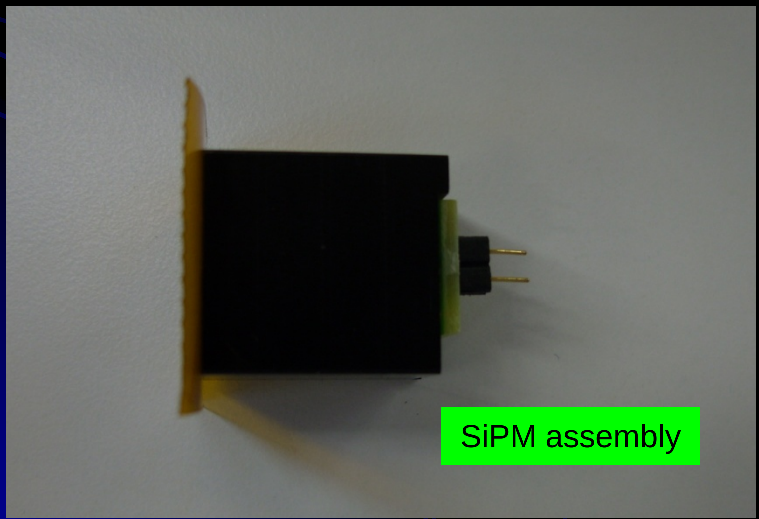


Goal is to spatially resolve the shower in 3D

Ligth Readout R&D

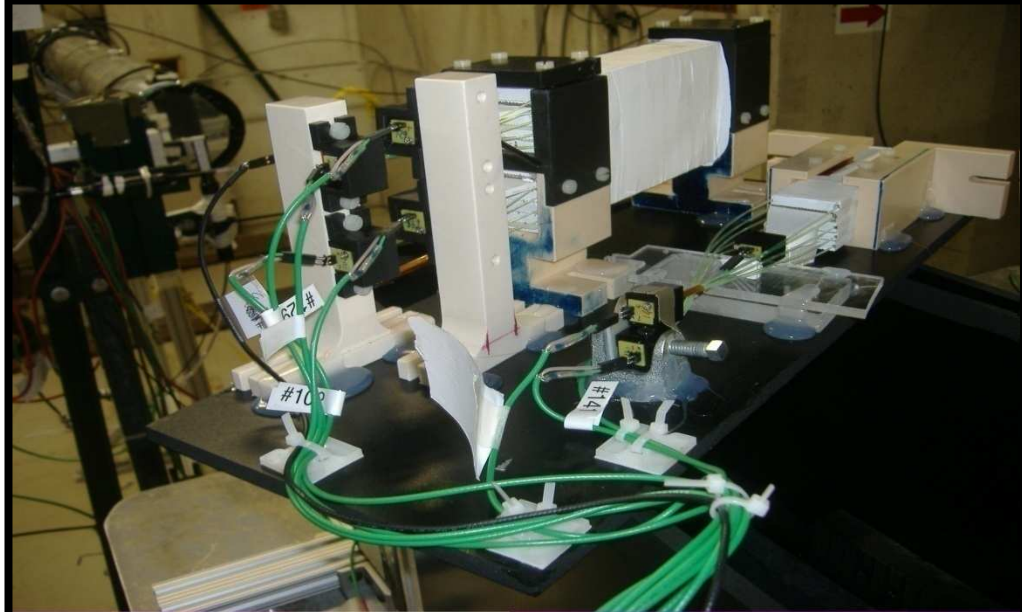

Trieste concentrators

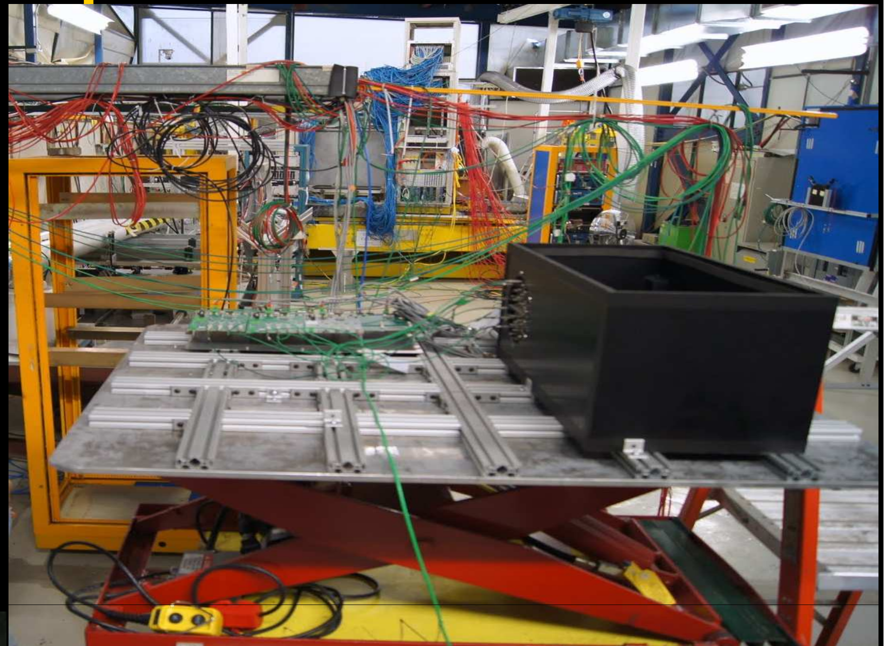

Winstone Cone concentrator
(G. Sellberg & E. Hahn)

