



G-2 Update

G. Venanzoni
(for the GMINUS2)
INFN/LNF

Riunione CSN1 20 Maggio 2014

Outline

- Reminder interesse internazionale
- Stato dell'esperimento
- Reminder sul sistema di Calibrazione e riassunto attivita' Italiana
- Test Beam a SLAC
- Anagrafica e piano di lavoro GMINUS2
- Conclusioni

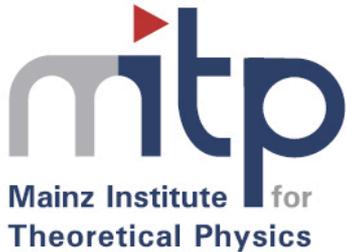
A glance at last workshops/articles focusing on $(G-2)_\mu$



(g-2) μ : Quo vadis?

7-10 April 2014

Institut für Kernphysik, Uni Mainz
Europe/Berlin timezone

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Hadronic contributions to the muon anomalous magnetic moment: strategies for improvements of the accuracy of the theoretical prediction

1-5 April 2014

Waldthausen Castle near Mainz
Europe/Berlin timezone

Understanding the correlation between $(g - 2)_\mu$ and $\mu \rightarrow e\gamma$ in the MSSM

Jörn Kersten^{1(a,b)}, Jae-hyeon Park^{2(c)}, Dominik Stöckinger^{3(d)}
and Liliana Velasco-Sevilla^{4(a)}

arXiv:1405.2972

Rare Kaon Decays, and Parity Violation from Dark Bosons

ooman Davoudiasl,¹ Hye-Sung Lee,^{2,3} and William J. Marciano¹

arXiv:1402.3620

Dispersive approach to hadronic light-by-light scattering

G. Colangelo, M. Hoferichter, M. Procura, and P. Stoffer

arXiv:1402.7081

Testing the Muon $g-2$ Anomaly at the LHC

A. Freitas¹, J. Lykken², S. Kell¹, and S. Westhoff¹

arXiv:1402.7065

Muon anomalous magnetic moment and positron excess at
AMS-02 in a gauged horizontal symmetric model

Gaurav Tomar* and Subhendra Mohanty†

Physical Research Laboratory, Ahmedabad 380009, India

arXiv:1403.6301

...and many others...



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List of unsolved problems in physics

From Wikipedia, the free encyclopedia

Main article: List of unsolved problems

Some of the major **unsolved problems** in **physics** are **theoretical**, meaning that existing theories seem incapable of explaining a certain observed **phenomenon** or experimental result. The others are **experimental**, meaning that there is a difficulty in creating an experiment to test a proposed theory or investigate a phenomenon in greater detail.

Contents [hide]

- 1 Unsolved problems by subfield
 - 1.1 Cosmology, and general relativity
 - 1.2 Quantum gravity
 - 1.3 High energy physics/particle physics
 - 1.4 Astronomy and astrophysics
 - 1.5 Nuclear physics
 - 1.6 Atomic, molecular and optical physics
 - 1.7 Condensed matter physics
 - 1.8 Biophysics
 - 1.9 Other problems
- 2 Problems solved in recent decades
- 3 References
- 4 External links

“G-2 e’ arrivato anche al grande pubblico”

Muon g-2: presentato il piano di un rivoluzionario esperimento sui muoni



Gli scienziati di 26 istituzioni stanno pensando ad un nuovo esperimento che potrebbe aprire la porta della fisica delle particelle. Ma prima, devono trasportare il cuore di questo esperimento, un elettromagnete complesso che si estende su 50 metri di diametro, dal Dipartimento Nazionale di Energia di Brookhaven a New York, al Fermi National Accelerator Laboratory del DOE, in Illinois.



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Neutrino mass

What is the mass of neutrinos, whether the normal or inverted? Is the CP violating pha:

Asymptotic confinement

Why has there never been measured a free them, like mesons and baryons? How does

Strong CP problem and axions

Why is the strong nuclear interaction invari: theory the solution to this problem?

Anomalous magnetic dipole moment

Why is the experimentally measured value ("muon g-2") significantly different from the constant?^[18]

18. ^ Thomas Blum; Achim Denig; Ivan Logashenko; Eduardo de Rafael; Lee Roberts, B.; Thomas Teubner; Graziano Venanzoni (2013). "The Muon (g-2) Theory Value: Present and Future". arXiv:1311.2198 [hep-ph].

E989 Milestones, last 12 months

- June to July 2013
 - Storage Ring relocated from BNL to Fermilab (see photos)
- July 2013
 - NSF Major Research Instrumentation award made to support Detectors, Electronics, DA
- September 2013
 - INFN approves 1st year funding of calibration system
 - DOE CD-1 review of experiment and budget
- November 2013
 - Detector group test beam run at SLAC
 - UK groups awarded funding for g-2
- December 2013
 - CD-1 approved at \$46.3 M TPC (excluding NSF and International)
- April 2014
 - MC-1 building beneficial occupancy for g-2

E989 Collaboration: 38 Institutes; >150 Members



Domestic Universities

- Boston
- Cornell
- Illinois
- James Madison
- Massachusetts
- Mississippi
- Kentucky
- Michigan
- Michigan State
- Mississippi
- Northern Illinois University
- Northwestern
- Regis
- Virginia
- Washington
- York College

- **National Labs**

- Argonne
- Brookhaven
- Fermilab

- **Consultants**

- Muons, Inc.



Italy

- Frascati,
- Roma 2,
- Udine
- Naples
- Trieste



China:

- Shanghai



The Netherlands:

- Groningen



Germany:

- Dresden



Japan:

- Osaka



Russia:

- Dubna
- PNPI
- Novosibirsk



England

- University College London
- Liverpool
- Oxford
- Rutherford Lab

Korea

- KAIST

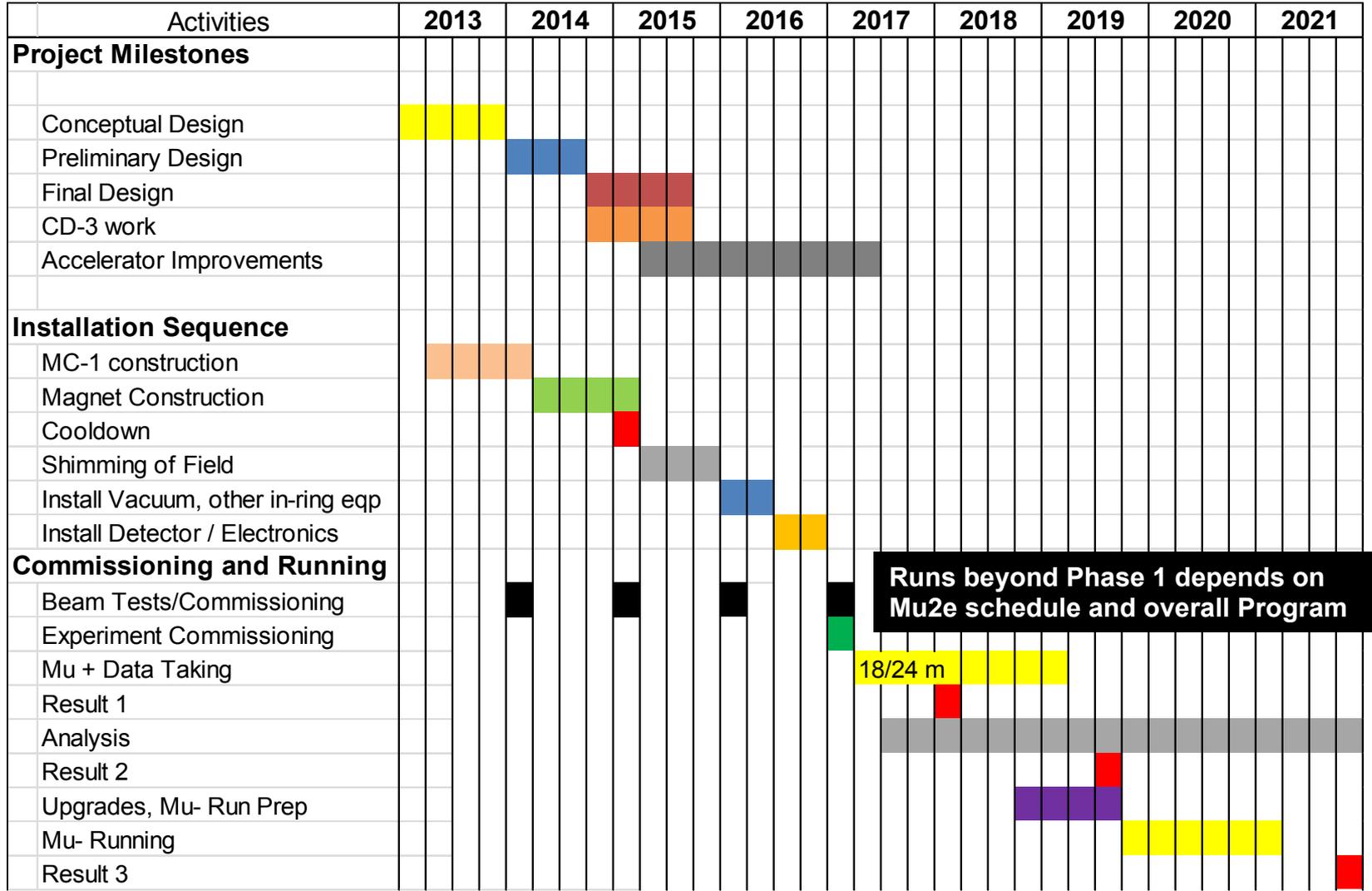


FTE Committed		
Survey of Collaboration for P5		
Construction	Running	Analysis
2014 - 2016	2017-2018	2019 - 2022
91	80	68

Technical Progress and Near-Term Plans

- Collaboration
 - Ring reassembly work in progress
 - Director's review, June 2014
 - CD-2 review July 2014 ←
 - Straw tracker group starts second test beam run April 2014
- Calorimeter Team Activities
 - PbF2 crystals ordered from SICCAS
 - Next-generation Hamamatsu SiPMs received and in tests
 - Bias control system designed
 - Digitizer prototypes built; Upgrade to 800 MSPS made
 - DAQ tests for timing and analysis throughput successful
 - Test Beam at SLAC July 2014 ←
- Calibration Specific Activities
 - New simulations confirm the essential gain monitoring stability benchmarks of 0.04% over 700 μ s for T method
 - Italian team design meeting all specs so far
 - More details on other slides

Timeline (fiscal year)

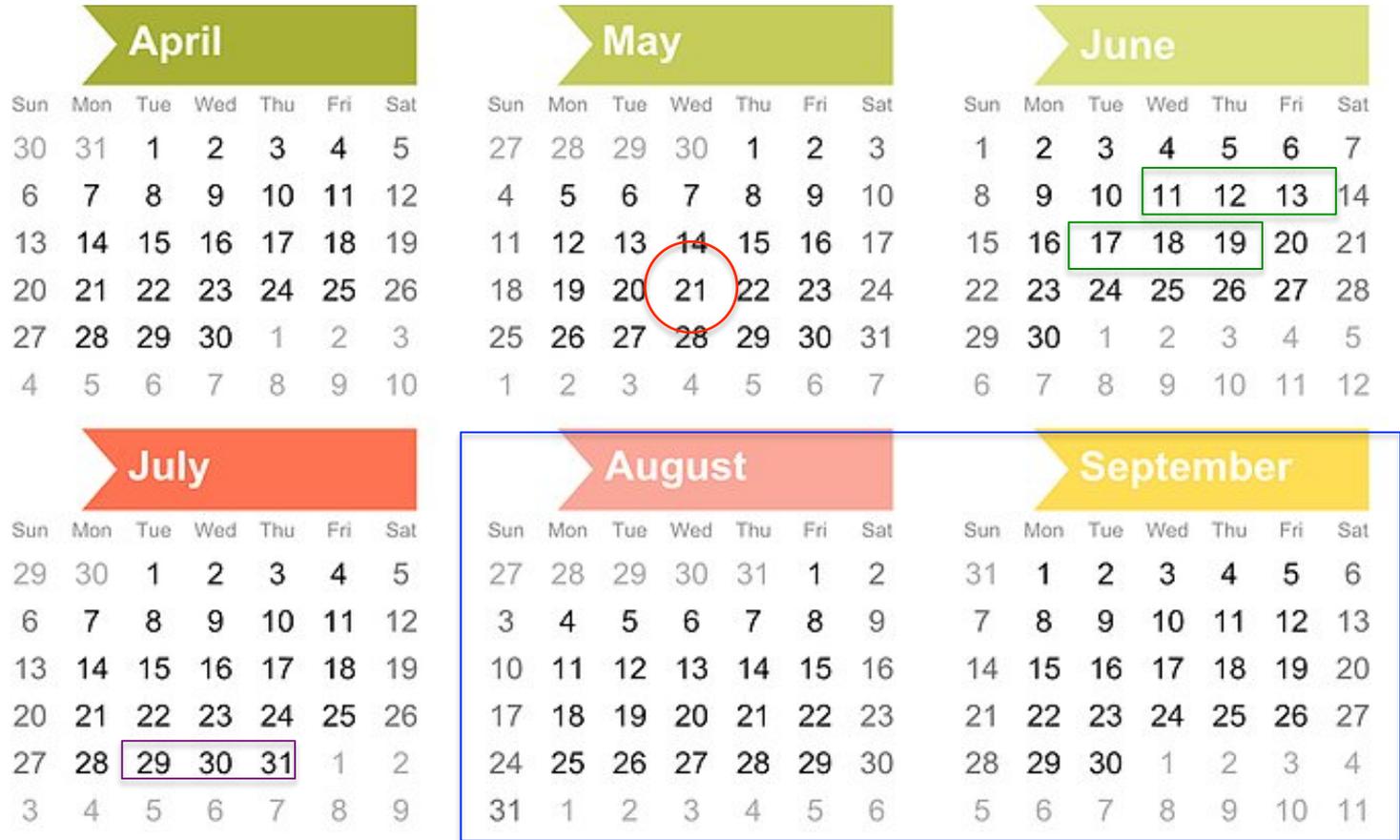


Runs beyond Phase 1 depends on Mu2e schedule and overall Program

18/24 m



CD2/3 Doe Review on 29-31 July



 Date to Post Documents

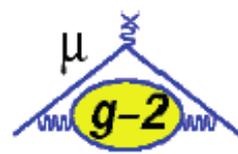
 Two week window for 2 day DOE Review

 Two week window for 3 day Director's review

 Last 10 weeks of fiscal year



MC-1 Reality vs Concept





In parallel with the g-2/Mu2e work



Fiscal Year	2012	2013	2014	2015	2016	2017	Total
MC-1 Building GPP	0.5	7.5	1.0				9.0
Beamline Enclosure GPP		0.4	3.7	5.6			9.7
MC Infrastructure GPP			0.5	0.5			1.0
(feeder if needed)						1.1	1.1
Cryo AIP		1.1	5.1	1.3	0.8	1.4	9.7
Recycler RF AIP		0.4	1.0	3.8	3.4		8.6
Beam Transport AIP		0.2	2.5	3.7	0.3		6.6
Delivery Ring AIP		0.1	1.9	3.3	4.3		9.5
Muon Campus TPC	0.5	9.6	15.6	18.2	8.8	2.5	55.2

needed
only for
Mu2e

■ Muon Campus Goals in CY14

- Finish MC-1 building
- Complete most of the work for g-2 portion of cryo plant
- Begin tunnel construction
- Start work on the accelerator construction AIPs

ω_a Systematic Requirements

E821 Error	Size [ppm]	Plan for the E989 $g - 2$ Experiment	Goal [ppm]
Gain changes	0.12	Better laser calibration; low-energy threshold; temperature stability; segmentation to lower rates; no hadronic flash	0.02
Lost muons	0.09	Running at higher n -value to reduce losses; less scattering due to material at injection; muons reconstructed by calorimeters; tracking simulation	0.02
Pileup	0.08	Low-energy samples recorded; calorimeter segmentation; Cherenkov; improved analysis techniques; straw trackers cross-calibrate pileup efficiency	0.04
CBO	0.07	Higher n -value; straw trackers determine parameters	0.03
E-Field/Pitch	0.06	Straw trackers reconstruct muon distribution; better collimator alignment; tracking simulation; better kick	0.03
Diff. Decay	0.05 ¹	better kicker; tracking simulation; apply correction	0.02
Total	0.20		0.07

Needs a 0.04% control of gain fluctuations ([0-700 μ s]) . How to do that?

“Guidelines” for the Laser Calibration system

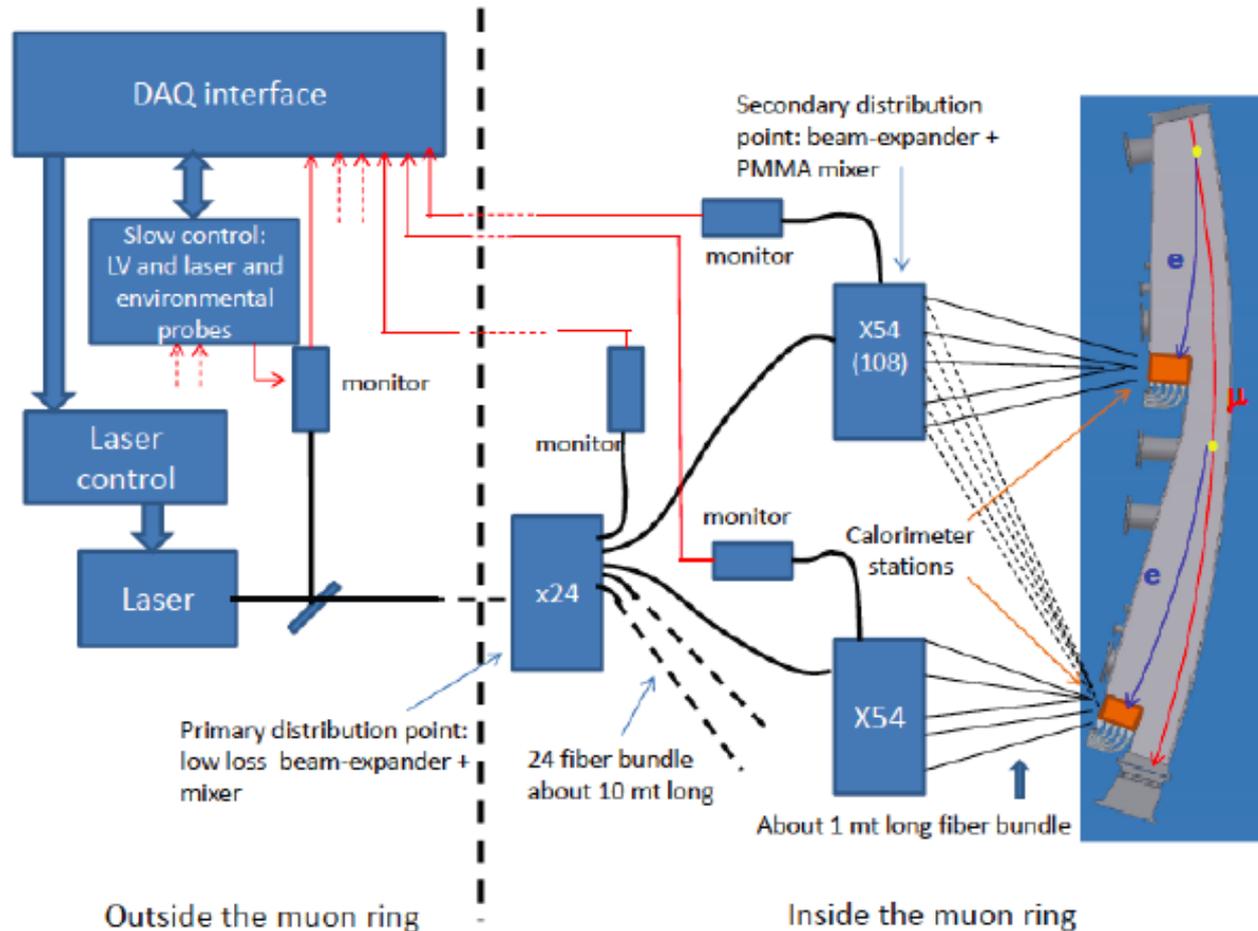
- “Calibration” signals as close as possible (in terms of energy and time) to “physical” events
- Source wavelength selected taking into account:
 - the spectrum of the Cherenkov light emission;
 - the light transmission of PbF₂ crystals;
 - PDF of Sipm
- Pulsed laser with a repetition rate high enough to collect the required statistics, without loading the DAQ throughput
- “Pulse” of the Laser triggerable and adjustable in energy and rate
- The source (and the distribution system) must be stable

“Guidelines” for the Laser Calibration system (cont’d)

- The Distribution system must guarantee:
 - an high transmission efficiency (to reduce the light losses, intensity and costs of the laser)
 - high uniformity of the device output (to moderate effects from beam-pointing stability of the source)
 - Dis-uniformity between channels must be kept constant in time (“Stability” of the distribution system)
- The monitoring (and associated electronics) stable, redundant, and auto-calibrating monitoring system and associated electronics



Baseline design Calorimeter calibration system:

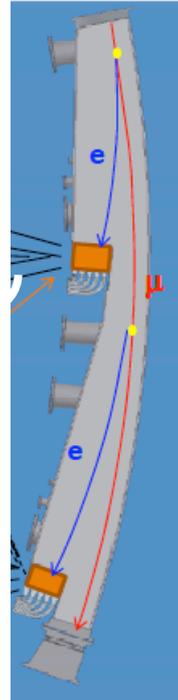
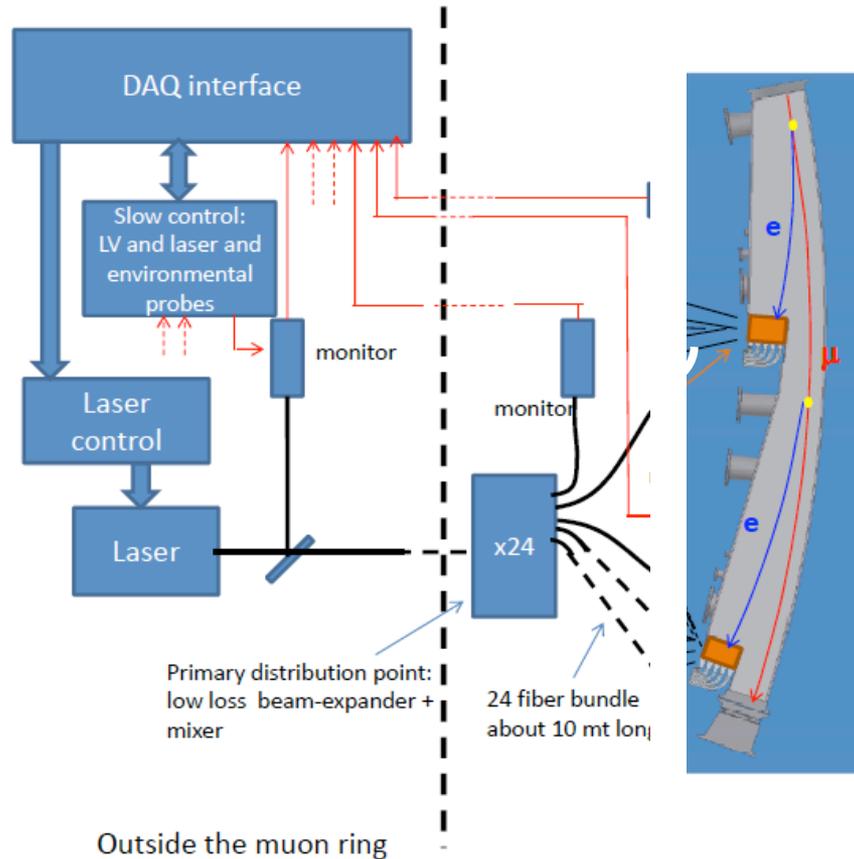


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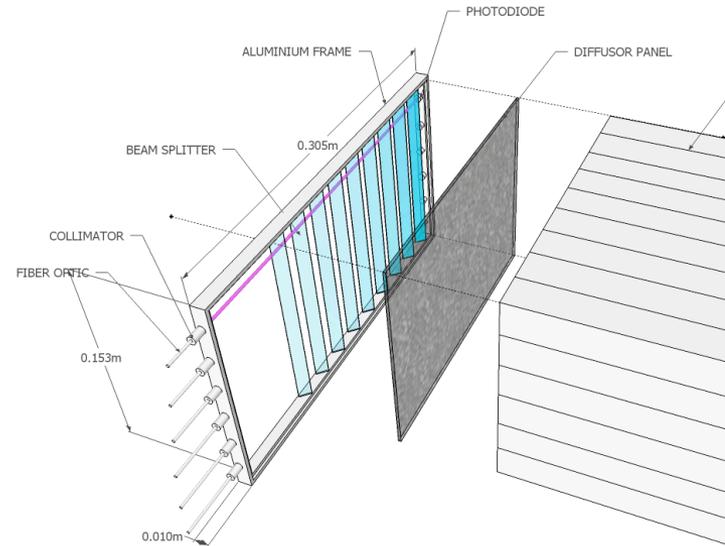
Graziano Venanzoni, WBS 478.04.02.06 Calibration System, Muon g-2 Independent Design Review, June 5-7, 2013

Due punti di distribuzione: 1 primario + [8-24] secondari. 1300 fibre. Per ogni punto di distribuzione un monitoring

Sistema di Calibrazione: Soluzione alternativa (“Pisa Frame”)



- Soluzione piu' semplice
- Monitoring anche per singola fila di cristalli
- Il costo dipende fortemente dal monitoring scelto (6 fotodiodi x modulo, $6 \times 24 = 150$ in totale)
- Stabilita' meccanica e temporale?