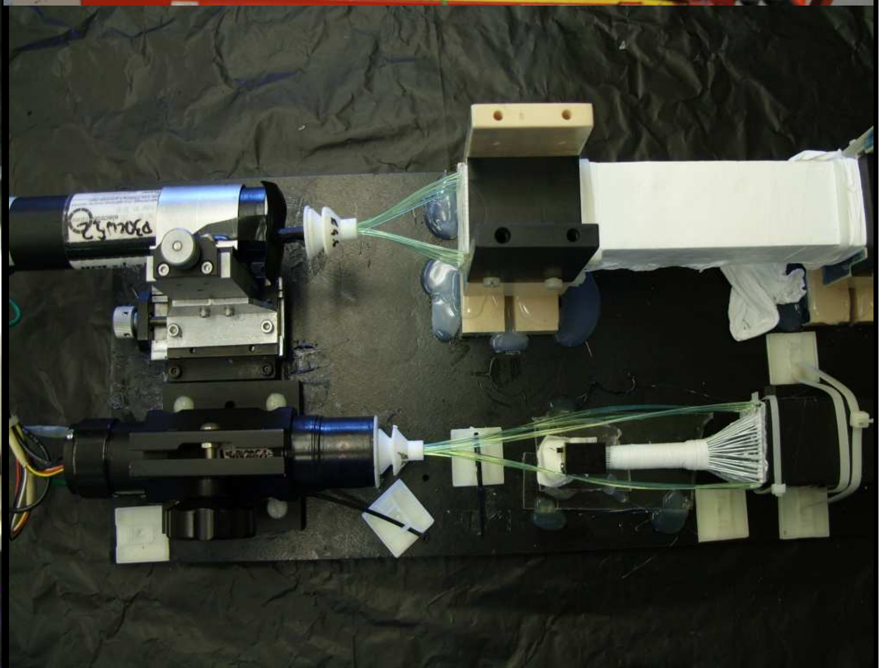

SiPM assembly


Light concentrator + fibers:
SiPM side

Test Beam Setup at FTBF



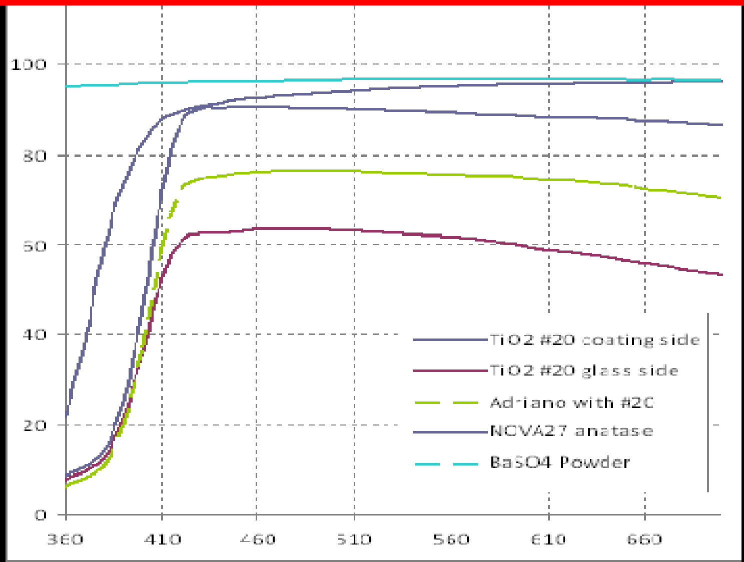




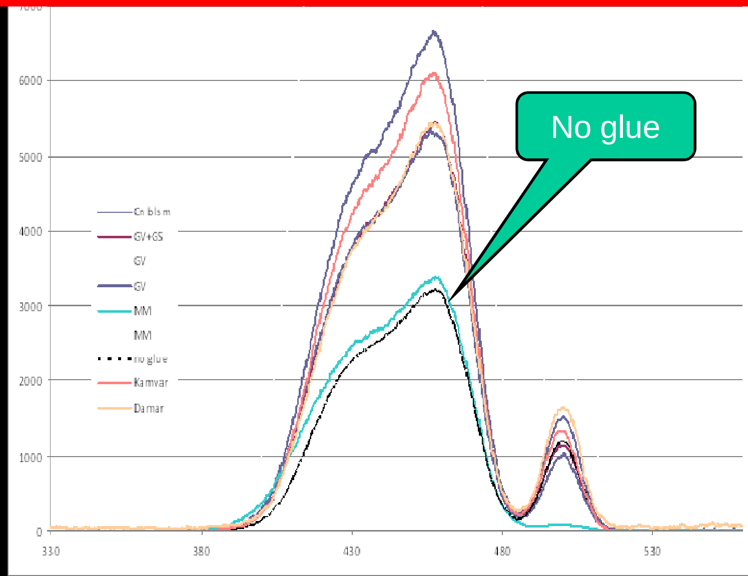