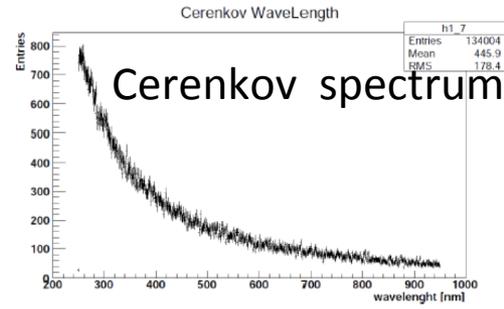
- Unico Punto di distribuzione primario con sole 150 fibre (invece di 1300), grazie ad un diverso routing delle fibre ai cristalli (“Pisa frame”). ~130 monitoring

- Le due soluzioni hanno caratteristiche e criticità diverse. Anche come componentistica richiedono soluzioni diverse
- Per il momento su suggerimento dei referee ci siamo concentrati sul disegno “baseline”

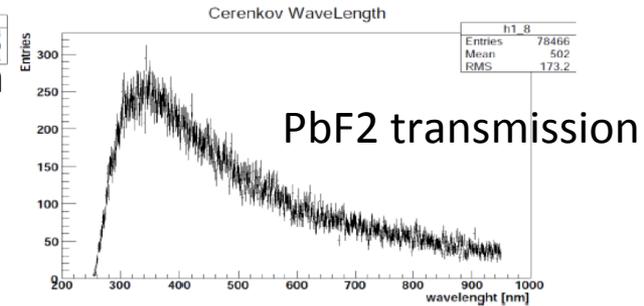
Laser characteristics: Wavelength

- Wavelength λ : [350-450], 400 nm as reference (our simulation)

Results obtained with Geant 2 GeV e^- su un Cristallo PbF2

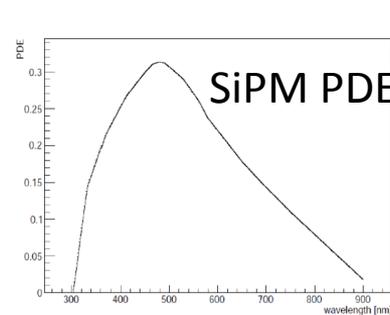


(a)

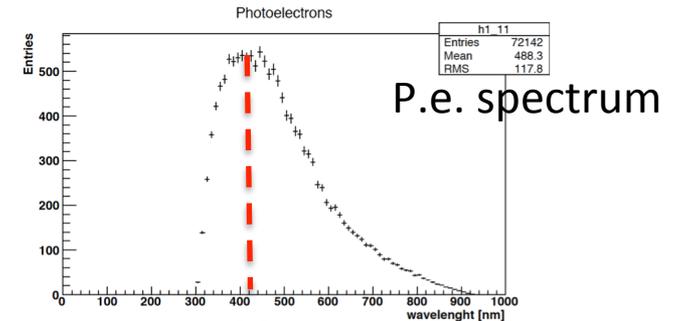


(b)

Byproduct:
Light yield $\sim 1.6/\text{MeV}$



(c)



(d)

Figura 1: (a) spettro in lunghezza d'onda dei fotoni Cerenkov emessi da un e^- di 2 GeV; (b) spettro dei fotoni che arrivano sulla faccia del SiPM; (c) PDE del SiPM; (d) spettro dei p.e. . La figura e'ottenuta da una simulazione con Geant di A. Anastasi

Laser characteristics: Transmission factor

- Energy pulse equivalent to 2 GeV (assuming *up to* 2p.e./MeV):

$$E_{pulse}^{TOT} = \frac{24 \times 54 \times E_{pulse}^{crystal}}{T} = \frac{24 \times 54 \times 0.01 pJ}{T} = \frac{13 pJ}{T}$$

- The “**light transmission factor**” **T** includes light loss along the optical path: filters, diffusive elements, fiber coupling, light routing to calorimeter, and depends on the adopted solution
- We have measured it for a 2” sphere and bundle finding ~1%
- As “conservative” estimate for the final set up we assume $T \sim 0.1\%$ (i.e. we include additional factor 10 loss)
- We were able to quantify the laser needed for the Test Beam (25 channel) with a bundle of ~1 mm fibers \rightarrow 50 pJ request (500 pJ laser bought)

Coeff di trasmissione – laser continuo

Fiber bundle:

quartz, 60 fibers, 0.2 mm diameter

Laser:

Nd:YAG, Wavelength $\lambda = 532$ nm, $P_{\max} = 7$ W (CW)

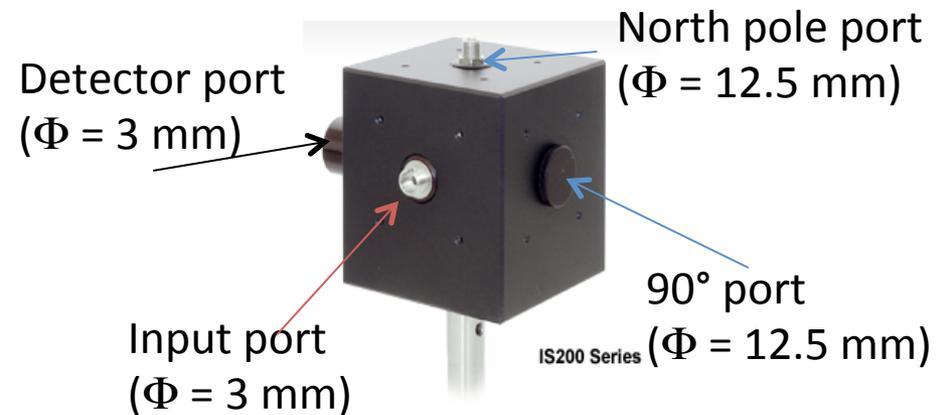
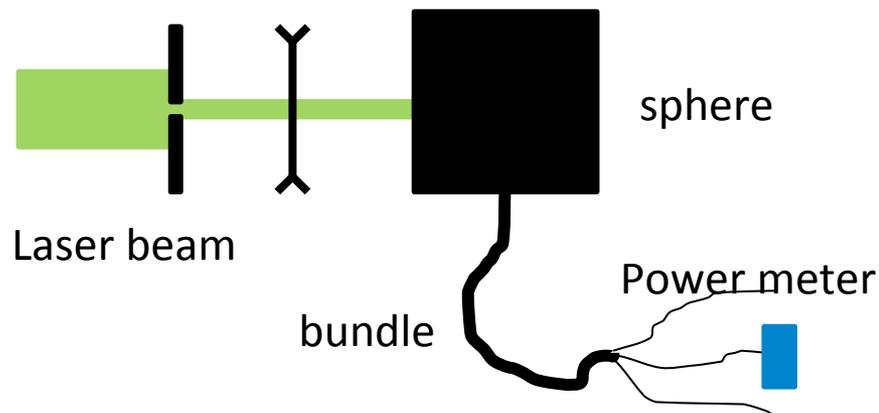
model: Coherent VERDI

Detector:

Power meter Coherent, model: fieldmaster

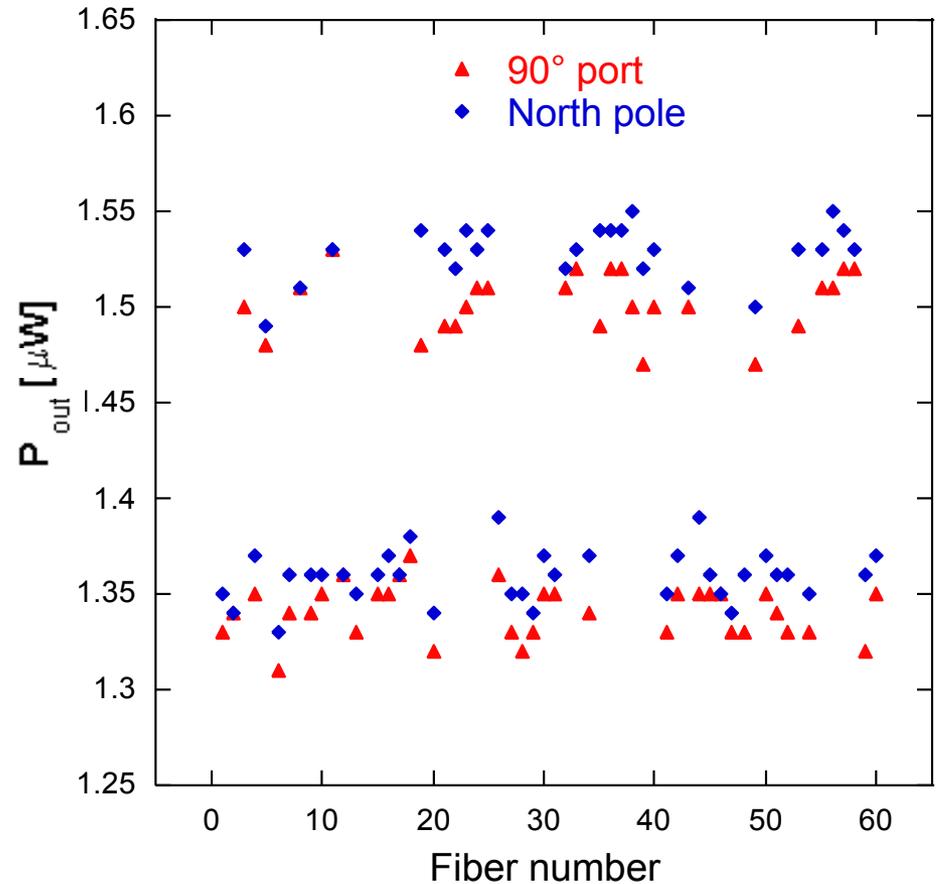
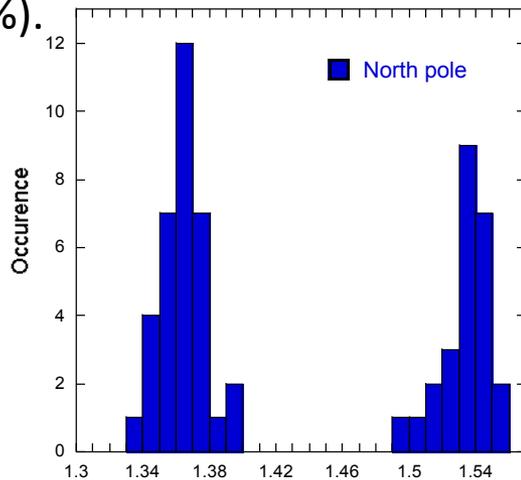
Set-up:

$P_{\text{in}} = 150 \pm 2$ mW, pinhole, lens ($f = 10$ mm)



Coeff di trasmissione - risultati

- Il bundle di fibre presenta due classi con trasmissione differente
- La trasmissione dei due gruppi differisce di circa il 10%. All'interno dei gruppi la trasmissione cambia molto meno, circa il 2%.
- La porta nord ha una trasmissione un po' superiore rispetto alla porta a 90° (circa 2%).



Il coefficiente di trasmissione per **singola fibra** del sistema sfera + bundle risulta

$$T_i = (1.01 \pm 0.03) \cdot 10^{-5}$$

→ $T_{\text{sphere+bundle}} \sim 1\%$ con 60 fibre da 1mm \emptyset

Coeff di trasmissione – laser pulsato

Fiber bundle:

60 fiber, 0.2 mm diameter (only a single fiber investigated)

Laser:

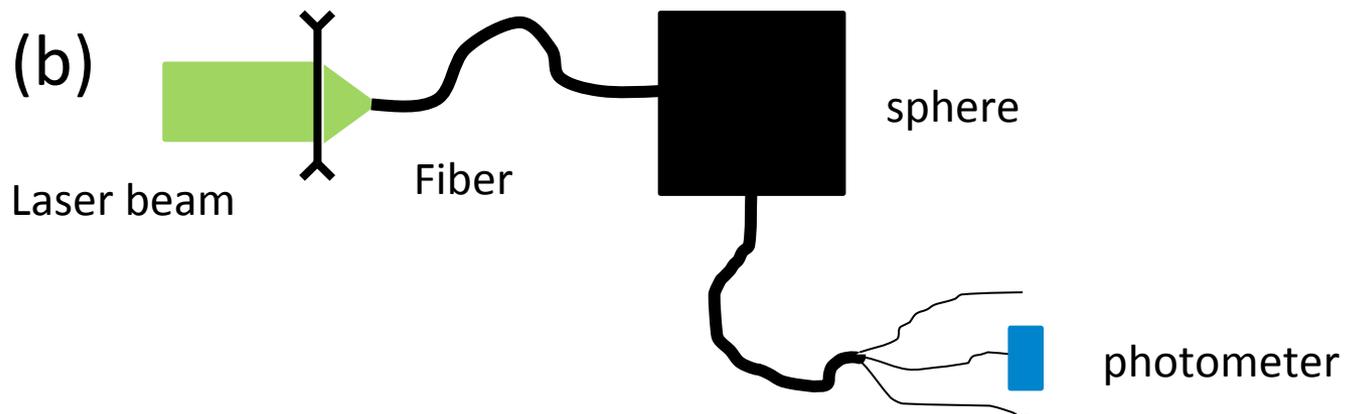
Nd:YAG, $\lambda = 532$ nm, $P_{max} = 5$ mW per pulse, 20 Hz repetition rate, 10 ns pulse width; model: Continuum I-20

Detector:

Photodiode, Hamamatsu, mod. S5973-02

Set-up:

Fiber optic, neutral filters (optional), lens, average on 64 pulses,

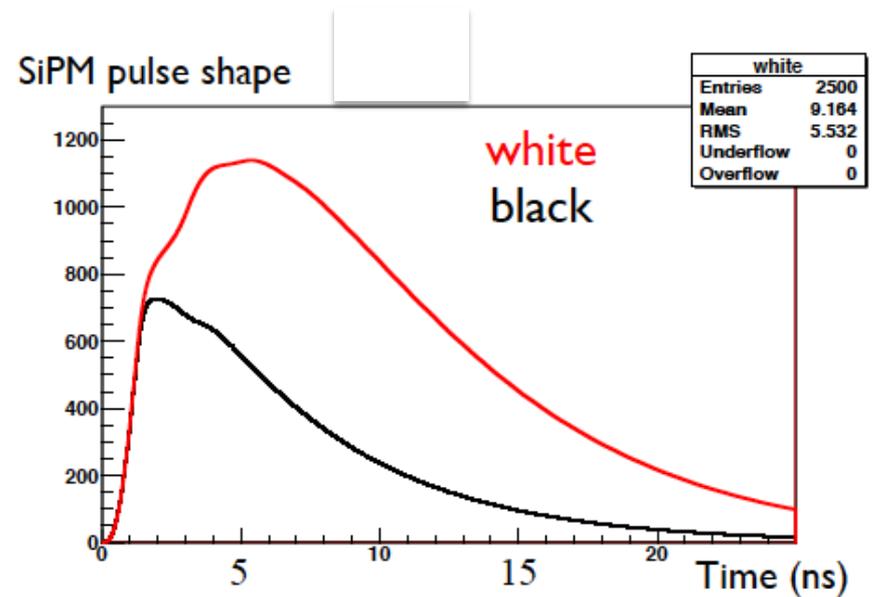
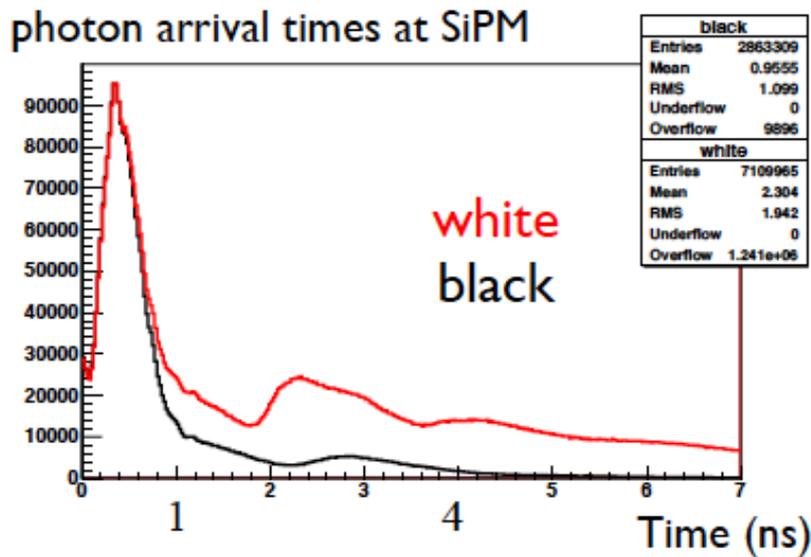


coeff di trasmissione per singola fibra del sistema sfera+bundle:

$$T_i = (2 \pm 1) \cdot 10^{-5} \text{ (consistente con il laser in continuo)}$$

Caratteristiche temporali segnale laser

- Segnale largo \sim ns per riprodurre il segnale dei fotoni in arrivo ai SiPM (che viene allargato dal SiPM)



Ci si aspetta che le caratteristiche temporali del segnale laser vengano modificate dal sistema di distribuzione (sfere, ecc...)

→ Confermate dai test fatti

Risposta temporale: setup sperimentale

Laser:

Ti-sapphire laser pulsed laser (wavelength 400 nm) with pulse duration of < 300 fs and pulse energy ~ 1 mJ.

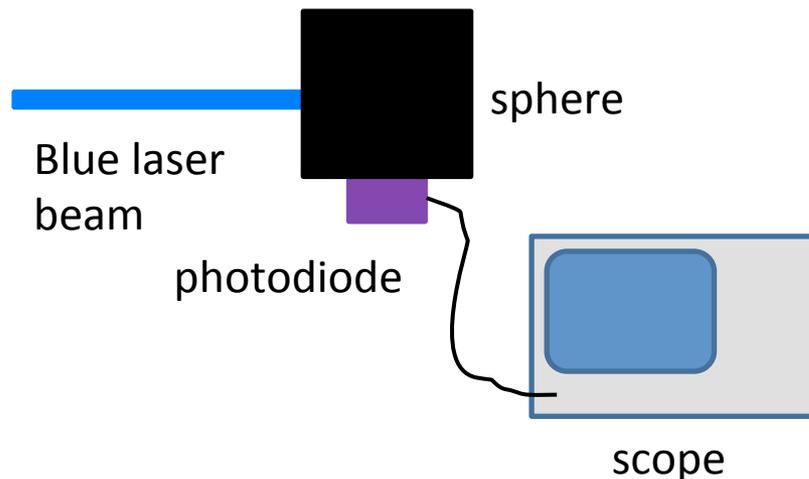
Detector:

photodiodes Hamamatsu, model S5973-02, which has high sensitivity in the UV region (0.3 A/W, QE = 91% at $\lambda = 410$ nm) and a bandwidth of 1.5 GHz. Without amplification.

Setup:

2 inch sphere, mod. IS200, Thorlabs

Oscilloscope LeCroy Wavesurfer, 500 MHz bandwidth

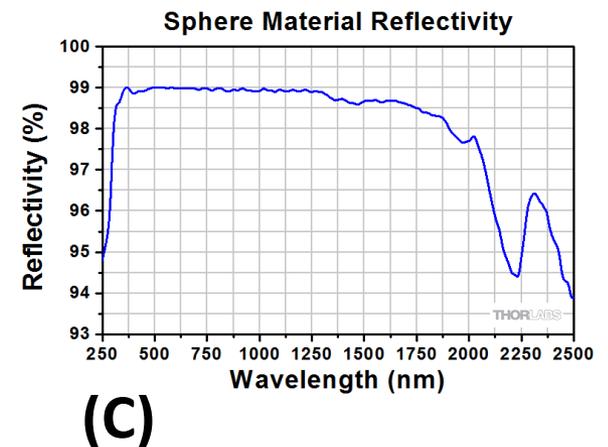
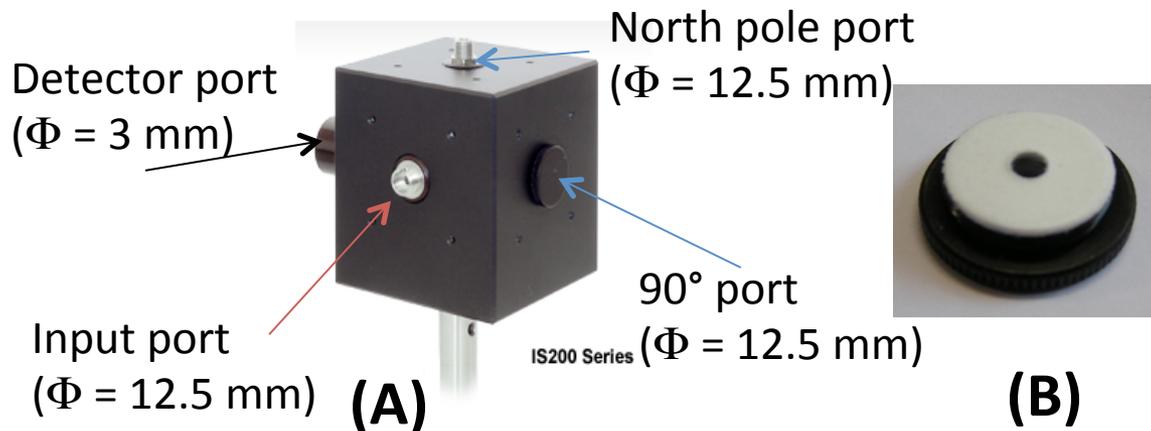


Risposta temporale: condizioni

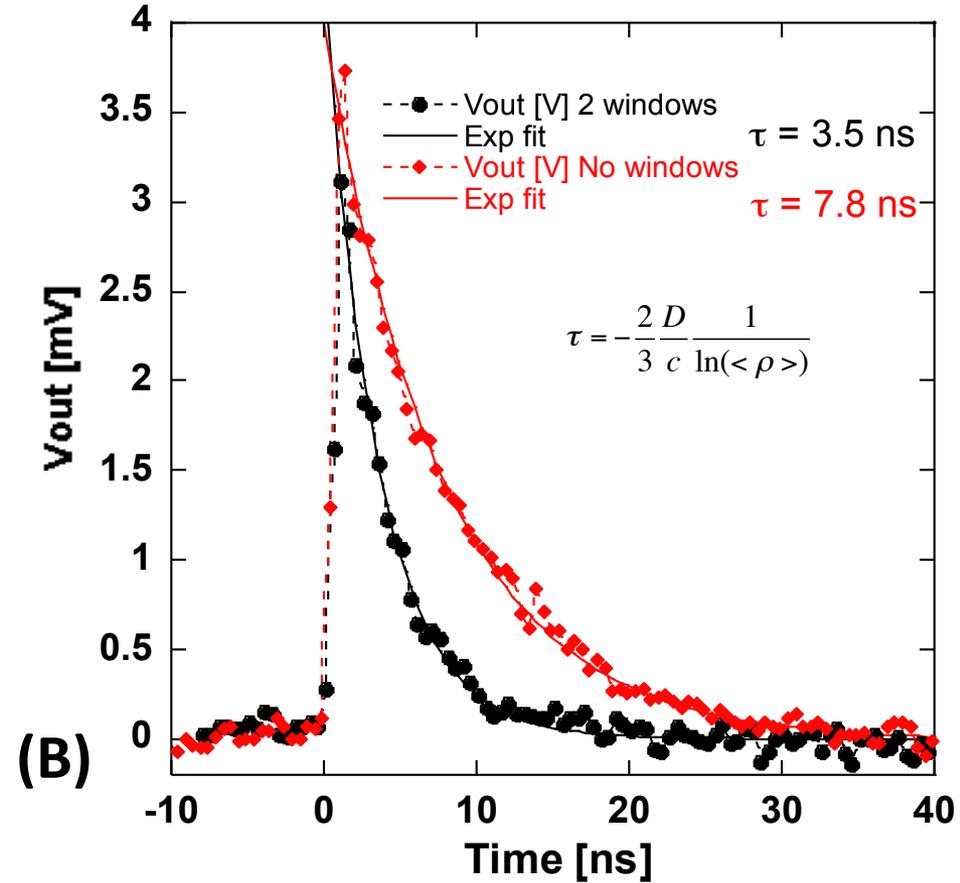
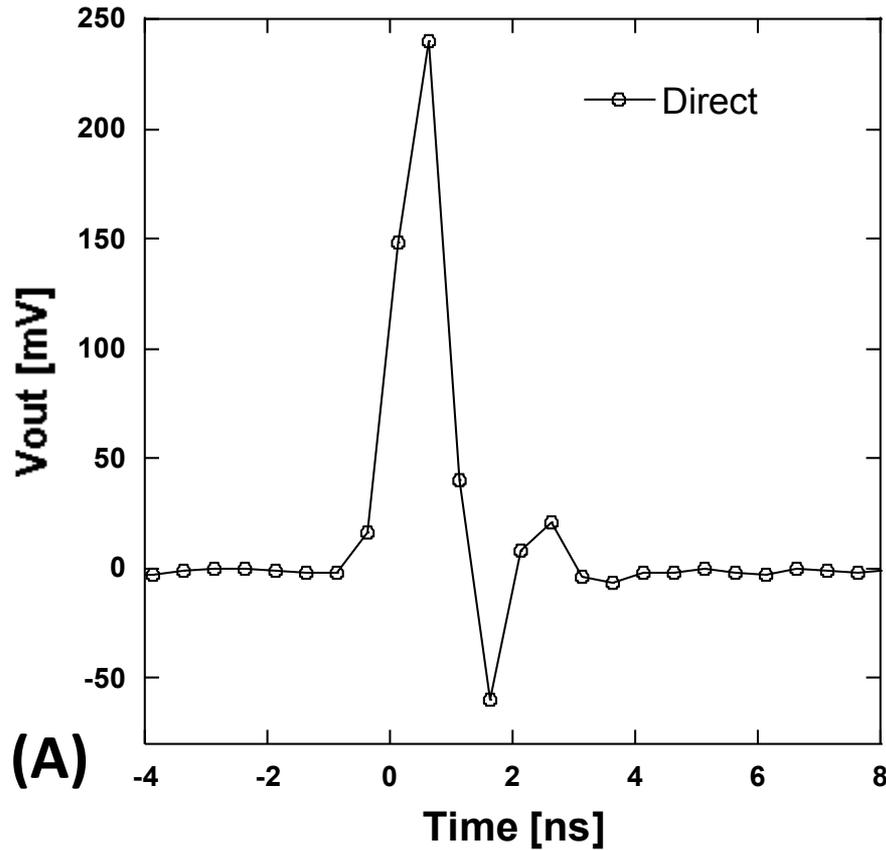
La risposta temporale della sfera è stata misurata in due diverse condizioni sperimentali:

- a) Con tutte le porte da 1/2" chiuse (con eccezione della porta di ingresso del laser e la porta del detector, entrambe di diametro 3 mm);
- b) con due porte da 1/2" aperte in più.

Le due condizioni hanno differenti riflettività medie e quindi devono fornire due differenti tempi caratteristici.

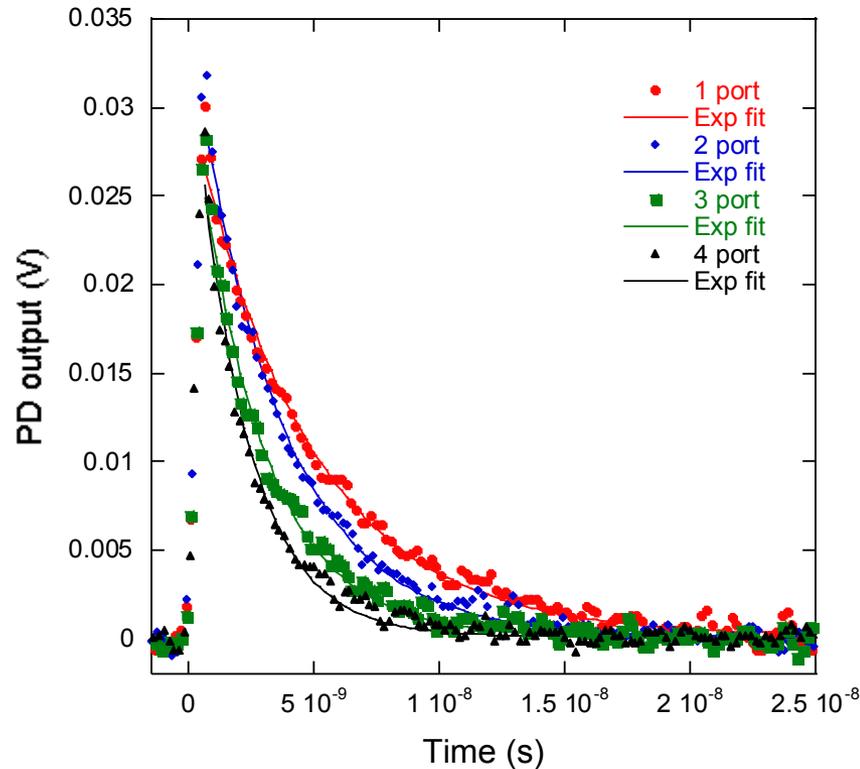


Risposta temporale: risultati



Conditioni	S_{open} (mm ²)	$\langle \rho \rangle$	τ_{th} (ns)	τ_{experim} (ns)
no ½" ports	14.1	0.985 ± 0.005	7.5 ± 2	7.8 ± 0.3
2 ½" ports	267.4	0.954 ± 0.003	2.4 ± 1	3.5 ± 0.3

Risposta temporale: ulteriori misure



$$y = m1 + m2 * \exp(- (M0-m3)/m...)$$

	Value	Error
m1	0.00013643	4.5773e-05
m2	0.03416	3926.3
m3	-5.3e-10	0.00053185
m4	4.6271e-09	6.0804e-11
Chisq	5.7016e-05	NA
R	0.99572	NA

$$y = m1 + m2 * \exp(- (M0-m3)/m...)$$

	Value	Error
m1	3.0339e-05	4.2003e-05
m2	0.040793	4647.3
m3	-5.4985e-10	0.00039926
m4	3.5045e-09	4.6284e-11
Chisq	5.6473e-05	NA
R	0.99552	NA

$$y = m1 + m2 * \exp(- (M0-m3)/m...)$$

	Value	Error
m1	8.4613e-05	4.2016e-05
m2	0.041674	10882
m3	-7.4952e-10	0.00071505
m4	2.7381e-09	4.736e-11
Chisq	6.2322e-05	NA
R	0.99223	NA

$$y = m1 + m2 * \exp(- (M0-m3)/m...)$$

	Value	Error
m1	0.00010097	3.9843e-05
m2	0.04676	15072
m3	-6.4938e-10	0.00067111
m4	2.0819e-09	3.8339e-11
Chisq	6.052e-05	NA
R	0.99113	NA

➤ Con 4 porte aperte (+ porta detector per ingresso laser) la costante tempo sperimentale scende a 2.1 ns

Calibration signal: Statistics

$$R = \frac{Q_{SiPM}}{Q_{mon}}$$

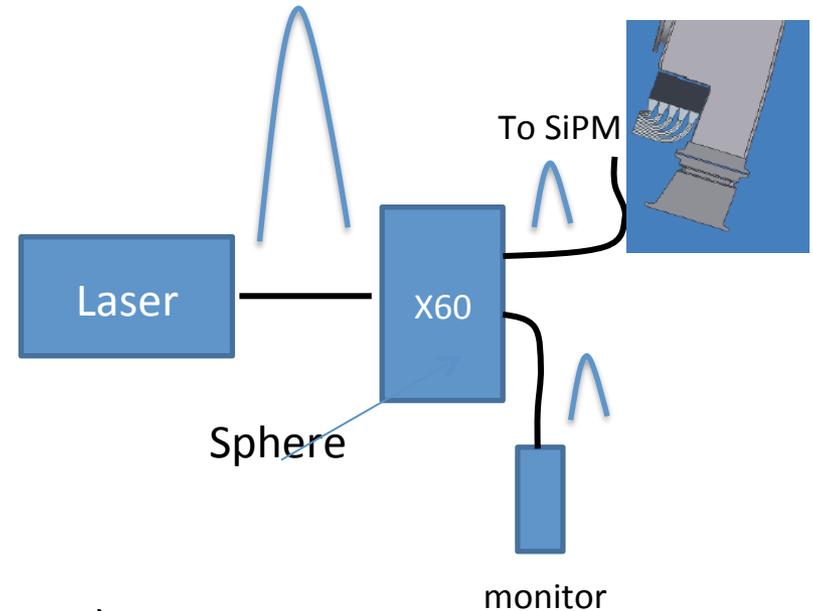
$$\sigma_R^{stat} = \sigma_{phe,SiPM} + \sigma_{phe,PD} + \sigma_{elect\ noise}$$

$$\sigma_R^{stat} \rightarrow \sigma_{phe,SiPM} \sim 1 / \sqrt{3000} \sim 2\%$$

$\sigma_{phe,SiPM}^{stat}$ = fluctuation of ph.e. of SiPM

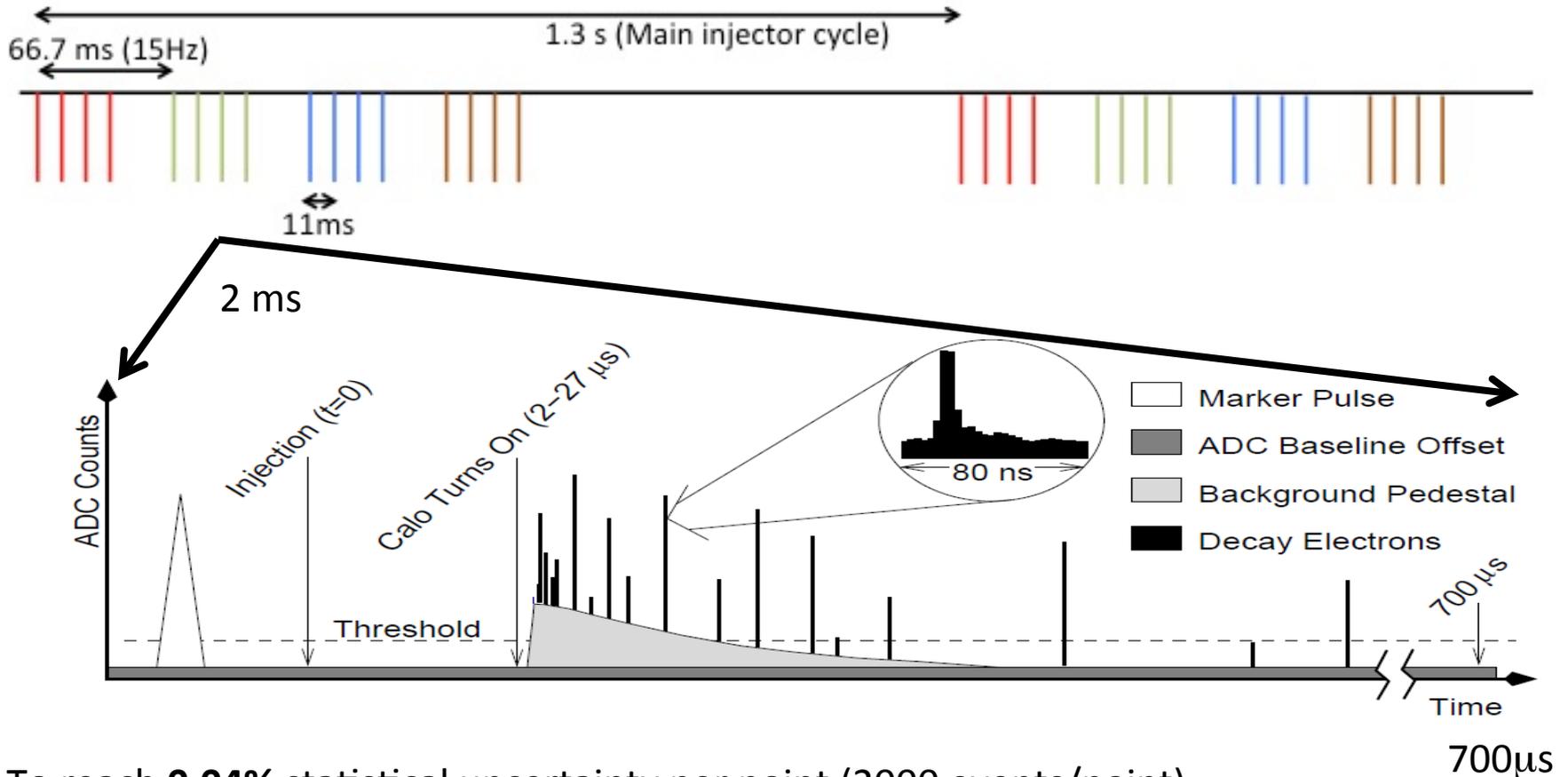
$\sigma_{phe,PD}^{stat}$ = fluctuation of ph.e. of Pin Diode (monitoring)

$\sigma_{elect\ noise}^{stat}$ = electronics noise (stat component)



Statistical error: dominated by the photostatistics of SiPM. can be brought to 0.04% by taking 2000 pulses/point

Statistical Goal



To reach **0.04%** statistical uncertainty per point (2000 events/point)

- Let's assume 9 points per fill (1 every 80 μs, 12.5 kHz laser repetition rate)
- By moving the offset by 5 μs after a fill → 16 fills to have a single event calibration cycle (i.e. one point every 5 μs), i.e. 1.3 s (1/2 hour to have full calibration cycle (1600 events every 5 μs)).

30' calibration runs with ~10 kHz laser frequency → sampling of $G(t)$ in 140 points between 0 and 700 μs

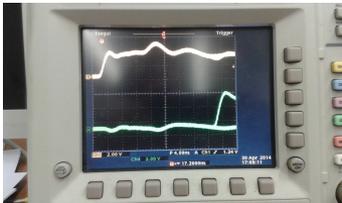
Laser mode: driving electronic board

- The laser must be pulsed a $O(10 \text{ KHz})$ (but also other modes are foreseen)
- A Virtex prototype has been setup and put in operation at NA



Sistema di controllo laser tramite VIRTEX5. La sequenza di trigger e' visualizzata all'oscilloscopio.

- First results very promising with a generation of signals $1\mu\text{s}$ distant, with a time jitter $< 1\text{ns}$



Time jitter del segnale di trigger: traccia in basso in persistenza $\rightarrow Dt < 1 \text{ ns}$

General overview

DAQ

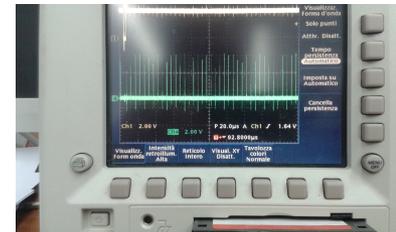
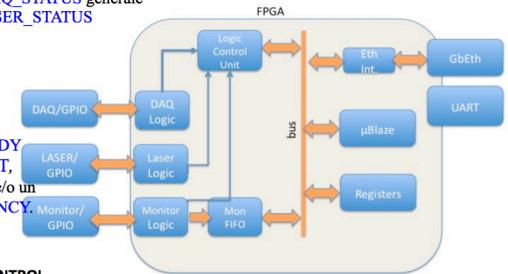
IN: **FILL** e **END_OF_FILL** relativamente alla macchina e/o **DAQ_STATUS** generale
OUT: **READY** e **LASER_STATUS**

LASER

OUT: **START** e **READY**
IN: **Ack dello START**, **WARNING/FAULT** e/o un segnale di **EMERGENCY**

MONITOR/SLOW CONTROL ...

IN: n canali ADC/SiPM
OUT: data frame



Riempimento della finestra dei 700 micros

Calibration signal: systematic error

$$R = \frac{Q_{SIPM}}{Q_{mon}}$$

$$\sigma_R^{sist} = \sigma_{Mon} + \sigma_{Electr} + \sigma_S^{syst}$$

σ_S^{syst} = Drift of the uniformity of the source

σ_{Mon}^{syst} = Drift of the Monitoring response

σ_{Electr}^{syst} = Drift of the Electronic behaviour
(Pre-amplifier, Charge conversion, etc...)

Systematic error: must be kept <0.1% (in 30' run)

Our measurements (so far):

$\sigma_{Mon}^{syst} \sim 0.1\%_{PD} \oplus 0.5\%_{Calibsource}$ (dominated by the fluctuation of the baseline of the electronics) (UD)

σ_{Electr}^{syst} (PD+Preampli) $\sim 0.1\%$ (TS)

σ_S^{syst} = (Sphere+fibers) $\sim 0.2\%$ (LNF)

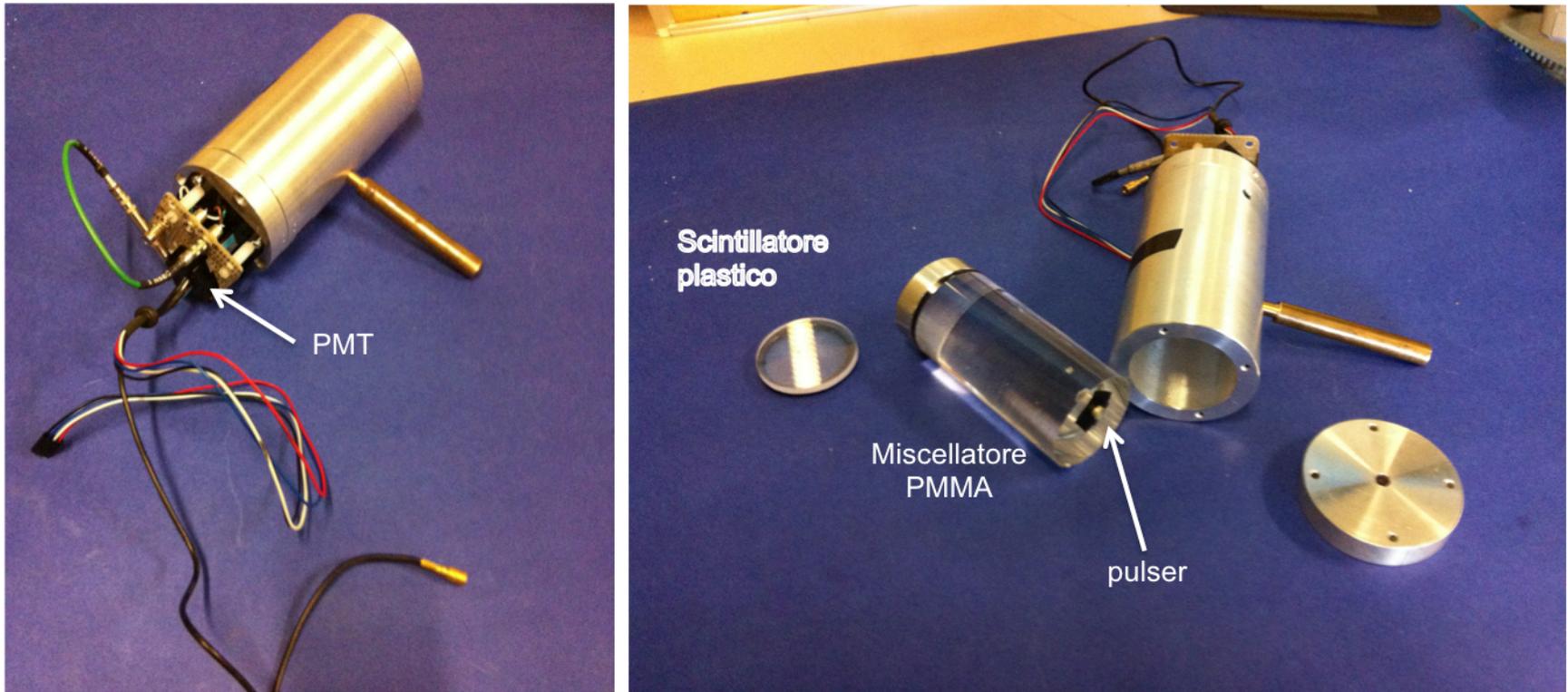
$$\sigma_R^{sist} = \sigma_{PD+Ampli} + \sigma_{Calibsource} + \sigma_S^{syst}$$

$$\sigma_R^{sist} = 0.1\% \oplus 0.5\% \oplus 0.2\%$$

We expect a big improvement on Calibration source with the new electronics, and also on the other components

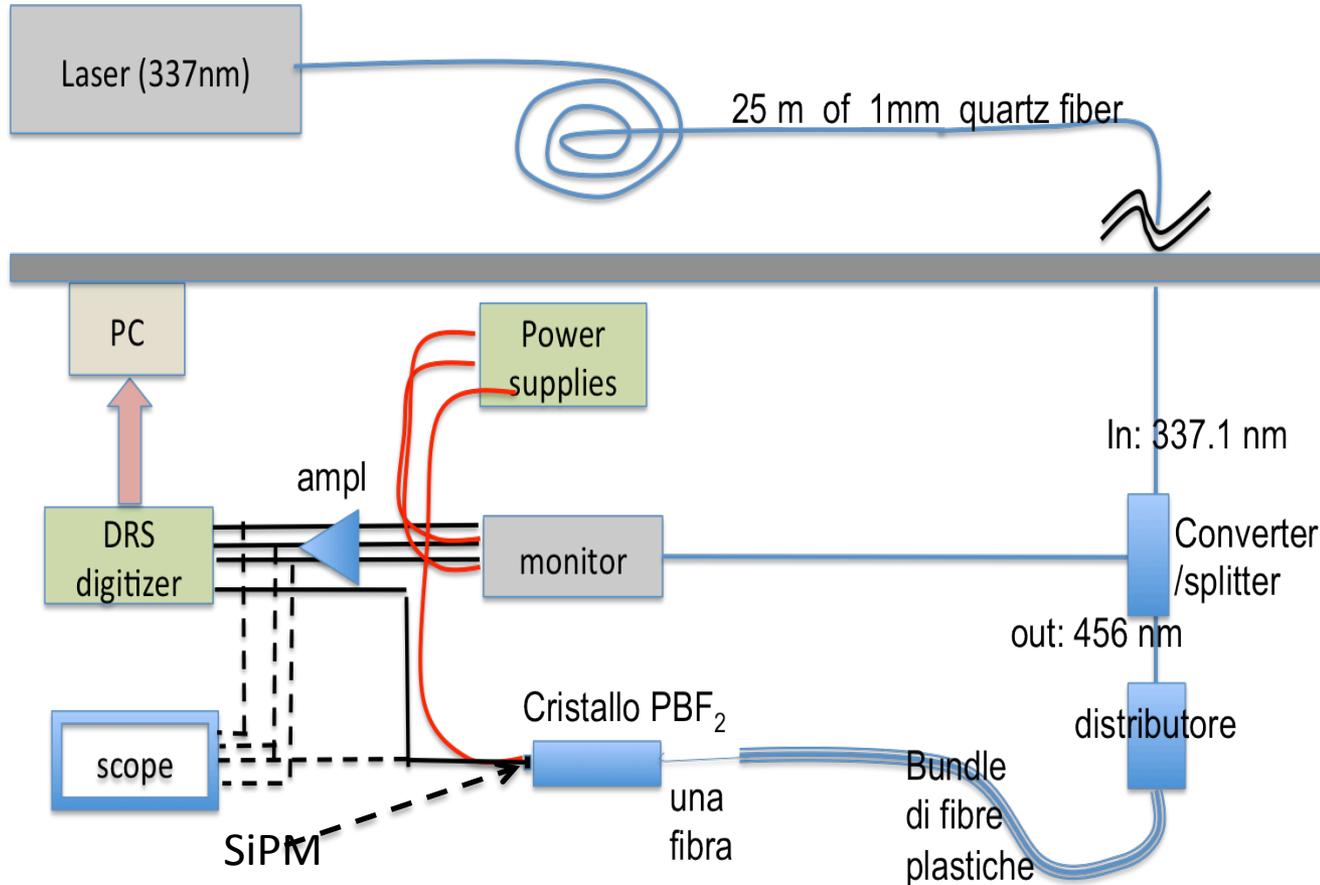
Stabilita' del segnale di Monitoring (UD)

Our first attempt at incorporating these qualities are represented by the following prototype:



This prototype incorporates two PIN diodes and one PMT as photodetectors, a plastic scintillator as “ideal” diffuser and a PMMA cylinder as a “mixer” The photodetectors are widely distributed to maximize sensitivity to anisotropic fluctuations and one of them views both the laser pulse and an NaI signal generated by a ^{241}Am source as absolute reference.