A. Pla

Spectroscopy Measurements

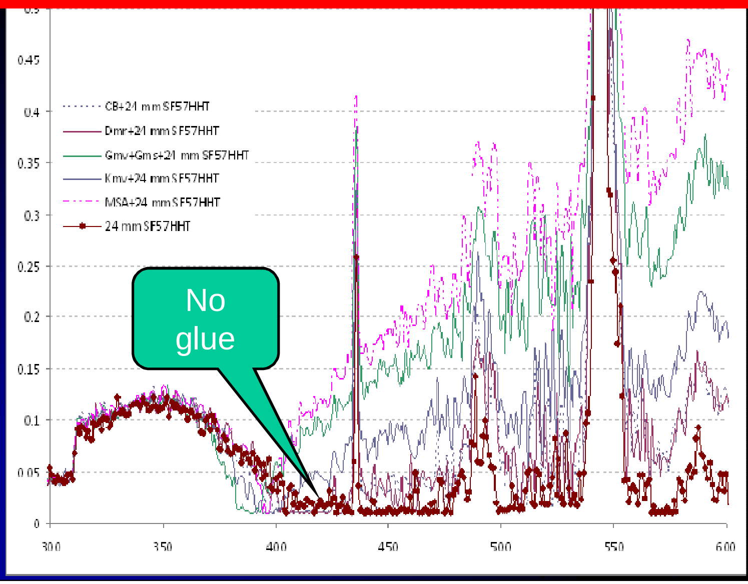
Spectral reflectivity of various coatings



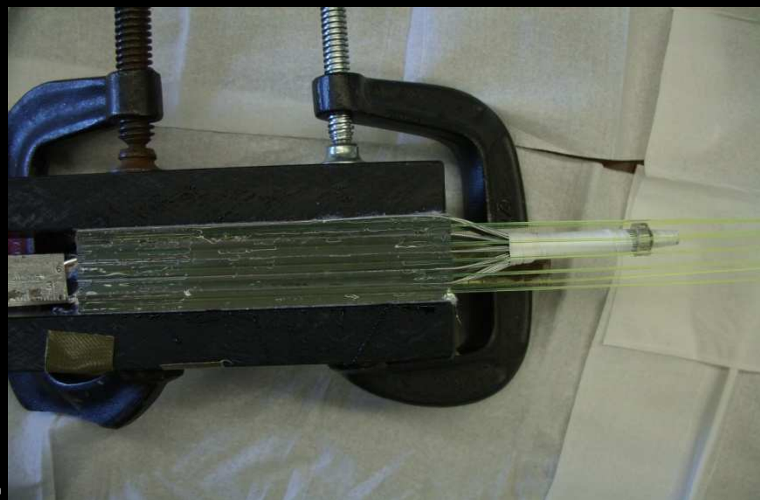
Spectral excitation curves of glass+WLS+optical glues