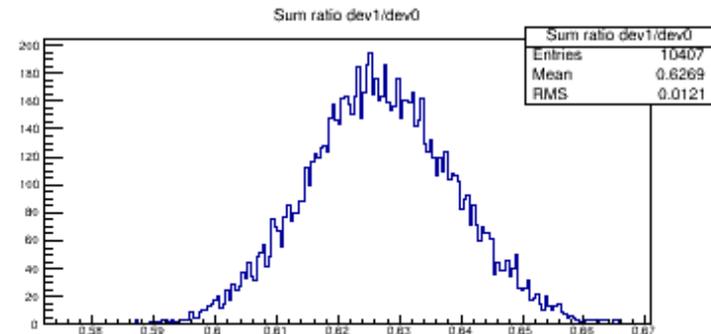
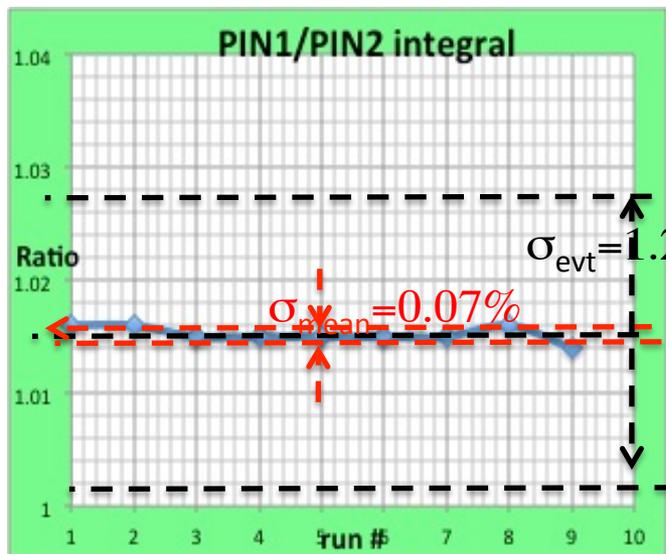
We have attempted to approach operating conditions. In the absence of the required laser (still on the way) and of the monitor electronics (almost ready) we have resort to the following experimental setup.



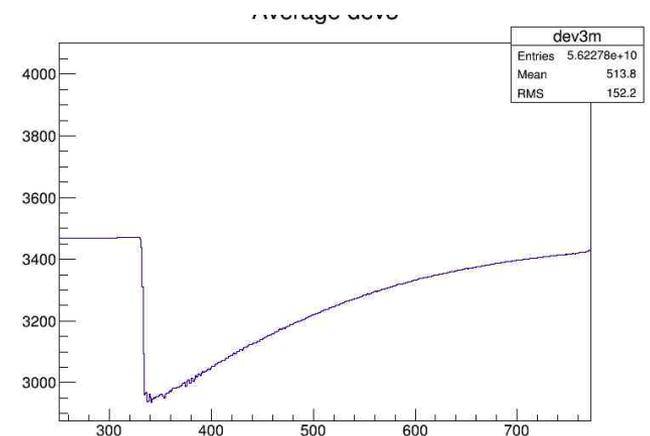
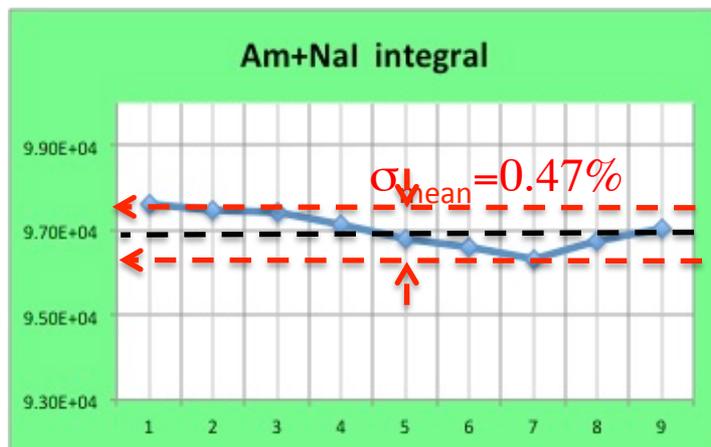
**Fluttuazioni
laser~10%;
elettronica e
sistema ottico
non ottimizzato**

A wavelength-shifter/splitter is used to convert the 337.1 nm laser light to 456 nm and to distribute it between 3 output quartz fibers. One of them, generates a large trigger pulse by illuminating a PIN diode directly. The other two share the light between the monitor and the distributor

Stabilita' di
PD1/PD2:
 $\sigma_{\langle R \rangle} \sim 0.07\%$



Stabilita' del
"pulser" ^{241}Am
+NaI



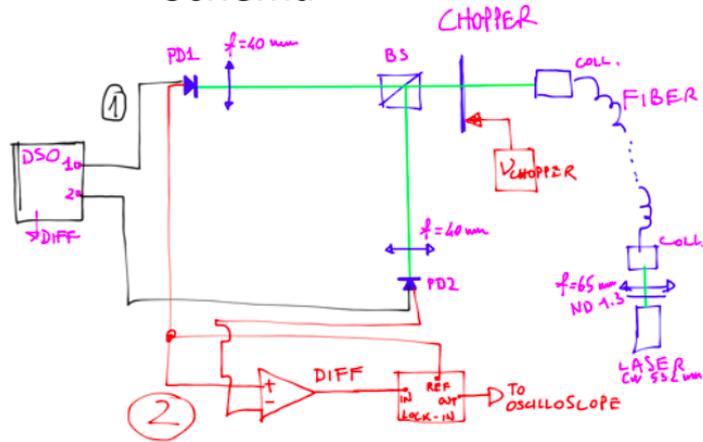
$$\sigma_{\text{Monit}} \sim 0.07\%_{\text{PD}} \oplus 0.47\%_{\text{Calib source}}$$

In un ambiente assai peggiore di G-2, dominato dall'instabilita' dell'elettronica.

Il segnale dal NaI e' relativamente lento e va integrato per centinaia di nanosecondi. Pertanto e' molto sensibile a fluttuazioni della baseline (DRS).

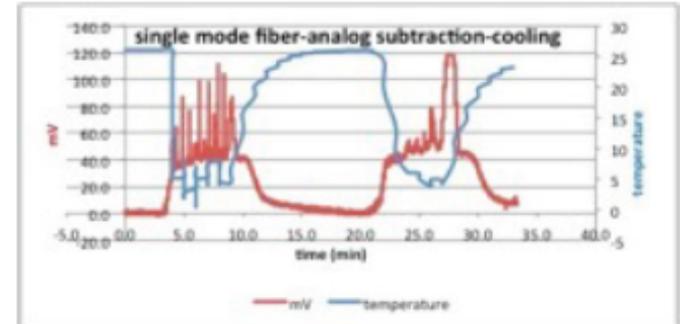
Stabilita' Pin Diode e Amplificatore in eterodina (TS)

Schema

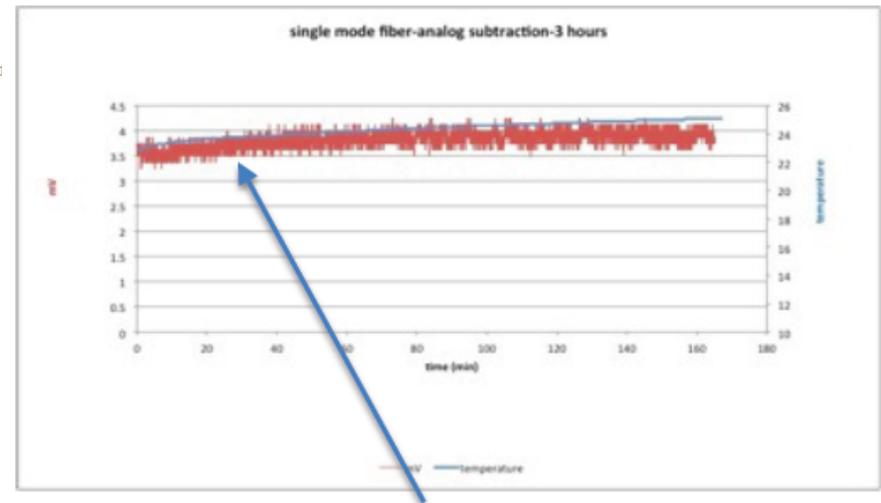


PD1 & PD2 = HAMAMATSU S5973-02
+ FEMTO DLPCA200

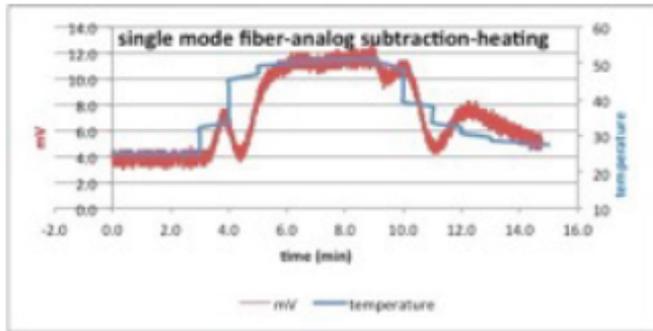
PD2 - ciclo di raffreddamento (sopra) e riscaldamento (sotto)



Prova di stabilità su 3 ore di misura



Stabilita' (PinD e Ampli) ~0.1%



Stabilità dell'uniformità della sfera in funzione del tempo

Fiber bundle:

quartz, 60 fibers, 0.2 mm diameter

Laser:

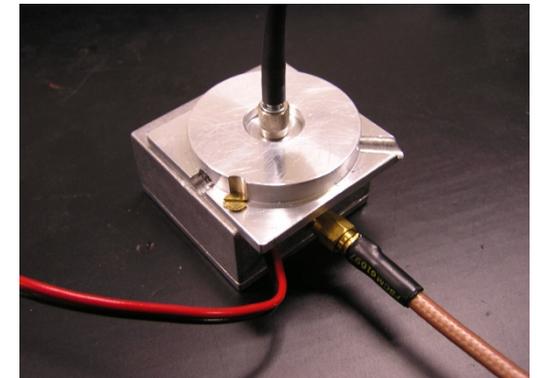
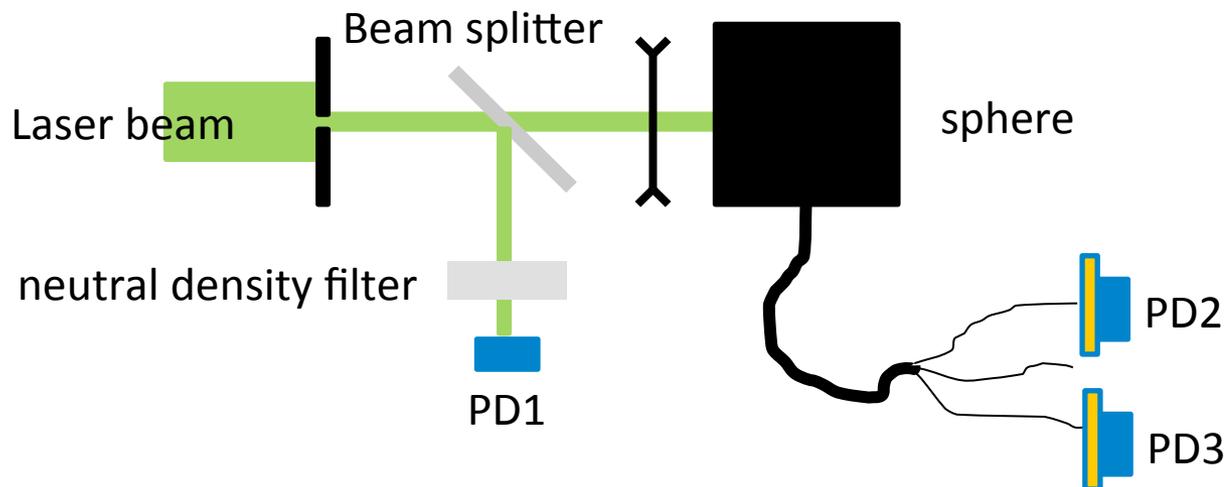
Nd:YAG, $\lambda = 532$ nm, $P_{\max} = 5$ mW per pulse, 20 Hz repetition rate, 10 ns pulse width, model: Continuum I-20

Detector:

photodiodes Hamamatsu, model S1226-18BK (low noise)

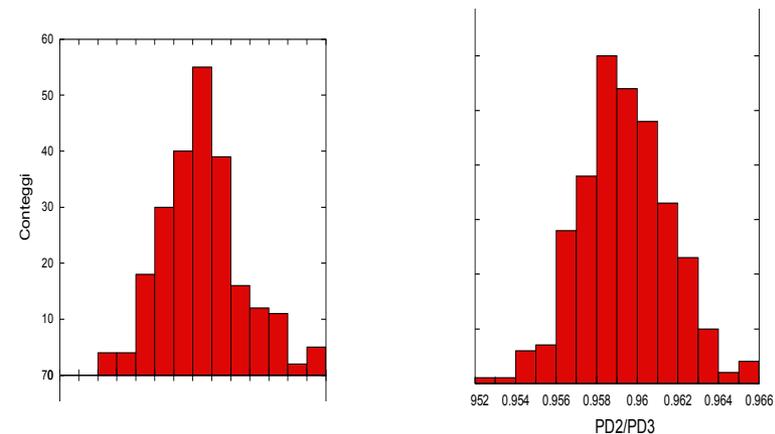
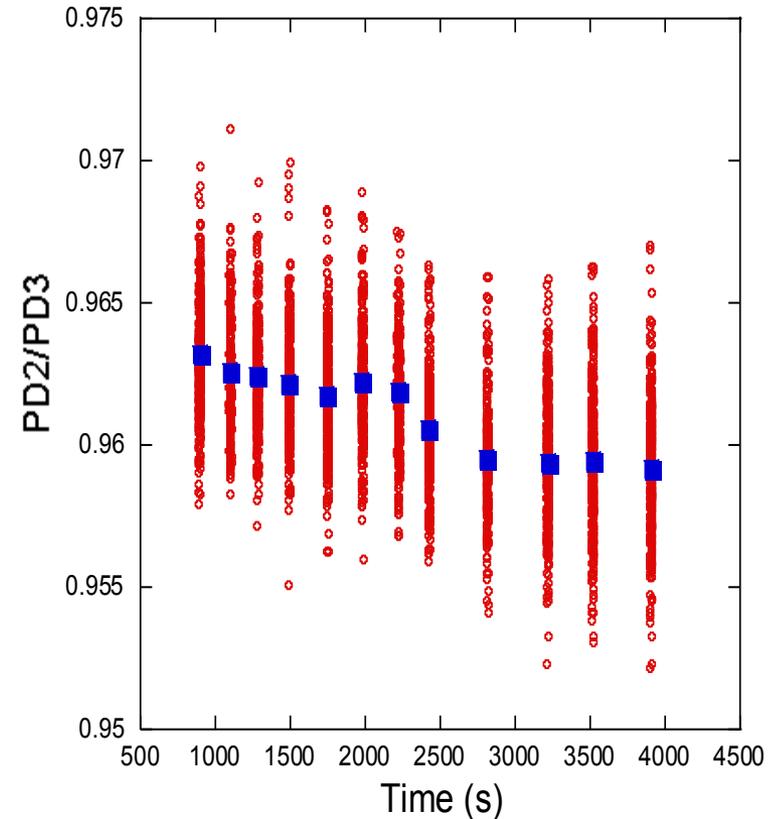
Set-up:

$P_{in} = 150 \pm 2$ mW, pinhole, lens ($f = 10$ mm), beam splitter



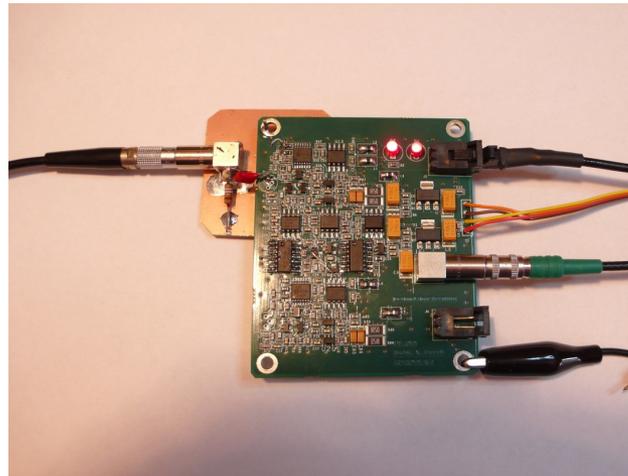
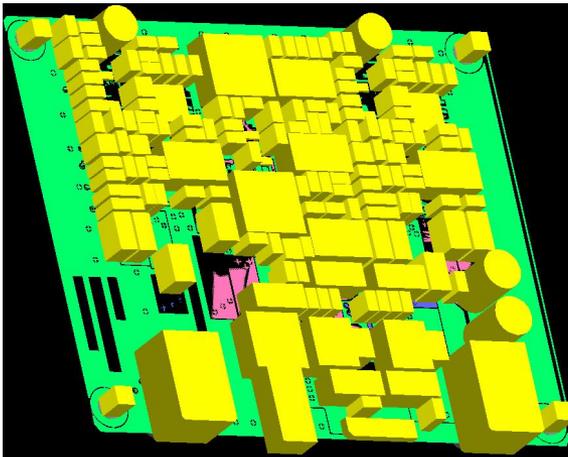
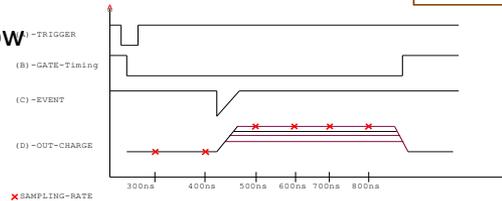
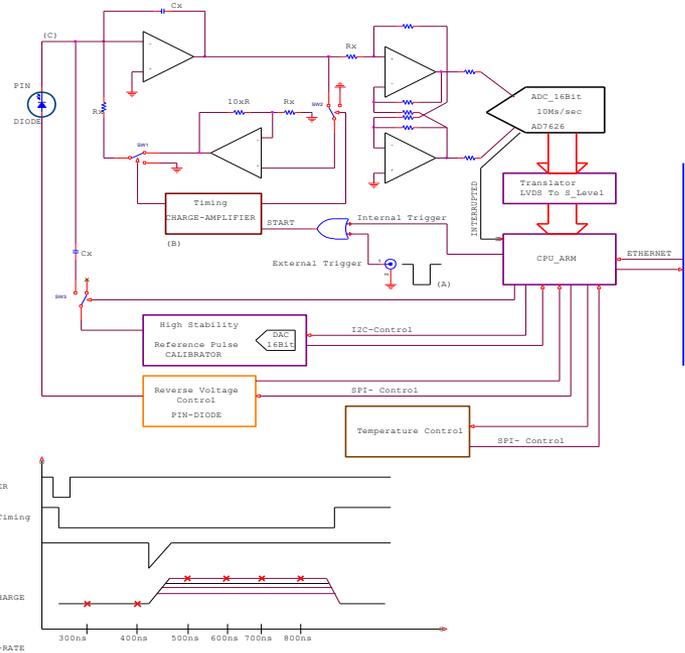
Stabilità vs. tempo - risultati

- Gli impulsi del laser variano molto in ampiezza
- Per ogni gruppo di acquisizione consecutiva, il rapporto dei fotodiodi PD2/PD3 è caratterizzato da una variabilità dell'1%
- La media su ogni gruppo (200 impulsi) varia dello 0.2% in un ora



Elettronica di Monitoring: Scheda custom charge integrator

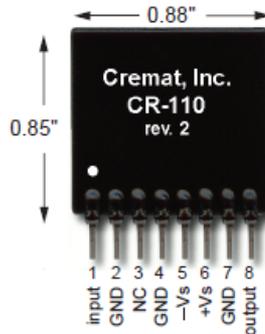
- Rivelatore candidato, Diodo PIN
- Accuratezza di misura dell'ordine del %
- Risoluzione del campionatore 16Bit
- Stabilità a lungo termine, meglio del %
- Rate previsto del LASER 100Khz
- Preamplificatore in carica, sensibilità $\geq 100\text{mV/pC}$
- Banda passante del preamplificatore, 200Mhz
- Dinamica del campionatore $\pm 2\text{V}$
- Campionatore ultraveloce a 16 Bit
- Processore ARM-M3
- Protocollo di comunicazione previsto con l'utente, ETHERNET
- Trasferimento completo dei Dati su pagina Web e Slow Control
- Compensazione automatica della temperatura accuratezza 0.1°C



Soluzione di Backup

- Sistema basato su due componenti commerciali che svolgono la funzione di preamplificazione (CR-11X, X=0-3) e di shaping (CR-200).

- Il primo è un “charge sensitive preamplifier” a basso rumore, il cui guadagno va da 1.3 mV/pC (CR-113) fino ad un massimo di 1.4 volts/pC (CR-110). La figura 7.2 riporta alcune caratteristiche del modulo.



cremat

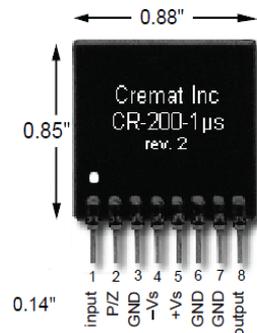
FAX: (617) 527-2849
http://cremat.com

Specifications

Assume temp =20 °C, $V_s = \pm 6.1V$, unloaded output

	CR-110	units
Preamplification channels	1	
Equivalent noise charge (ENC)*		
ENC RMS	200	electrons
Equivalent noise in silicon	0.03	fermiCoul.
Equivalent noise in CdZnTe	1.7	keV (FWHM)
ENC slope	2.4	keV (FWHM)
ENC slope	4	elect. RMS /pF
Gain	1.4	volts /pC
Rise time **	7	ns
Decay time constant	140	μ s
Unsaturated output swing	-3 to +3	volts
Maximum charge detectable per event	1.3×10^7	electrons
	2.1	pC
Power supply voltage (V_s)		
maximum	$V_s = \pm 13$	volts
minimum	$V_s = \pm 6$	volts
Power supply current (pos)	7.5	mA
(neg)	3.5	mA
Power dissipation	70	mW
Operating temperature	-40 to +85	°C
Output offset	+0.2 to -0.2	volts
Output impedance	50	ohms

- Il secondo è un modulo “Gaussian shaping amplifier”, che accetta un impulso di ingresso a gradino e fornisce in uscita un impulso di forma gaussiana, filtrando gran parte del rumore del segnale di ingresso. Il modulo è disponibile con 9 differenti tempi di shaping, da 25 ns a 8 μ s. La figura 7.3 riporta alcune caratteristiche del modulo.



part #	shaping time	output pulse width (FWHM)	R_{in}	C_{in}	gain
CR-200-25ns	25 ns	59 ns	82 Ω	220 pF	4
CR-200-50ns	50 ns	120 ns	220 Ω	220 pF	8
CR-200-100ns	100 ns	240 ns	220 Ω	470 pF	10
CR-200-250ns	250 ns	590 ns	240 Ω	1000 pF	10
CR-200-500ns	500 ns	1.2 μ s	510 Ω	1000 pF	10
CR-200-1 μ s	1 μ s	2.4 μ s	1.0 k Ω	1000 pF	10
CR-200-2 μ s	2 μ s	4.7 μ s	2.0 k Ω	1000 pF	10
CR-200-4 μ s	4 μ s	9.4 μ s	1.2 k Ω	3300 pF	10
CR-200-8 μ s	8 μ s	19 μ s	2.4 k Ω	3300 pF	10

Riassunto attivita' Italiana (ultimi 12 mesi)

- Maggio 2013: Contributo al CDR con la scrittura del paragrafo sul sistema di calibrazione. Proposta di un sistema baseline (con due stadi di distribuzione) ed uno alternativo ("Pisa Frame")
- Giugno 2013: Presentazione del Sistema di Calibrazione Laser all'Independent Design Review di FNAL per il CD1;
- Luglio 2013: Presentazione alla CSN1 per l'apertura di Sigla GMINUS2;
- Settembre 2013: Approvazione per il 2014; Ottenimento di un finanziamento di ~100kE per attivita'di R&D Calibrazione 2014.
- Novembre 2013: primi ordini concordati con i referee INFN;
- Gennaio-Maggio 2014: test in laboratorio e sviluppo prototipi; evoluzione della proposta; scrittura capitolo calibrazione per il TDR

Test Beam: Preparation Schedule at UW **SEATTLE**

- June 2 - 6 : **Crystal and SiPM preparations**
 - Transmission measurements for each crystals, wrap, assemble housing
 - SiPMs and boards tested in stand-alone setup at CENPA or Muon Lab
- June 9 – 13: **Installation of SiPMs with Bias and Crystals**
 - SiPMs mounted to crystals; tested with a standard light source setup
 - Mount units inside mechanical housing.
 - **UVa Group at Seattle**; install and debug Bias and it's control. Cable and mount to SiPMs.
- June 16 – 19 (or just before CD2 review); **Calibration Installation**
 - **Italian team in Seattle**. Setup laser, distribution, monitoring; test it locally (train locals);
 - Attaches front plate to housing and does pe calibration exercises.
 - arrives and is used together with local readout electronics to practice pulsing the detectors. Italian groups here.
- June 23 – 27: **Digitizer Installation / Software Coordination**
 - **Cornell group arrives** with digitizers and does basic setup (trains locals).
 - **Kentucky group arrives** and works on MIDAS readout of Digitizers
 - UW group continues to test stand-alone installation and perform calibrations
- June 30 – July 3 (short). **System Tests Continue on WFDs, DAQ, Detectors**
 - By now need enough on-site experts to keep system running. Who will be here then?
- July 7 – 11. **Reserved for any slippage; Pack up at end of week**
- July 14th: **Drive equipment to SLAC (full day); others fly**
- **RUN: July 17 to 28TH (morning); Packup on 28th, return to Seattle**

@SLAC

- July 15-17: Daytime Installation
 - If area “open”, anyone can enter; Once secured, limited to 4 – 6 using key system
 - Schedule Safety Class in here (2 h); **required**
- July 17 – 28: Two Shifts; Split Group accordingly with 4 h overlap;
 - Beam is 9 pm to 9 am (nominally)
 - Access to area 9 am to 9 pm will not cost our beam time
 - We must divide into two groups:
 1. Those that must “get it going” (hardware, online DAQ);
 2. Those that can start analyzing the data and organizing the output and results and suggesting next running steps and daytime calibrations
 3. 8 AM report is given each day (Hertzog) at Control Room
- July 27th overnight is last beam shift, ending Monday morning, the 28th;
- July 28th Packup; begin return trip...

What we plan to provide

- Laser source (LDH-PC-405M)
- 1 2" Sphere, 1 Beam-expander+mixer; 1x4 FBT Beam Splitter
- 1 Bundle of 60 fibers silica 1mt 200 μm \varnothing ; 1 Bundle of 56 Kuraray plastic fibers 0.93 mm \varnothing 1.5mt; 1 Bundle of 50 fibers PMMA of 0.6 mm \varnothing 2mt
- Monitor prototype with $^{241}\text{Am}+\text{NaI}$ "pulser"
- 2 Amplifier CREMAT; at least 1 "Custom" Charge integrator Preamplifier
- 16 channels DRS-based Board (CAEN); 2 4 channels DRS4 evaluation Board
- Virtex for driving the laser source
- Other Optical material (lens, collimators, etc..)

In total One or two Monitoring; 3-5 Channels

For the Test Beam at Slac we will have 25 channels ($E_{\text{pulse}}^{\text{TOT}} \sim 50\text{pJ}$)

Ricerca candidati Laser ($\lambda=405\text{ nm}$)

Company	Model no.	Pulse width [ps]	Energy/pulse [pJ]	Nominal Avg Power [mW@kHz]	Avg Power @10kHz rep (constant energy/pulse) [mW]	No. photons/pulse	Notes	Distributor	Price (incl VAT) [EUR]	Delivery (wks)
PicoQuant	LDH-P-C-405 (high-P)	300	50	2@4000	0,0005	1,02E+08	Including PDL 200-B driver	Crisel Instruments	11056	4-8
PicoQuant	LDH-P-C-405B (high-P)	300	75	3@4000	0,00075	1,53E+08	Including PDL 200-B driver	Crisel Instruments	12276	4-8
PicoQuant	LDH-P-C-405M (high-P)	300	500	20@4000	0,005	1,02E+09	Including PDL 200-B driver (multimode output, poor beam quality)	Crisel Instruments	13496	8
Alphas	PICOPOWER-LD-405-10k	1000	50	0.0005@10	0,0005	1,02E+08	Including driver	Alphas	5661	4
Advanced Laser Diode Systems	Pilas PiL040X	45	13	0.00013@10	0,00013	2,65E+07	Including driver EIG2000DX	Advanced Laser Diode Systems	10760	5-6
Advanced Laser Diode Systems	Pilas PiL040X +PiL040SPS	45	35	0.00035@10	0,00035	7,13E+07	Including driver EIG2000DX and high power option PiL040SPS	Advanced Laser Diode Systems	11492	5-6

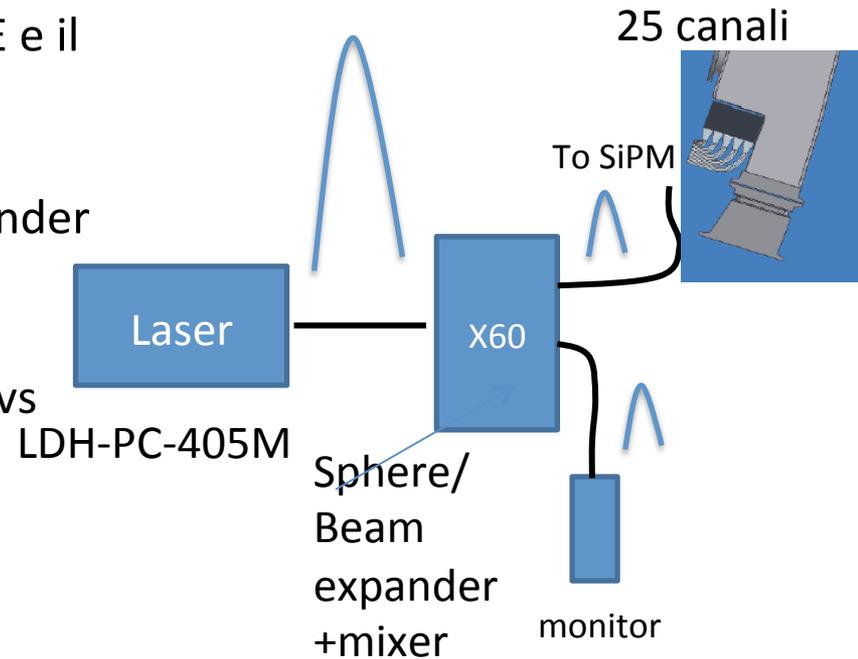
Picoquant is OK

$T = 2 \cdot 10^{-4}$ = Trasmission efficiency on fiber for a bundle of 60 fibers 1mm \varnothing connected to 2'' Sphere

$$E_{\text{pulse}}^{\text{TOT}} \sim 0.01\text{pJ}/T = 0.01\text{pJ}/(2 \cdot 10^{-4}) = 50\text{ pJ}$$

Cosa vorremmo fare al TB

- Testare il sistema di calibrazione in un environment realistico ma “semplificato” di presa dati
- Calibrare, equalizzare i SiPM, esercitare l’FEE e il DAQ
- Confrontare le soluzioni Sfera vs Beam-Expander +Mixer
- Confrontare le soluzioni elettronica Custom vs LDH-PC-405M Commerciale
- Testare il Monitor
- Testare la virtex per il controllo del laser



Partecipazione Italiana e FTE (2014)

- **LNF (2 FTE):**

- G. Venanzoni 70% (RN,RL)
- D. Babusci 40%
- R. Cimino 30%
- S. Dabagov 30%
- D. Hampai 30%

- **TS/UD (2 FTE):**

- G. Cantatore 50% (RL)
- M. Karuza 50%
- D. Cauz 40 %
- G. Pauletta 20%
- L. Santi 40%

- **Na (0.6 FTE):**

- S. Catalanotti 20%
- M. Iacovacci 20%
- S. Mastroianni 20%

- **RM2 (0.4 FTE):**

- G. Di Sciascio 20%
- D. Moricciani 20%

TOT 5 FTE, 15 persone

<FTE> ~0.3

Grande potenzialita' di crescita nei prossimi anni

Partecipazione Italiana e FTE (2014 Effettiva)

- **LNF (4.5 FTE):**

- G. Venanzoni 70% (RN,RL)
- D. Babusci 40%
- R. Cimino 30%
- S. Dabagov 30%
- D. Hampai 30%
- C. Ferrari (INO) 50%
- A. Fioretti (INO) 50%
- C. Gabbanini (INO) 50%
- A. Anastasi (PhD) 100%

- **RM2 (0.4 FTE):**

- G. Di Sciascio 20%
- D. Moricciani 20%

In rosso le persone già associate su GMINUS2

- **TS/UD (3 FTE):**

- G. Cantatore 50% (RL)
- M. Karuza 50%
- D. Cauz 80 %
- G. Pauletta 40%
- L. Santi 80%

← Transizione Mu2e → G-2

- **Na (1.6 FTE):**

- S. Catalanotti 20%
- M. Iacovacci 20%
- S. Mastroianni 20%
- R. Di Stefano 100%

TOT **9.5** FTE, **20** persone

<FTE> ~0.5

FTE sostanzialmente raddoppiati

Partecipazione Italiana e FTE (Previsione 2015)

- **LNF (4.3 FTE):**

- G. Venanzoni 70% (RN,RL)
- D. Babusci 40%
- S. Dabagov 30%
- D. Hampai 40%
- C. Ferrari (INO) 50%
- A. Fioretti (INO) 50%
- C. Gabbanini (INO) 50%
- A. Anastasi (PhD) 100%

- **TS/UD (3 FTE):**

- G. Cantatore 50% (RL)
- M. Karuza 50%
- D. Cauz 80 %
- G. Pauletta 40%
- L. Santi 80%

- **Na (2.0 FTE):**

- M. Iacovacci 40%
- S. Mastroianni 40%
- S. Catalanotti 20%
- R. Di Stefano 100%

- **RM2 (0.4 FTE):**

- G. Di Sciascio 40%
- D. Moricciani 30%

TOT **10** FTE, **19** persone

<FTE> ~0.5

Consolidamento FTE

Programma di Lavoro seconda meta' 2014

- Giugno-Luglio: Partecipazione Test Beam a UW e SLAC
- Da Settembre in poi:
 - Completamento test con sfera da 2'' e sfera 1''
 - Proseguo test Monitoring
 - Ottimizzazione Diffusore Beam expander+mixer
 - Test del beam splitter 1x4 (gia' comprato)
 - Completamento test Eterodina
 - Sviluppo scheda Virtex e completamento prototipo scheda monitoring con parte intelligente
 - Studio dipendenza del guadagno Sipm dalle caratteristiche del Laser
 - Costruzione prototipo "Pisa Frame"

Programma di lavoro 2015/16

- Il **2015** verra' dedicato principalmente al completamento dei test su prototipi e al congelamento del disegno finale. Si vorranno inoltre confrontare 2 prototipi realistici (ossia ciascuno con una catena di distribuzione completa) sistema base vs pisa frame per un modulo calorimetrico. Sulla base dei risultati ottenuti nei test, dalla meta' del 2015 si potra' iniziare a acquistare parte del sistema finale
- Per il **2016** prevediamo richieste principalmente per costruzione e invio a FNAL del sistema completo, manutenzione, debugging, ed (eventuali) turni.

Conclusioni

- G-2 sta marciando molto bene verso le varie fasi di approvazione; a breve il CD2; Collaborazione molto forte; previsione data taking ~2017
- Partecipazione Italiana molto importante e sentita in G-2; ruolo critico del sistema di Calibrazione per il raggiungimento del goal sistematico; partecipazione alle fasi decisionali dell'esperimento (Institutional Board e meeting dedicati)
- Attività Italiana negli ultimi 12 mesi molto consistente, con progressi tecnici sul fronte della Calibrazione: test in laboratorio, sviluppo prototipi, simulazione; discussione alloggiamento laser e spazi nel nuovo building; uffici. Programma per il 2014 (inc. il TB a SLAC) e per i prossimi anni chiaro.
- Gruppo Italiano de facto raddoppiato (rispetto a quanto dichiarato nel 2013): 20 persone ~**10** FTE, <FTE>~0.5; Si prevede un consolidamento per il 2015.

Huge progress since our last PAC presentation

- The E989 Collaboration is now very strong, with a large international component that is making major contributions
- Ring Move almost finished
- Building almost finished
- Prototype detectors being tested in beams at SLAC and Fermilab
- Ring reassembly to begin by March 2014.
- We are working toward CD-2 review in May-June timeframe.

Conclusione della presentazione di Lee Roberts (spoke) al Comitato Scientifico di FNAL, 22 Gennaio 2014

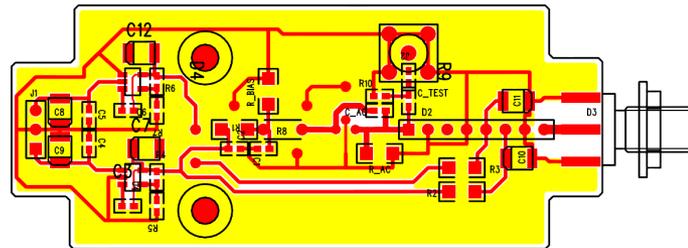
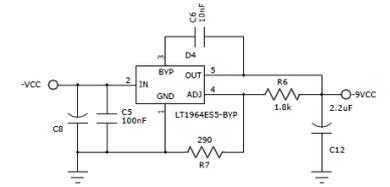
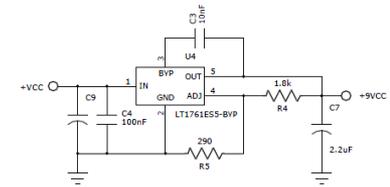
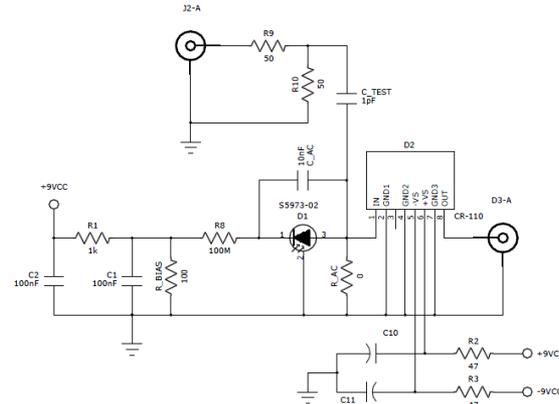
SPARES

Conclusioni (FE)

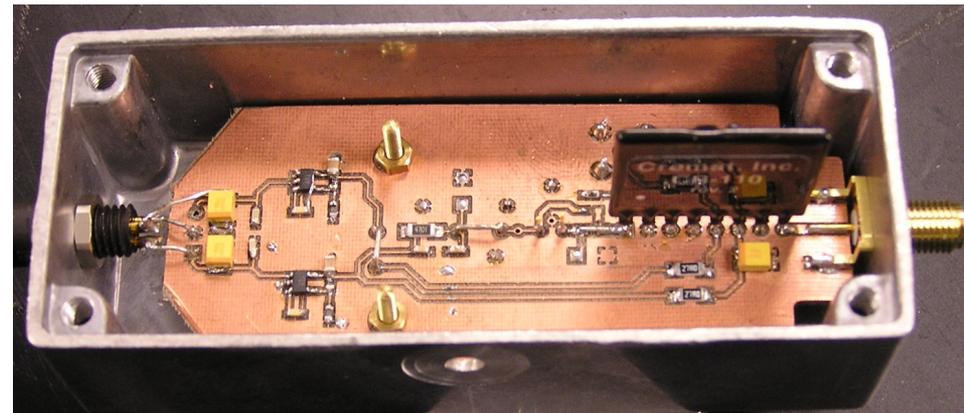
- Ad oggi il progetto del Front-End e' stato completato, cosi' come il layout.
- La scheda e' in fase di montaggio nella sua versione priva del blocco di gestione (ARM3) e di calibrazione (DAC). Sara' testata a meta' Maggio e verosimilmente pronta per il Test Beam di Luglio a SLAC.
- La soluzione di backup vede la prima delle due schede realizzata in prototipo e testata nelle performance, sebbene in modo semplice, mentre della seconda scheda non è ancora stata completata l'implementazione su CAD.

Scheda Alimentazione Fotodiode e modulo CR-110

scheda per il collegamento del fotodiode al modulo CR-110. Nel caso fornisce la tensione di bias al fotodiode, di valore regolabile tramite un partitore resistivo posto all'uscita del regolatore di tensione. Inoltre, è possibile collegare il fotodiode sia in configurazione DC che in configurazione AC.



La figura riporta lo schema della prima scheda, l'implementazione CAD e la foto del primo prototipo. Su suggerimento dei datasheet del modulo CR-110 è stato scelto un regolatore di tensione a basso rumore (LT1761, 20 mVRMS),



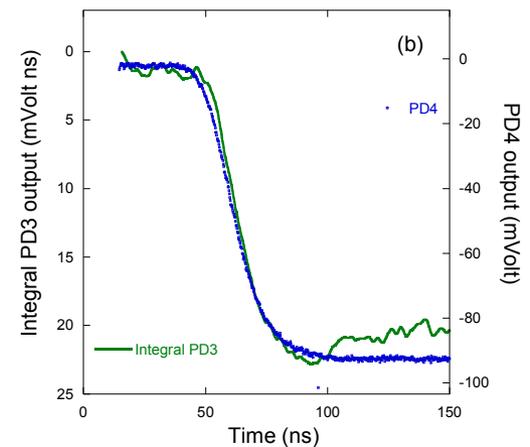
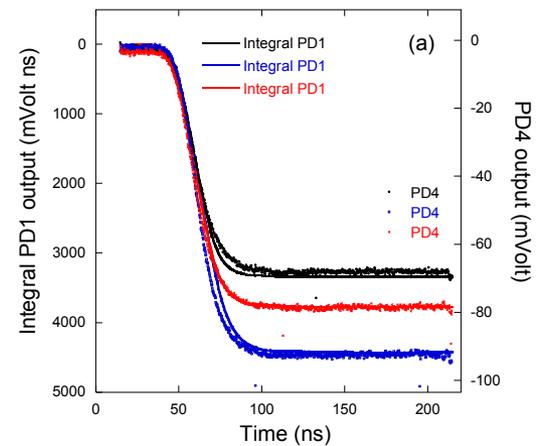
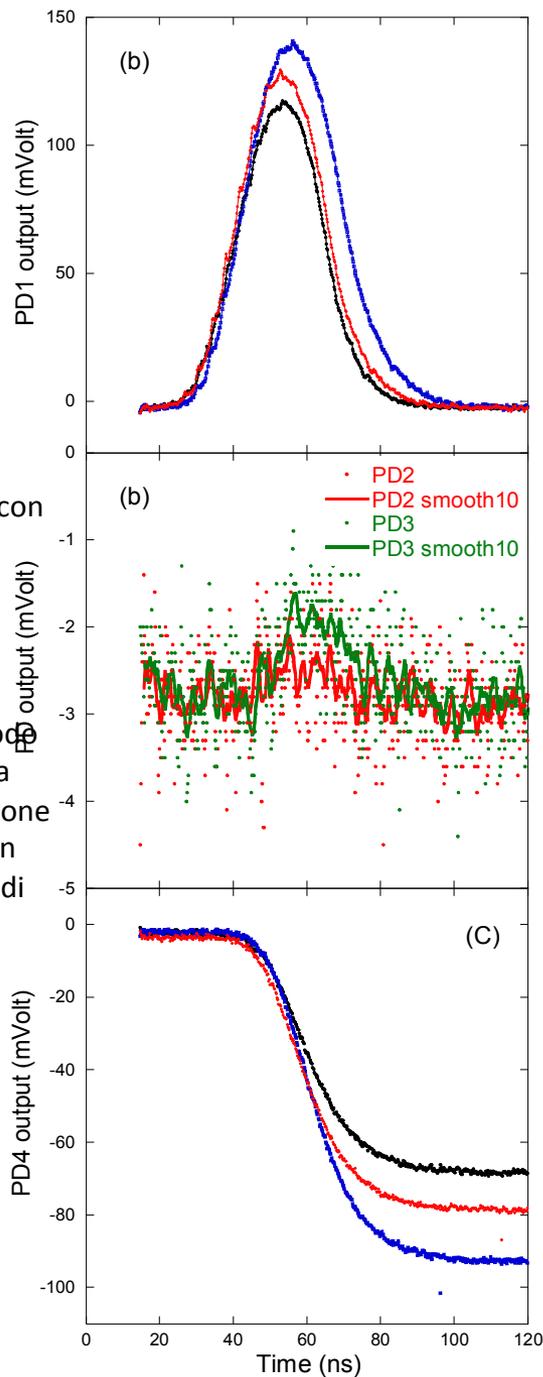
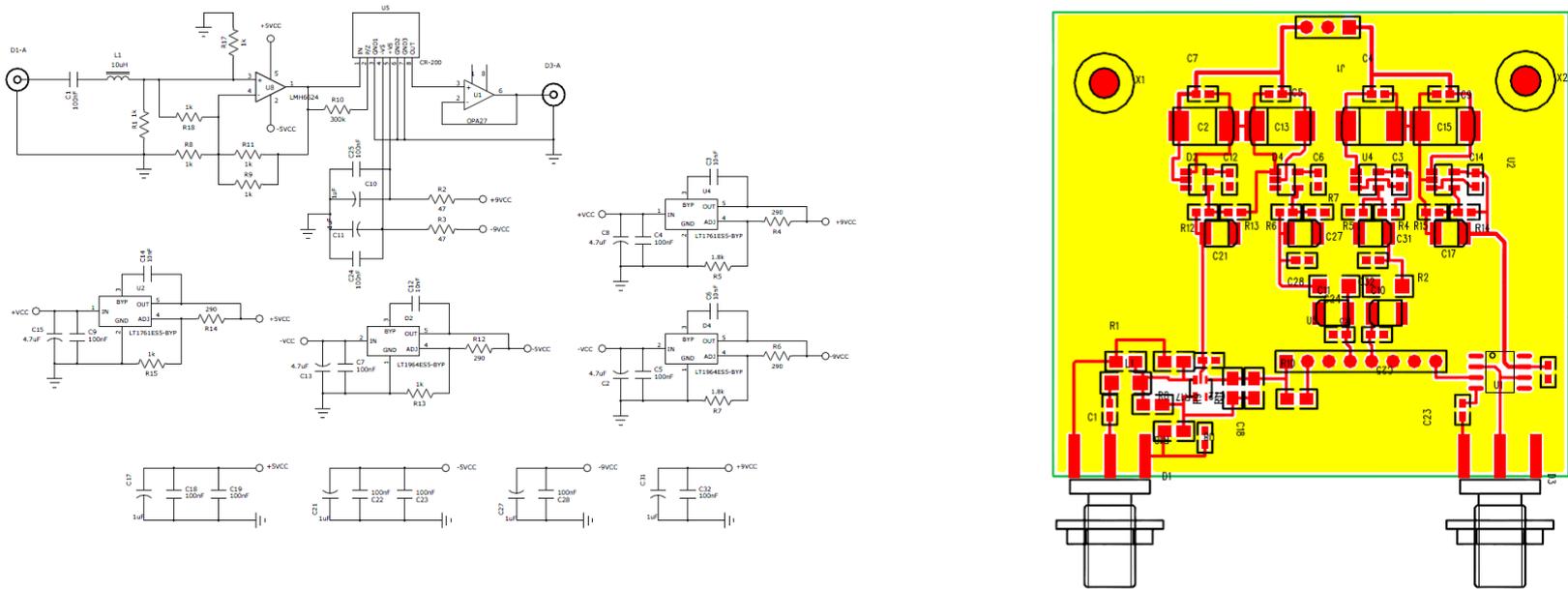


Fig 7.6: Confronto tra integrali numerici dei segnali ottenuti dal fotodiode PD1 (a) o PD3 (b) con i segnali ottenuti dal fotodiode PD4 ed amplificati dalla scheda elettronica equipaggiata con il modulo CR-110.