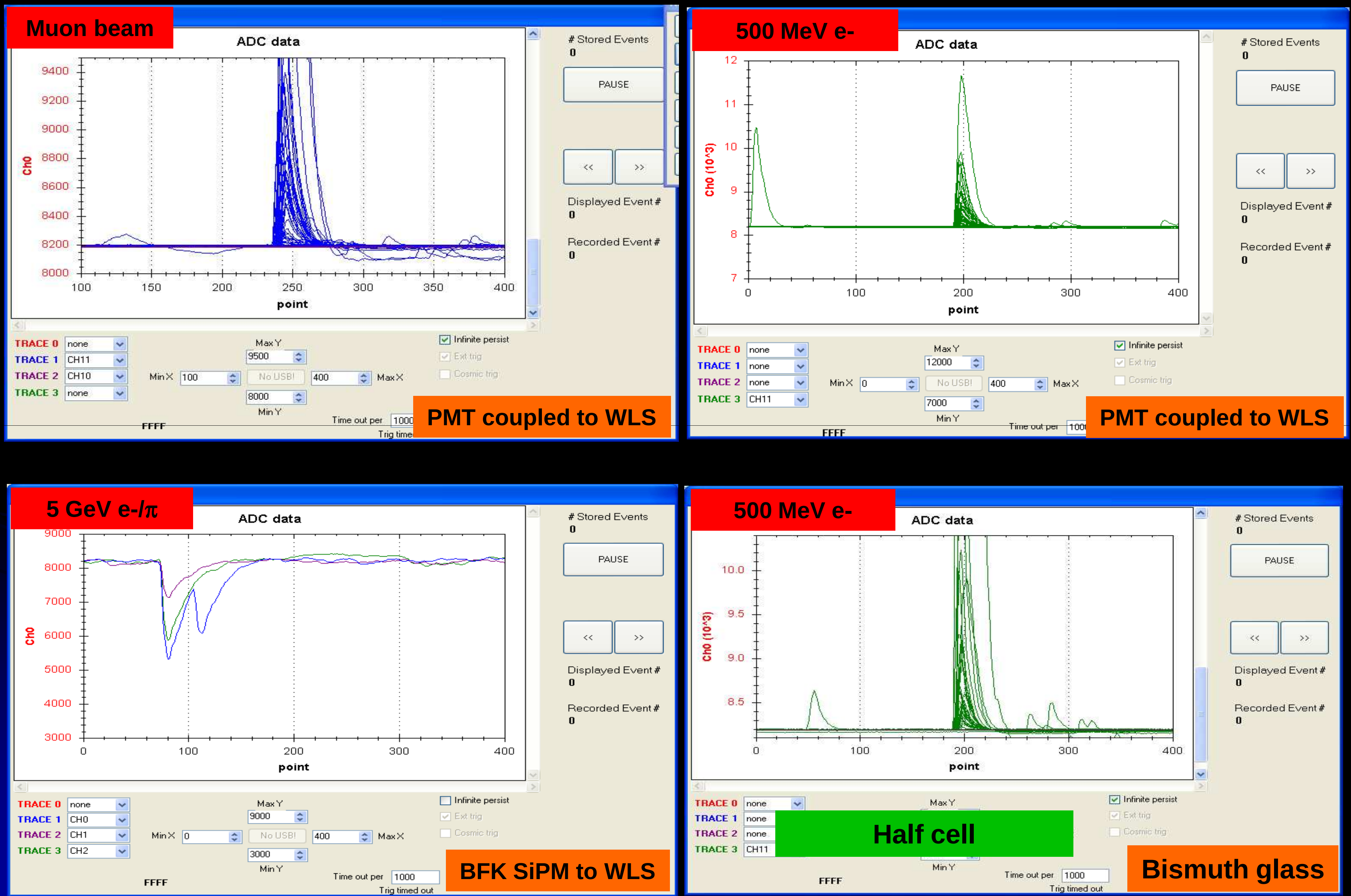
Spectral transmission curves of glues+glass