Test preliminare scheda con CR-110: tre impulsi laser consecutivi. (a) PD1 fotodiode sul fascio del beam splitter; (b) PD2 fotodiode all'uscita della fibra ottica e PD3 fotodiode all'uscita della fibra ottica con scheda di amplificazione veloce Femto; (c) PD4 con scheda preamplificatore di carica CR-110.

Il scheda (in progress)

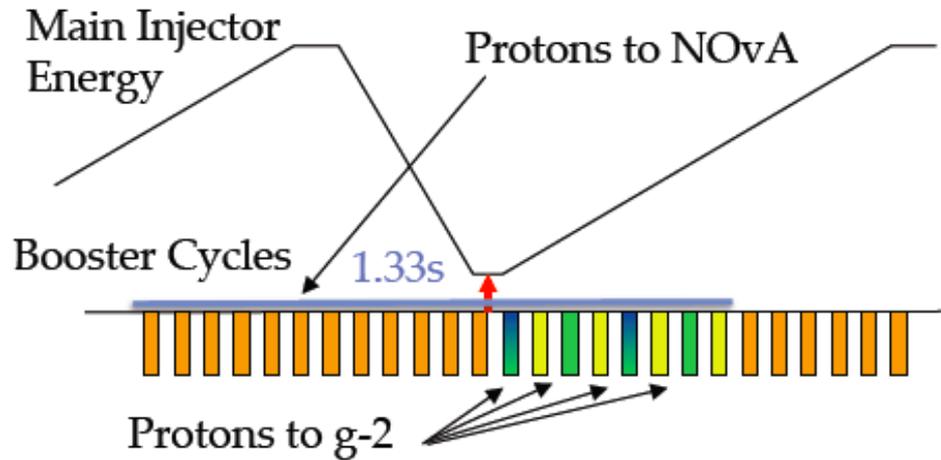
- La seconda scheda è costituita da un filtro bassa banda passivo all'ingresso (1 kHz – 10 MHz), un primo stadio di amplificazione basato su amplificatore operazionale retroazionato, a seguire il modulo CR-200 ed infine un buffer di uscita. Anche in questo caso sono stati utilizzati regolatori di tensione a basso rumore (LT1761 e LT1964 per la tensione negativa). Inoltre, per realizzare lo stadio di amplificazione è stato selezionato un amplificatore operazionale (LMH6624) con una grande banda passante (1.5 GHz), bassissimo rumore di ingresso ($0.92 \text{ nV/Hz}^{1/2}$, $2.3 \text{ pA/Hz}^{1/2}$) e bassissimi errori in dc ($100 \mu\text{V}$ di V_{OS} , derive termiche di $\pm 0.1 \mu\text{V/}^\circ\text{C}$).



Schema della seconda scheda elettronica con il CR-200 e la sua implementazione su CAD (attività in corso).

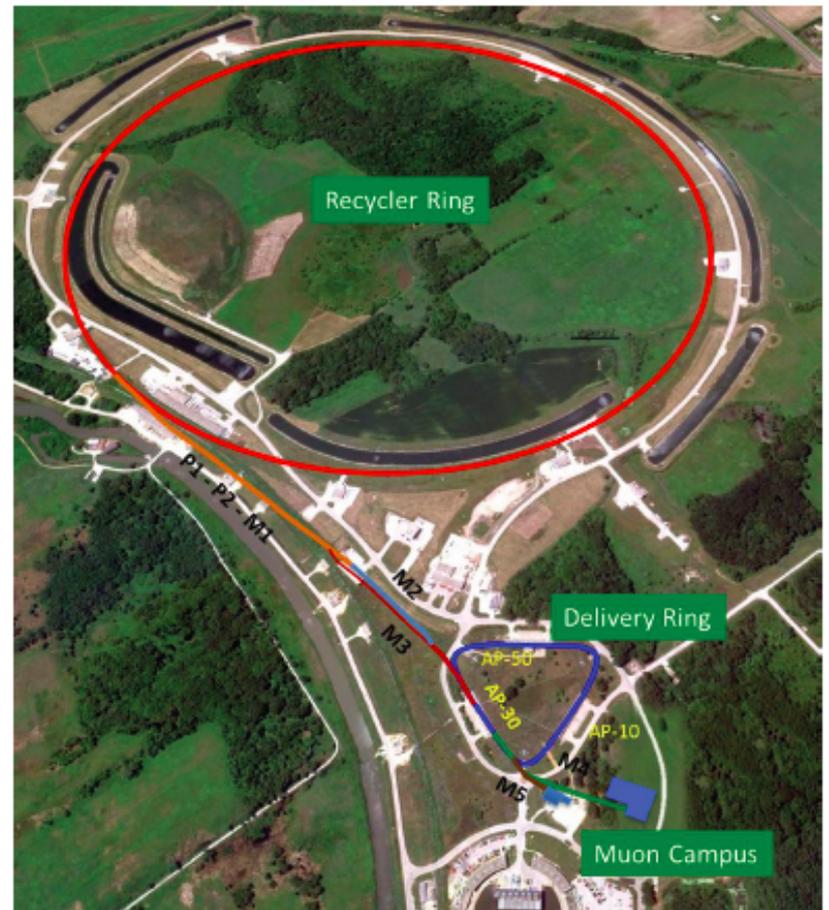
Convert Anti-Proton Source to Custom Muon Source

- share bunches

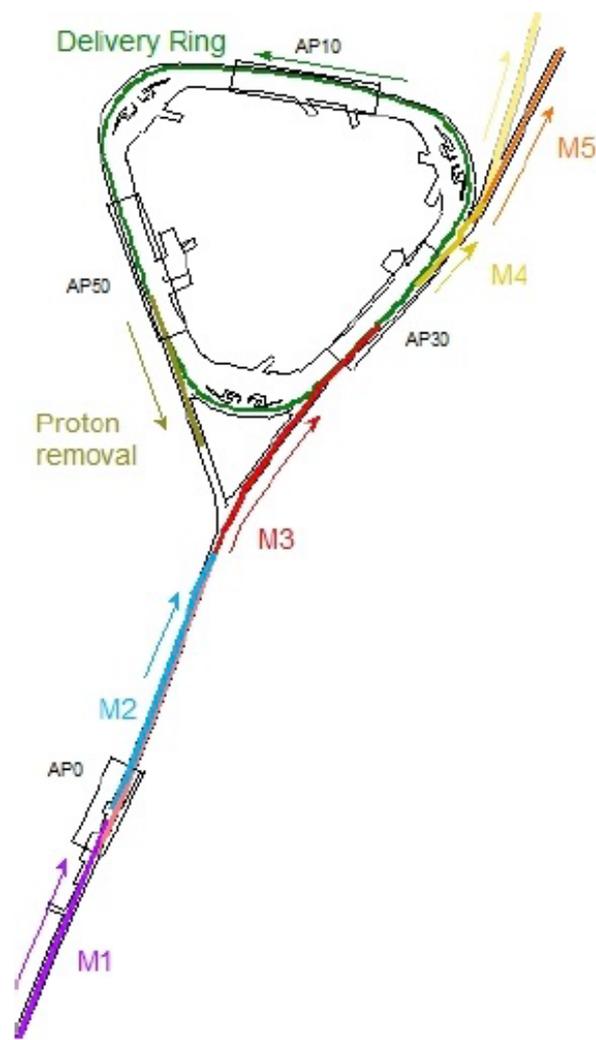


- > 6x more muons than BNL

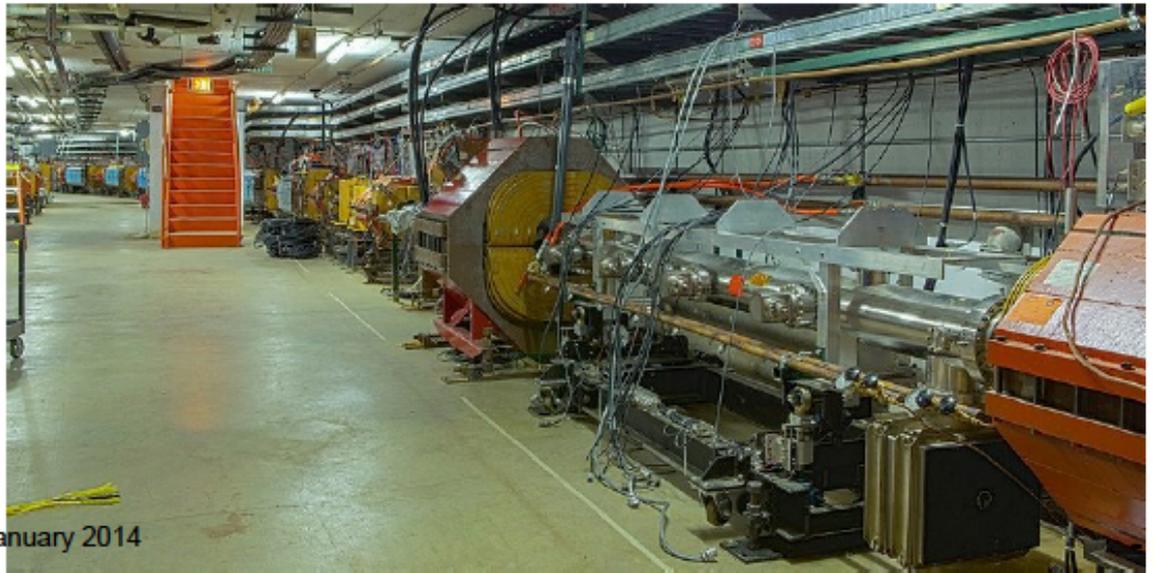
- 0.4, for reduced π yield
- 1.8, smaller β in FODO
- 2, longer decay L
- 3, forward decay
- 1.33, π dp/p
- 2, open inflector/ kicker



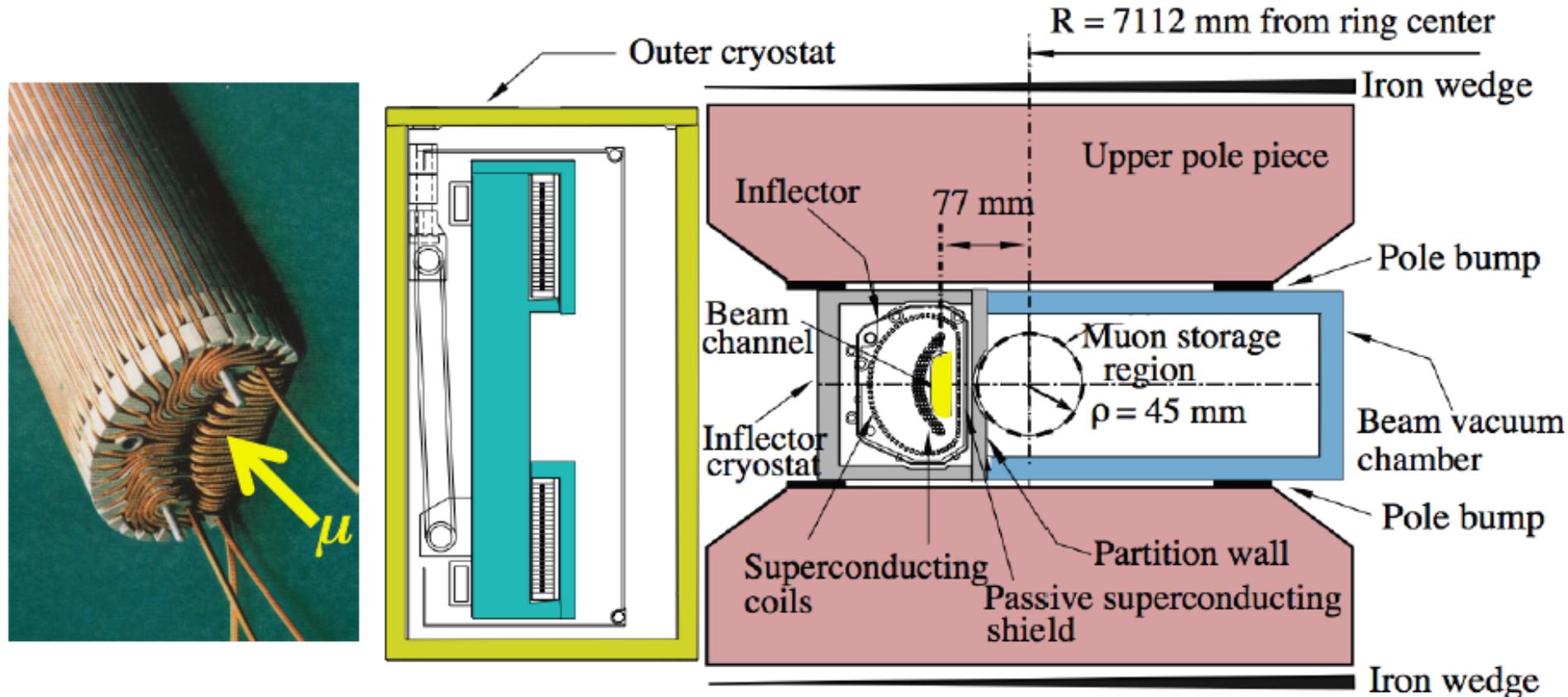
Beamlines



- Re-use existing Antiproton-source infrastructure
- Modify final focus on target for 8-GeV primary beam (M1)
- Improve acceptance / decay-muon capture in secondary lines (M2/M3)
- Reconfiguration of extraction region (D30 straight) and extraction from Delivery Ring
- New external beamline to g-2 storage ring (M4/M5)



New Superconducting Inflector to replace E821

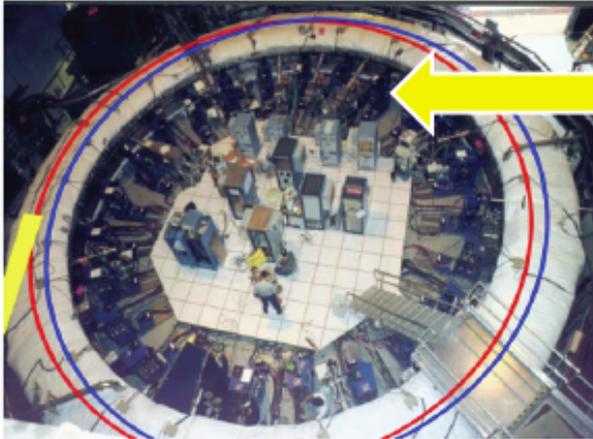


Goal: New inflector with no material over the beam and wider aperture

New Inflector Task Force (Boston, BNL, Cornell, Fermilab, KAIST, RAL)

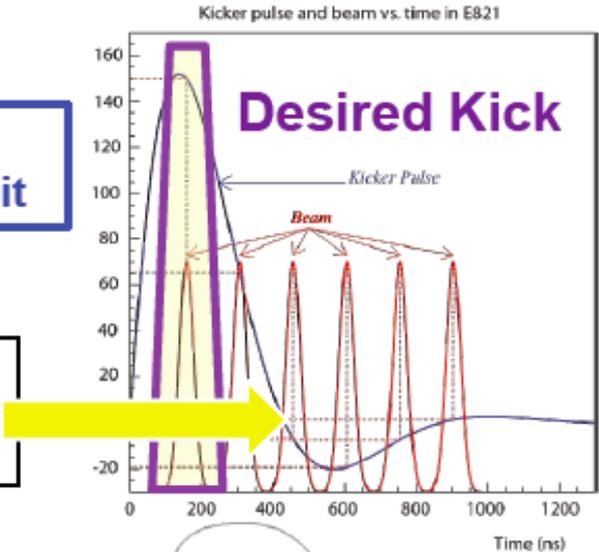
Victoria Bayliss, Tom Bradshaw, Nathan Froemming, Thomas Gadfort, Carol Johnstone, Vladimir Kashikhin, William Morse, Hogan Nguyen, Brett Parker, Chris Polly, Lee Roberts, David Rubin, Yannis Semertzidis, Vladimir Tishchenko, Alexander Zlobin

Improved muon **Storage Fraction** (**Kicker**, Quads and Inflector Upgrades)

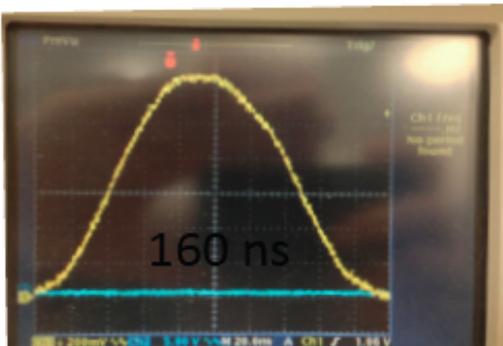
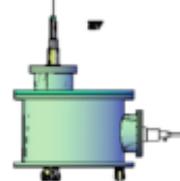


Kicker needed to put Muons onto a Stable Orbit

Old kick was too long, and not strong enough



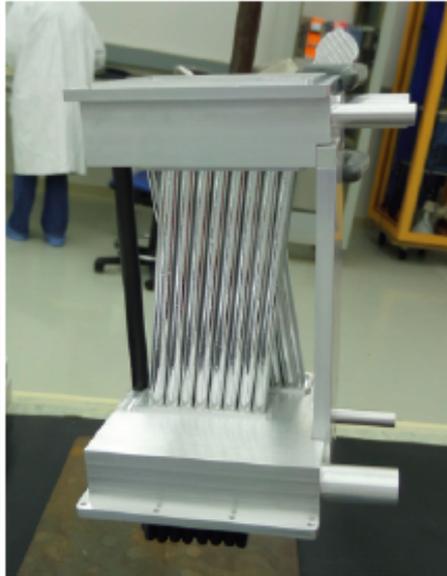
New Cornell Kicker



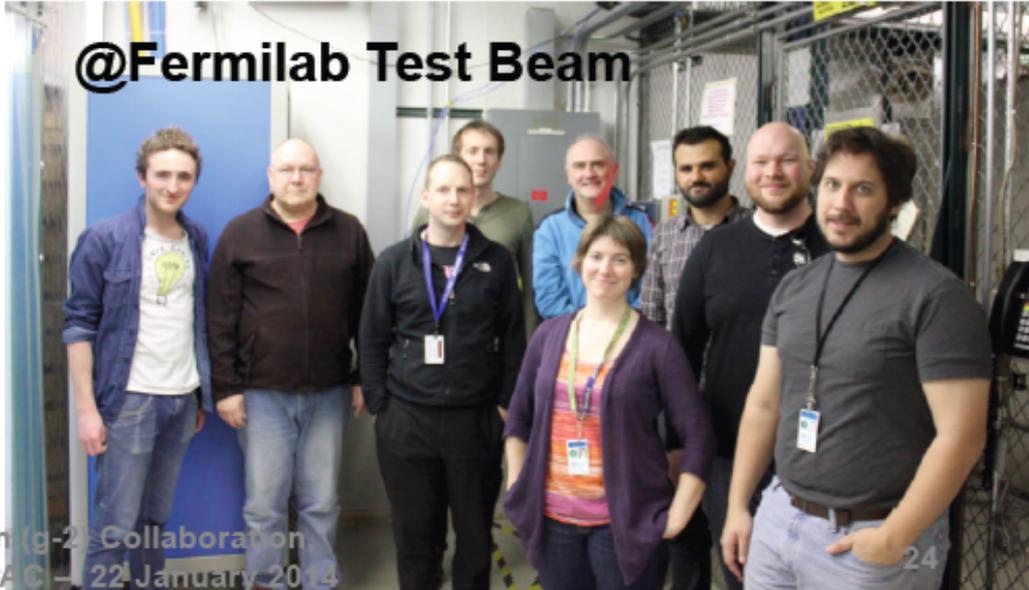
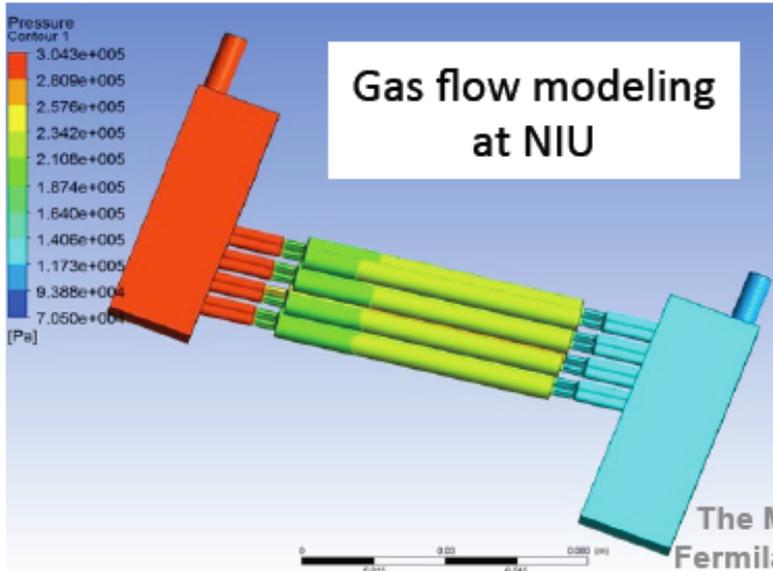
32 channel prototype
constructed by
Liverpool, NIU, and
Fermilab



Tracker Hardware



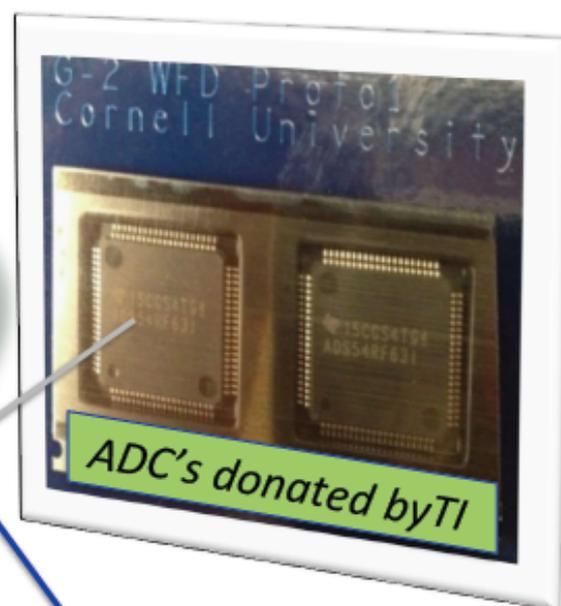
Electronics from Boston



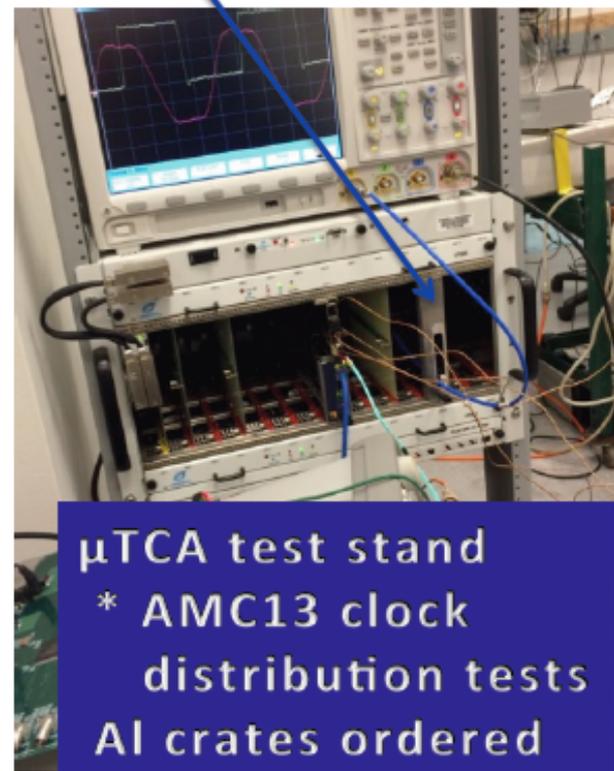
Wave Form Digitizer Highlights

Proto1 board complete

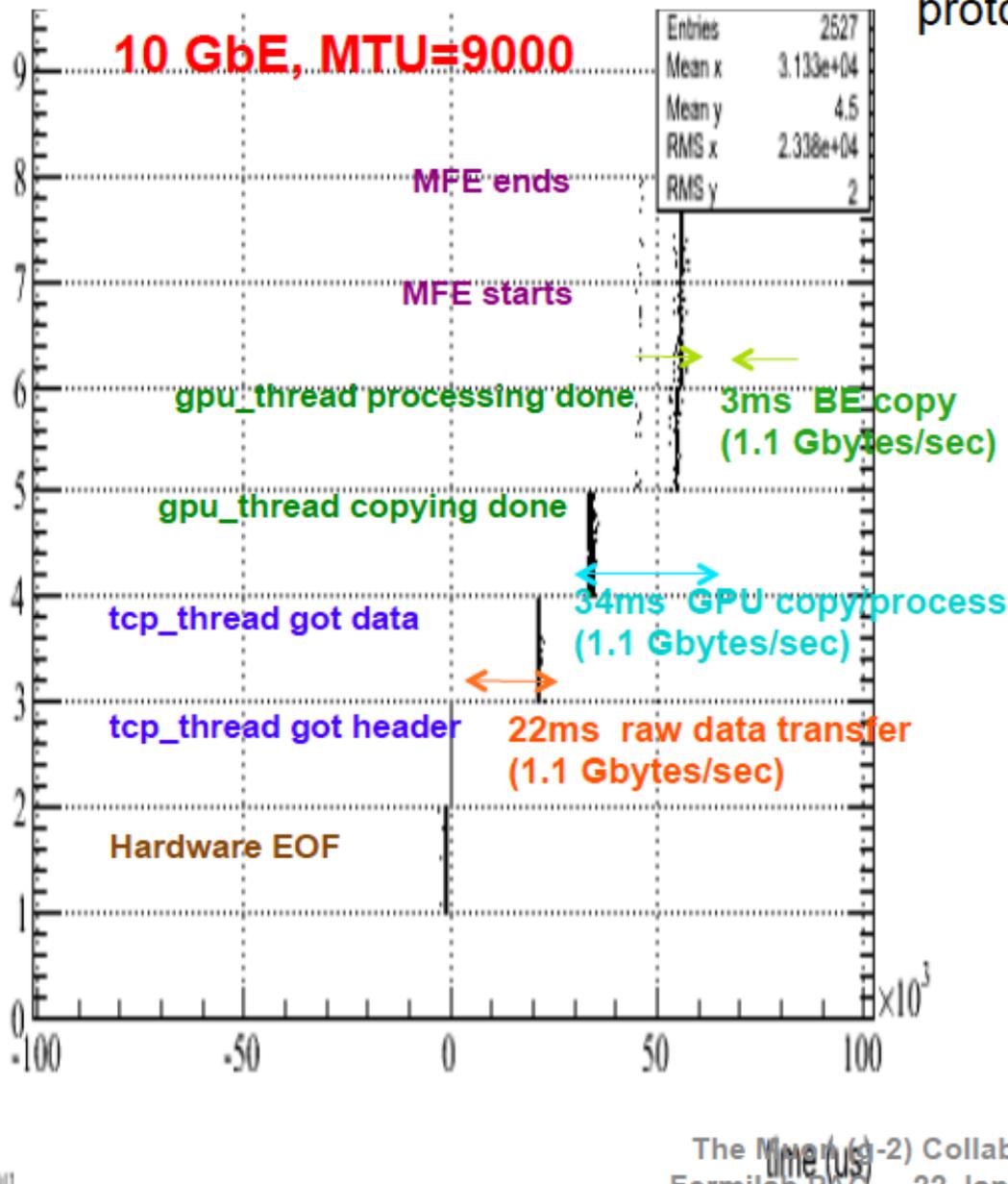
- * clock distributions studies
- * check mechanicals
- * MMC firmware



1 Channel Prototype
* final routing/simulation
underway
* FPGA programming
beginning



Calo readout timing tests



KY DAQ test stand: 10 GbE readout and GPU-based processing of emulator data, + prototype control synchronization system.

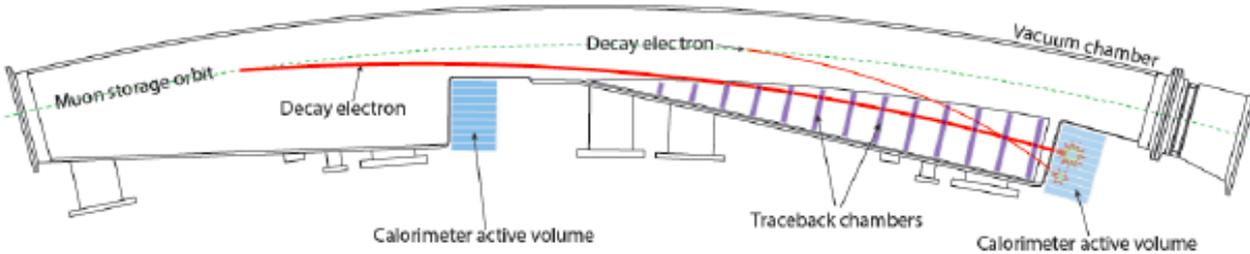


MIDAS experiment "UKY"		Tue May 28 08:14:35 2013		Refr: 1.0	
Start	ODR	Messages	Alarms	Programs	Config
RunLog	Logbook	Elog	Doc		
Run #2014	Stopped	Alarms: On	Restart: No	Data dir: /data/UKY/mid	
Start:	Sat May 25 10:15:08 2013	Stop:	Sat May 25 10:22:56 2013		
Equipment	Status	Events	Events [/s]	Data [MB/s]	
MagicBox	magic_box@mb	0	0.0	0.000	
VMEcrate	VMEcrate@fe01	0	0.0	0.000	
masterMT	(frontend stopped)	365	0.0	0.000	
EB	Ebuilder@bc	0	0.0	0.000	
ATS9870	(frontend stopped)	0	0.0	0.000	
EMC	(frontend stopped)	5	0.0	0.000	
master	master@fe02	0	0.0	0.000	
Channel	Events	MB written	Compression	Disk level	
#0:					
master (fe02)					

The Muon (g-2) Collaboration, Fermilab PAC - 22 January 2014

g-2 MIDAS-based DAQ

Reduced Precession Systematics: All new detectors, electronics & DAQ



At the SLAC test beam

Single particle beam 2.0 - 4.5 GeV

9 crystals, 5 PMTs, 4 SiPMs

Good energy resolution ~ 1 pe/MeV.

Excellent energy linearity.

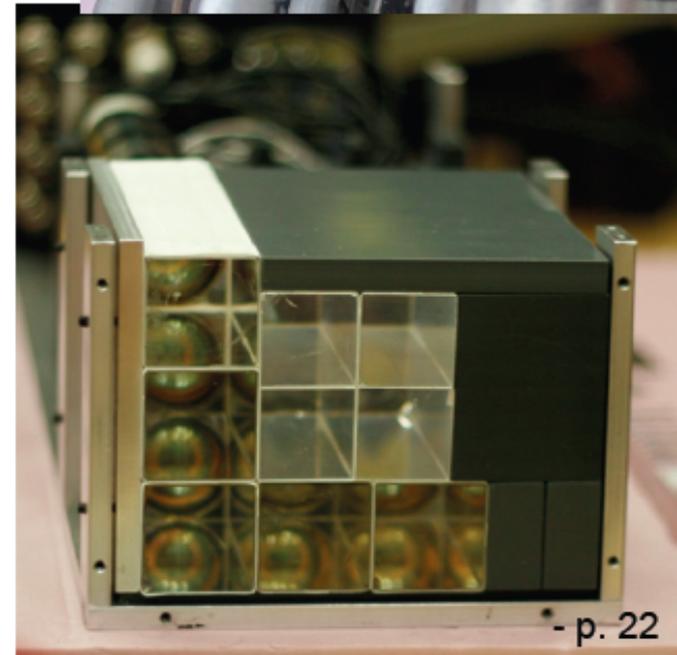
Good timing resolution.

SiPM proved good for photon readout.

SiPM response better than 2 nsec.

In-situ gain calibration by laser

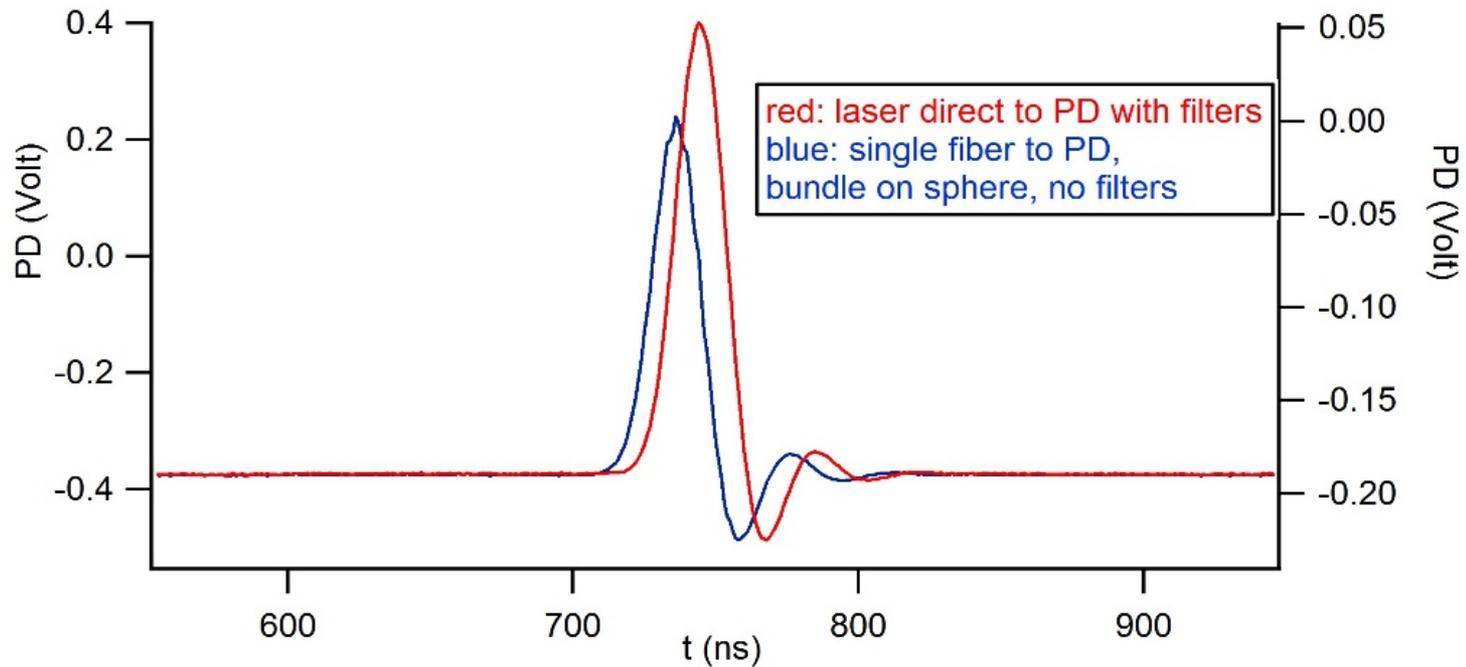
PbF2 crystal purchase in progress



Coeff di trasmissione - commenti

- Il valore atteso del coefficiente di trasmissione per singola fibra del sistema sfera + fibra ottica si ricava da: $\phi_{out} / \phi_{in} = 0.037 A_f / A_{sphere} \rho / (1 - \rho(1 - f)) = 1.8 \cdot 10^{-5}$
- Il valore sperimentale del coeff di trasmissione per singola fibra risulta: $T_i \sim 10^{-5}$
 - Aumentando il diametro delle fibre ottiche del bundle il coefficiente di trasmissione aumenta. Con fibre da 1 mm il coefficiente di trasmissione dovrebbe aumentare di un fattore 25
- Aumentando l'apertura numerica (NA) delle fibre il coefficiente di trasmissione di singola fibra dovrebbe aumentare: $\phi_{out} \sim (NA)^2$
- Il coefficiente di trasmissione complessivo T del sistema sfera+bundles dipende dal numero n di fibre connesse alla sfera: $T = n \cdot T_i$
 - Con due bundle di 90 fibre collegati alla sfera si ottiene un coefficiente di trasmissione complessivo del 3% circa. Con tre bundle si raggiunge il 5%

Coefficiente di trasmissione – risultati



Dopo la calibrazione dei filtri neutri si è calcolato il coefficiente di trasmissione per singola fibra del sistema sfera+bundle:

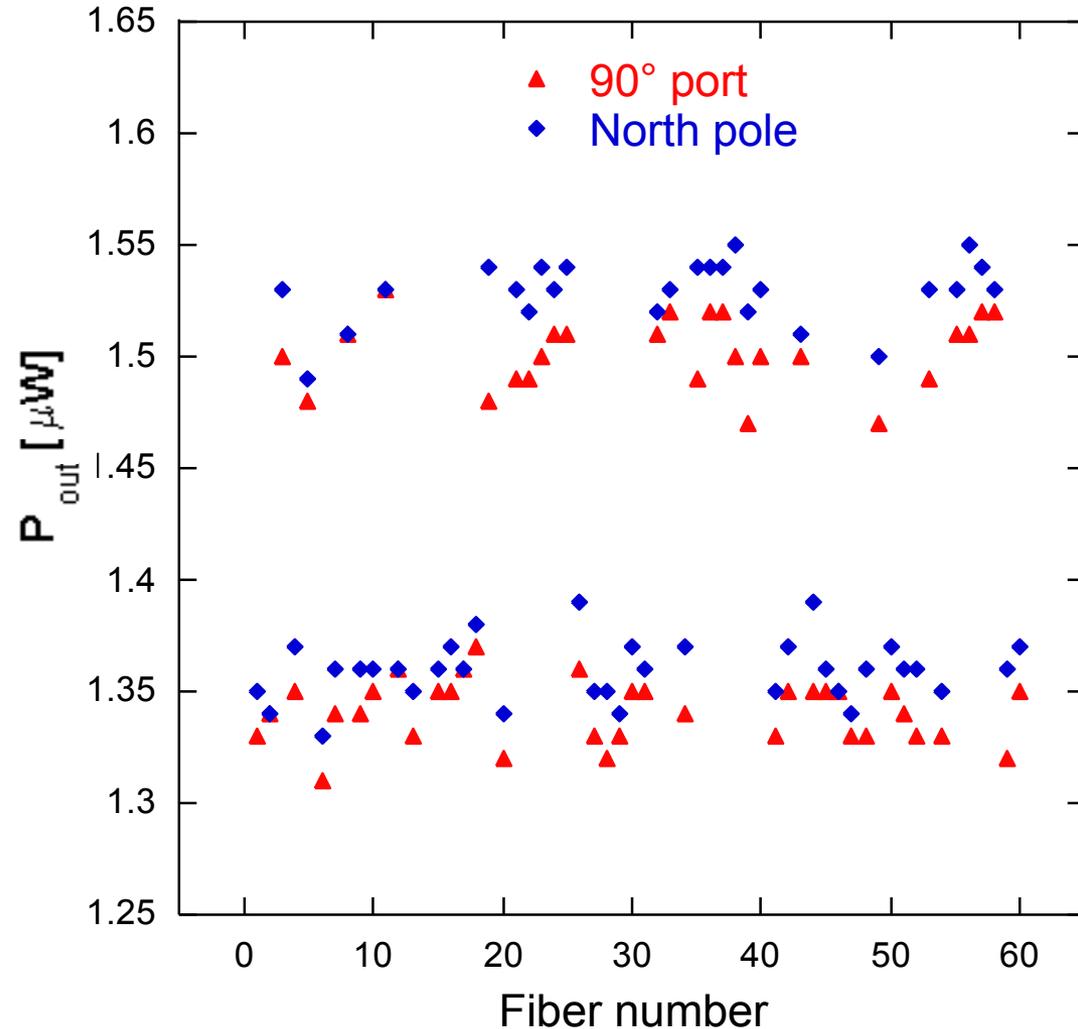
$$T_i = (2 \pm 1) \cdot 10^{-5}$$

Coeff di trasmissione - risultati

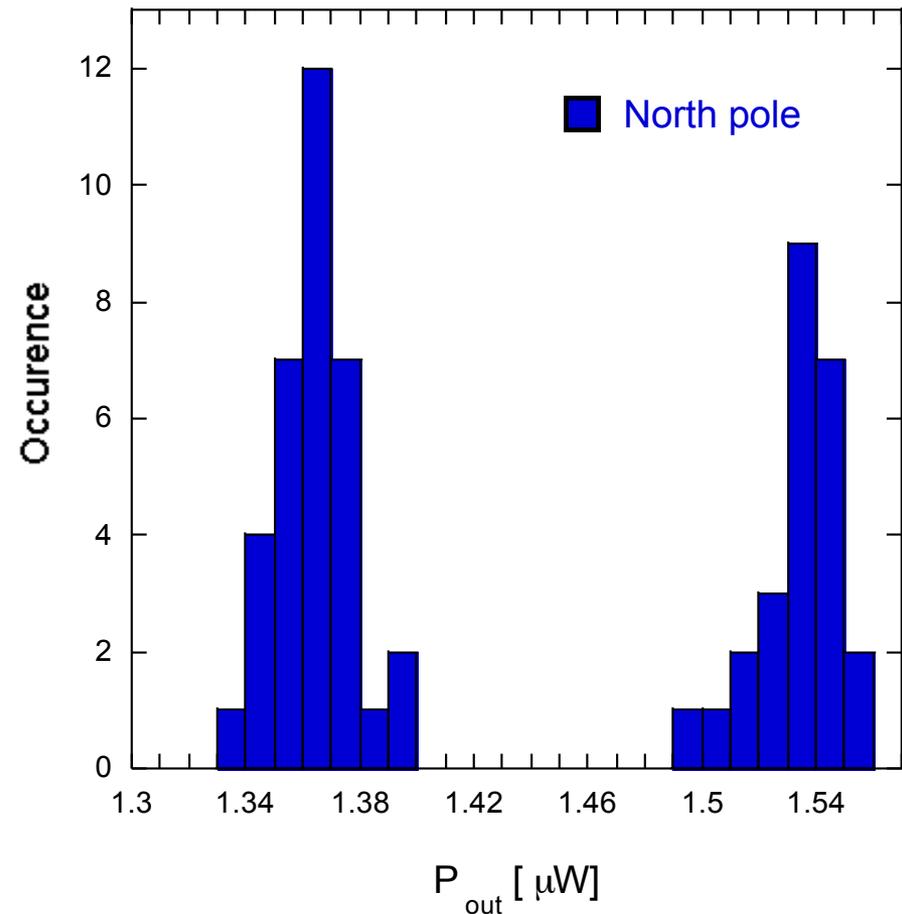
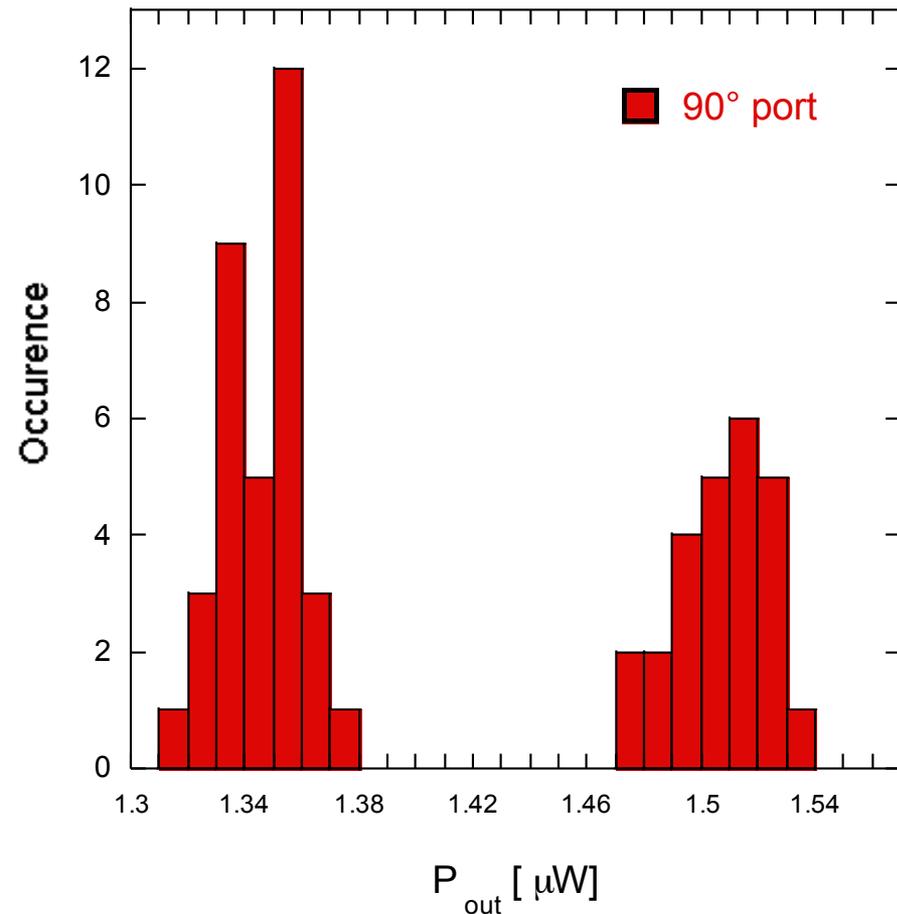
- Le fibre sono raggruppate in due classi con trasmissione differente.

Tale comportamento deve essere attribuito al bundle di fibre, non alla sfera: infatti, cambiare la porta della sfera a cui è collegato il bundle, il comportamento qualitativo non cambia.

- La trasmissione dei due gruppi differisce di circa il 10%. All'interno dei gruppi la trasmissione cambia molto meno, circa il 2%.
- La porta nord ha una trasmissione un po' superiore rispetto alla porta a 90° (circa 2%).