Best coating and optical glue resulted to be homemade mix

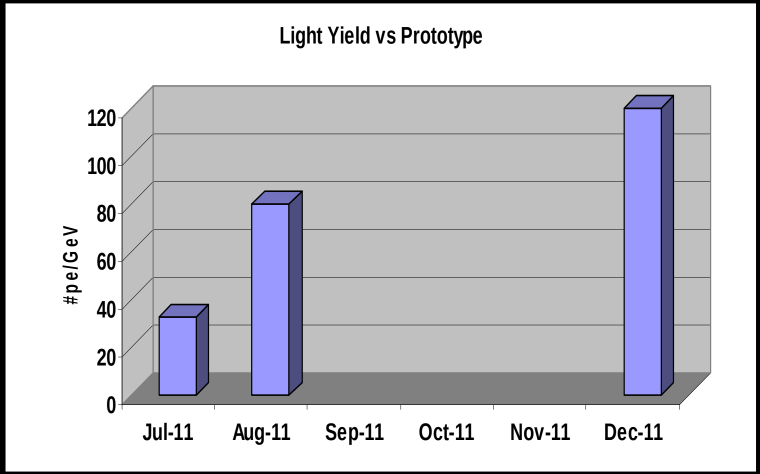


Waveforms from TB4 DAQ



Summary of Preliminary Analysis of 2011 Test Beam Data

- Light yield constantly improving with new prototypes; current limit ~120 pe/GeV



- August test beam yielded ~10 times 4th Concept detector light
- Light attenuation length critically depends on coating type and surface finishing of glass
- Coupling of fibers to SiPM is critical: air gap between light concentrator and SiPM more than halves the light yield
- Y11 fibers produce about 45% more light than BCF92 with Cerenkov light
- Different glues produce up to a factor of 2 in light yield
- Cold vs hot glass construction methods make no appreciable difference
- Direct reading from glass at back of cell yields less light than reading fibers
- SiPM and PMT produce comparable signals. However, large noise from present version of SiPm make them hard to use in low energy applications

T1015 R&D Completed Program

- Five test beam at FTBF by the spring of 2012: several cells in different configurations
- 4 glass type: lead and bismuth based + scintillating Ce doped glass
- 3 glass coatings
- 2 fabrication techniques: cold machining and high temp. molding
- 3 WLS fibers: Y11 (1.2mm) & BCF92 (1.0, 1.2 mm)
- 1 Scintillating fiber: SCSF81
- Several optical glues (mostly homemade)
- 4 photodetectors: 2 SiPM (2.8 round and 4.3x4.3 square) & 2 PMT (P30CW5 , R647)
- 4 light coupling systems: direct glass + direct WLS + 4 light concentrators

Goals are:

- ***Maximize light yield (Cerenkov)***
- ***Measure parameters for Montecarlo simulations***

Future Prospects

- First 2 year R&D on fabrication techniques already producing clear directions
- Precision molding technique is preferred (*ADRIANO*)
- Starting in year 2012 we will exploit
  - Laser-based technique coupled with diamond milling
  - Dedicated, high speed (< 30 min) molding machine with Pt-Ir coated (Ra ~ 5-10 nm) molds
  - Photo-etching techniques
- Ohara sponsorship/partership for bismuth optical glass (6.6 gr/cm^3, n_d = 2.0) in progress: two strips (total 1.4 Kg) provided at no cost
- New Ohara heavy glass just tested at FNAL
  - 7.54 gr/cm^3 ; n_d = 2.24
- *ADRIANO*2 (Cerenkov + scintillating glass)

  R&D just starting. First results: >600 pe/GeV
- Rare earth-doping tests under way at DIMA
- Heading toward a large prototype
  - 1,800 PMT appropriated from CDF
  - New experiments adopting *ADRIANO* (next slide)