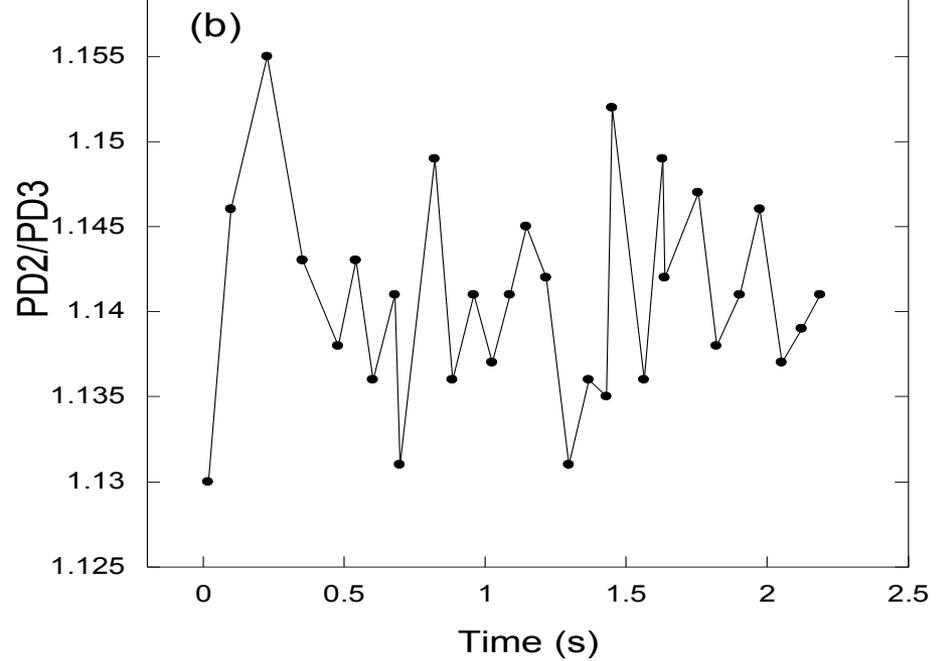
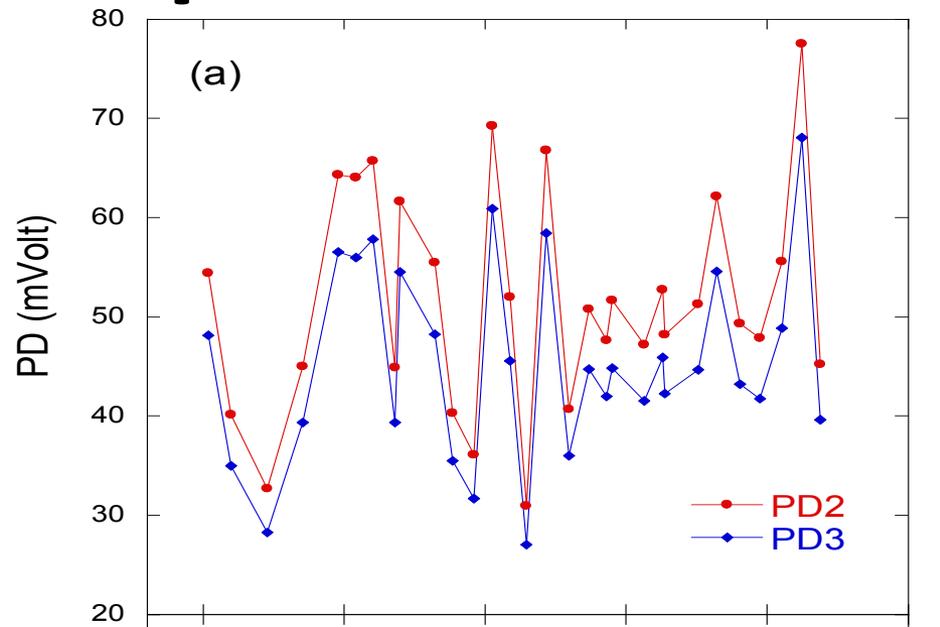
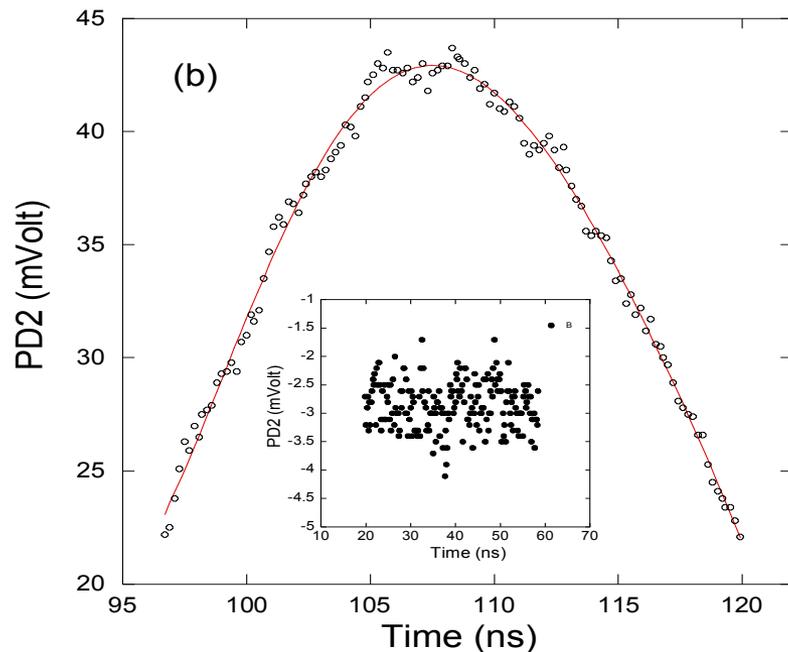
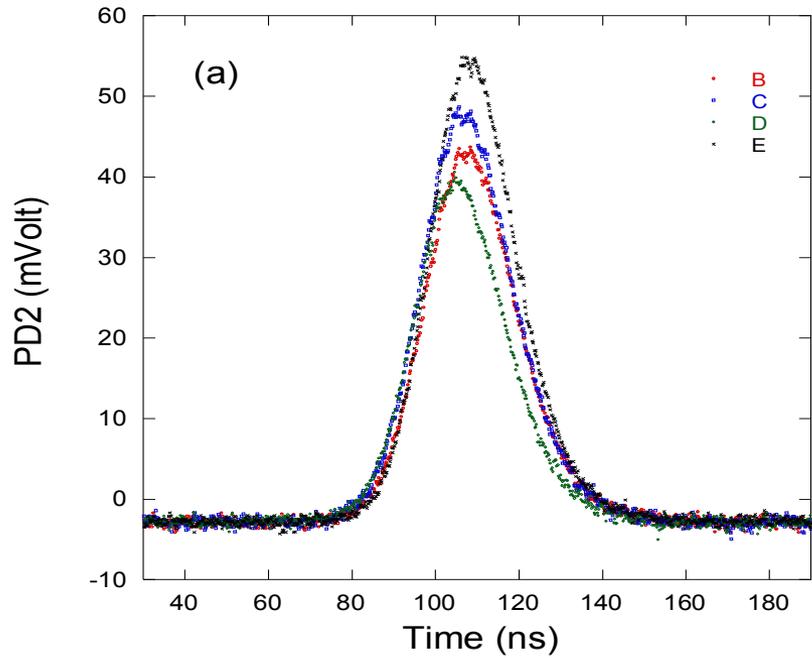
Coeff di trasmissione - risultati



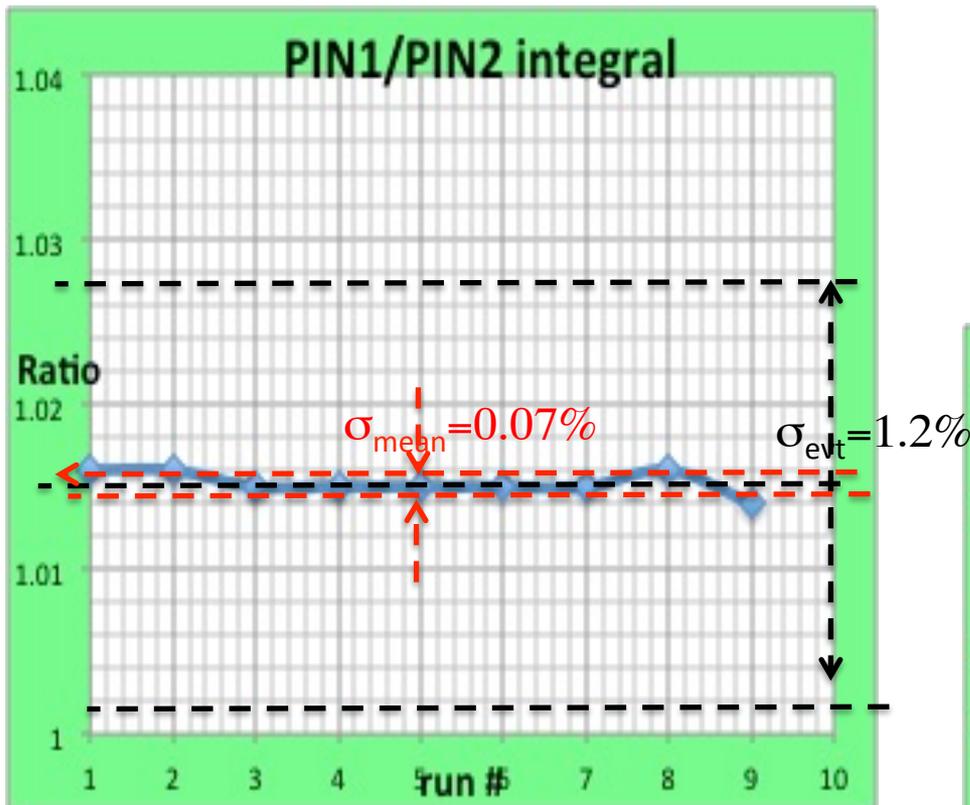
Il coefficiente di trasmissione per singola fibra del sistema sfera + bundle risulta :

$$\underline{T_i = (1.01 \pm 0.03) \cdot 10^{-5} \text{ or } T_i = (0.91 \pm 0.03) \cdot 10^{-5}}$$

Stabilità vs. tempo - risultati

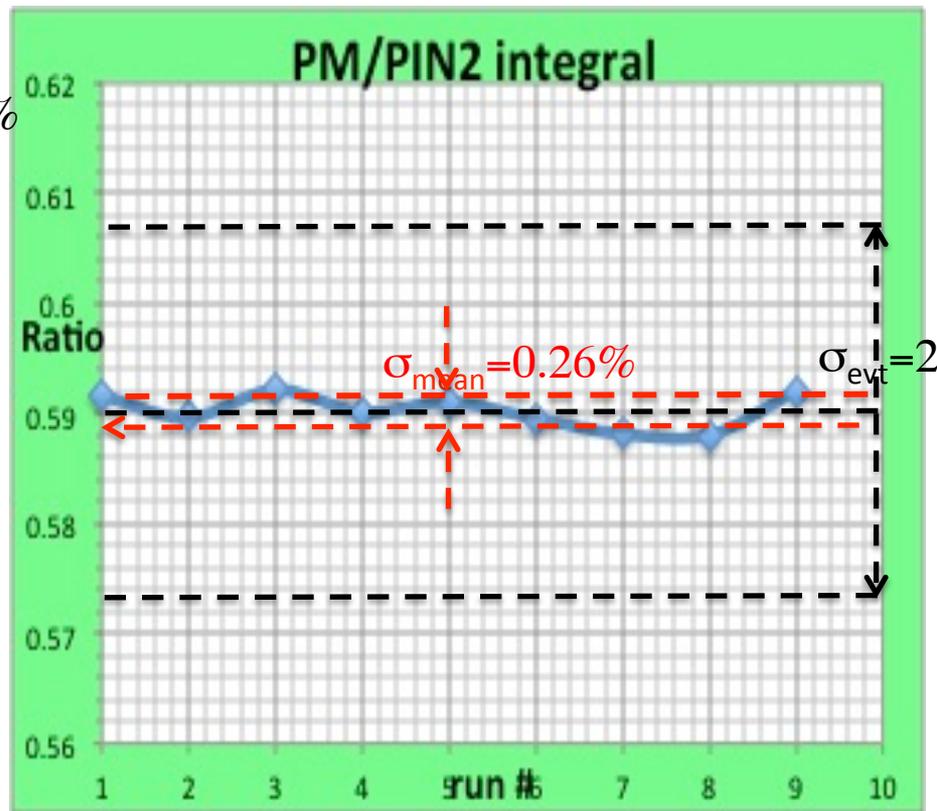


Oltre alla stabilita' di risposta allo stesso impulso laser di un diodo PIN rispetto all'altro, si e' anche monitorato la loro stabilita' di risposta rispetto al PM che vede , sia l'impulso laser che i segnali del pulser



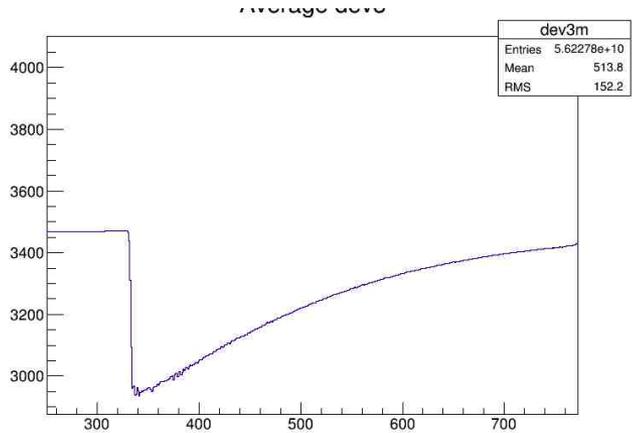
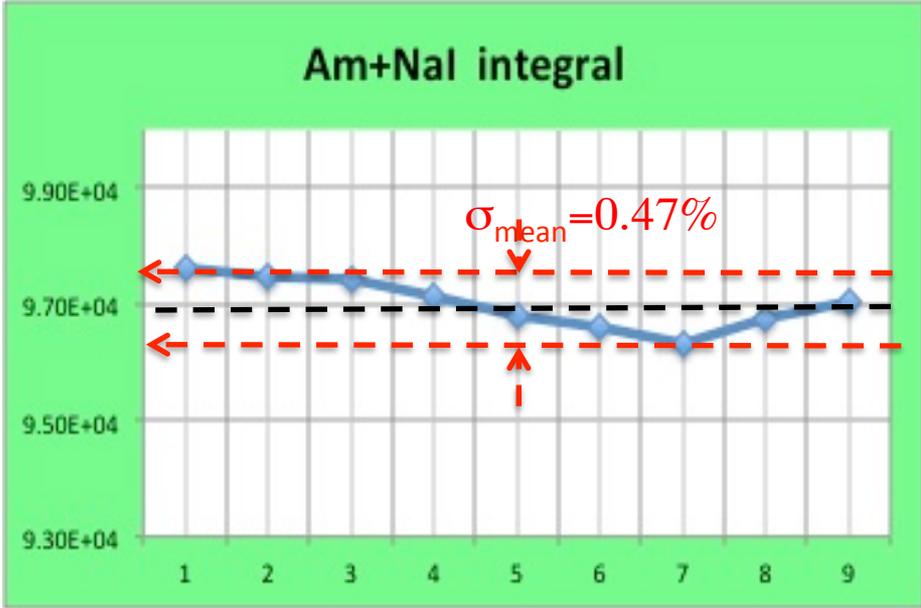
Rapporto dei segnali dei due PIN, dal quale si vedono eliminate le fluttuaioni laser al 0.07% (*varianza della media*) e al 1.2% evento-per-evento (RMS per un run).

Rapporto di un PIN rispetto il PM, dal quale si vedono eliminate le fluttuazione laser al 0.26%. Le fluttazioni evento-per-evento del segnale del PM sono piu' grandi (2.8% RMS per un run) a causa nel numero inferiore di fotoni (~1000) che incidono.



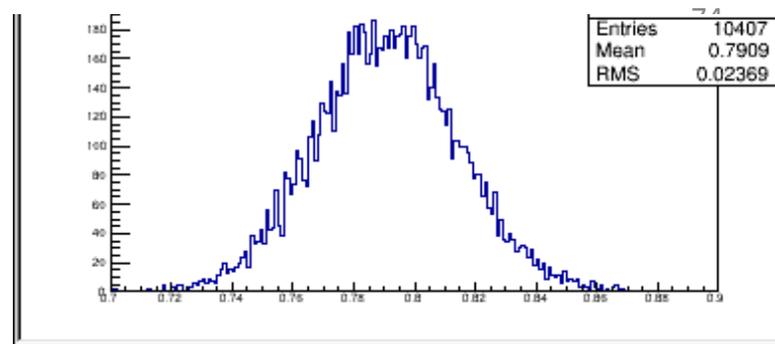
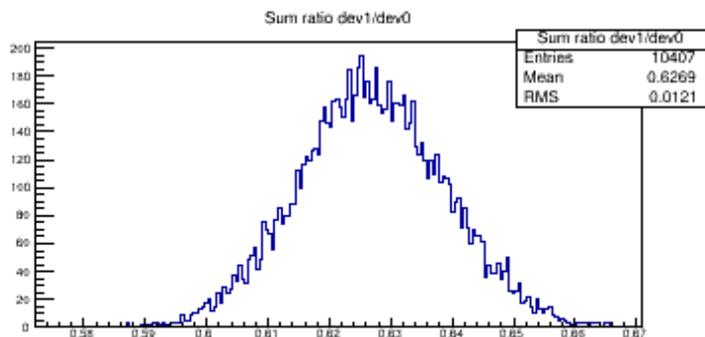
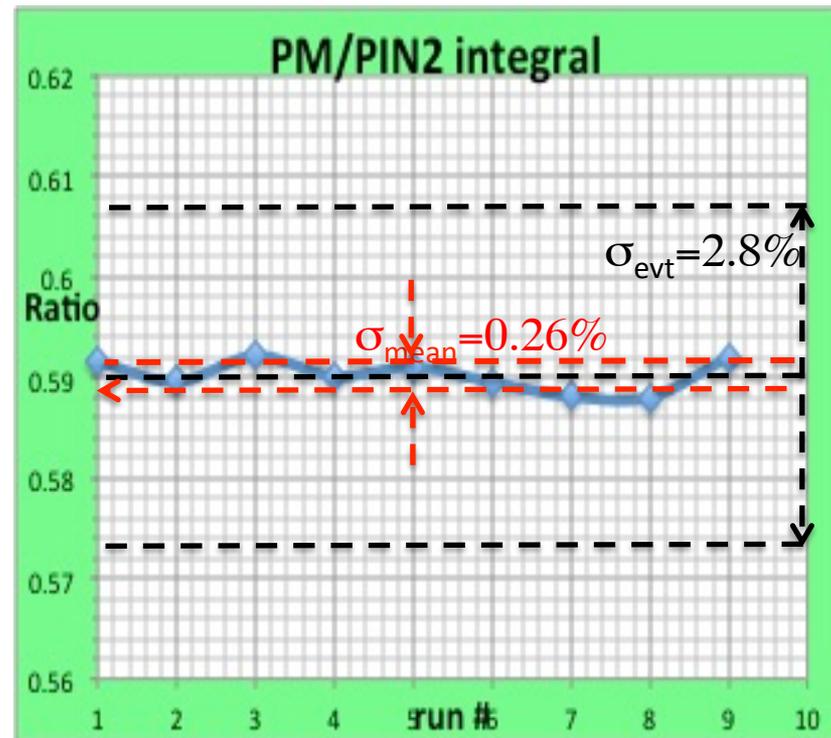
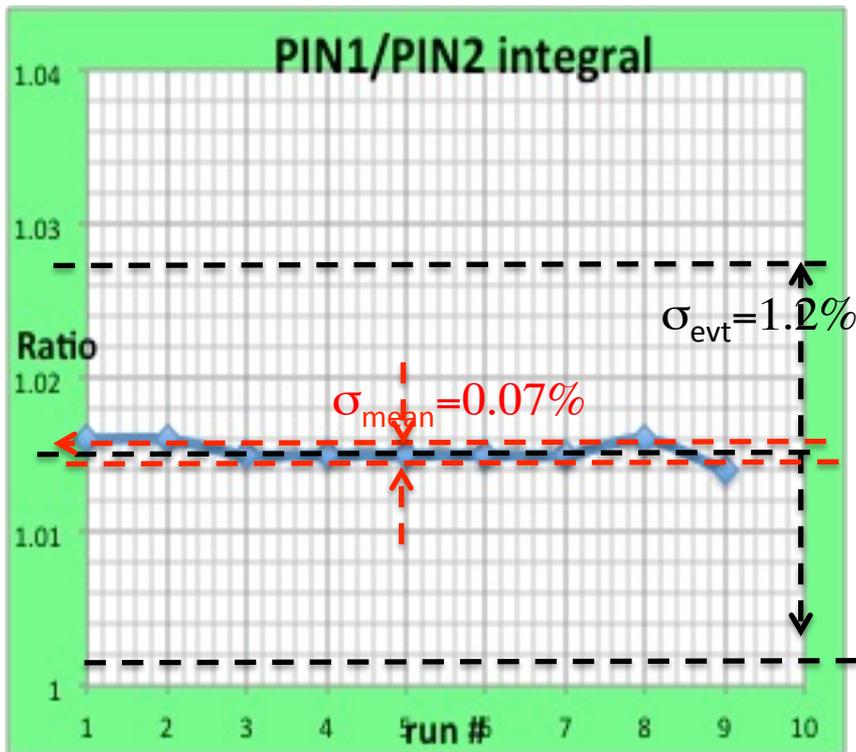
Monitorare la stabilita del segnale di riferimento generato nel PM dal "pulser" $^{241}\text{Am}+\text{NaI}$ e' difficile in assenza dell'elettronica che e' ancora in fase di sviluppo. Il segnale dal NaI e' relativamente lento e va integrato per centinaia di nanosecondi. Pertanto e' molto sensibile a fluttuazioni del baseline.

Le misure riportate in figura servono quale riferimento assoluto al 0.47%. Questo limite e' dettato dalla stabilita' dell'elettronica.



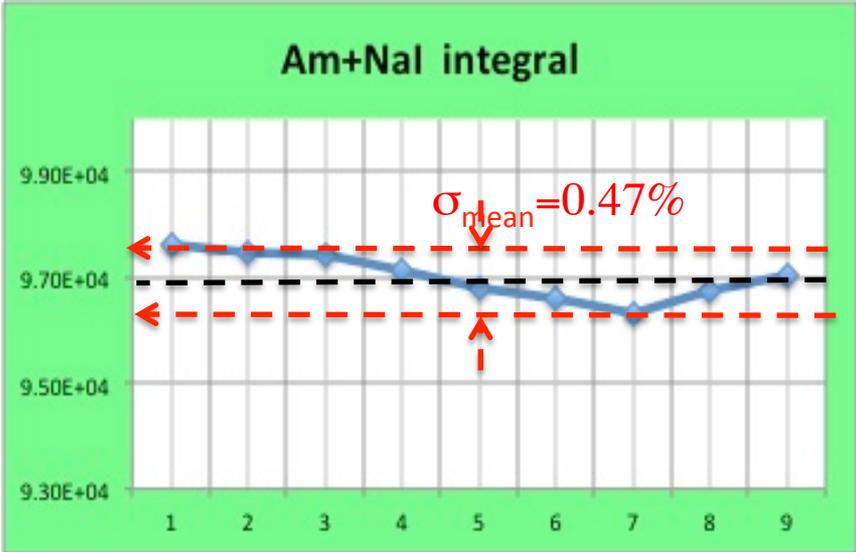
Stabilita' di PD1/PD2: $\sigma_{\langle R \rangle} \sim 0.07\%$

Stabilita' di PM/PD2: $\sigma_{\langle R \rangle} \sim 0.26\%$
(dominato dalla photostat del Sipm
(2.8% RMS))

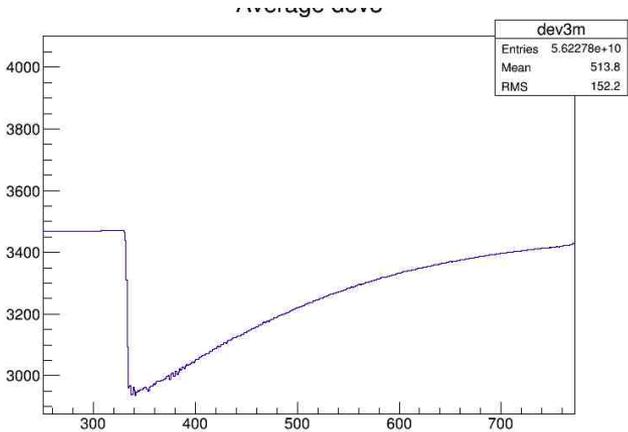


Stabilita del segnale di riferimento generato nel PM dal "pulser" $^{241}\text{Am}+\text{NaI}$

Il segnale dal NaI e' relativamente lento e va integrato per centinaia di nanosecondi. Pertanto e' molto sensibile a fluttuazioni del baseline.

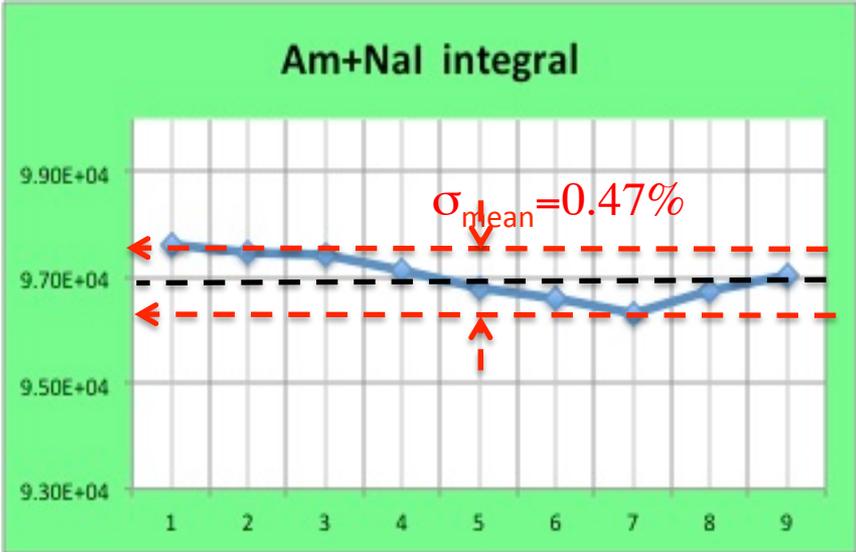


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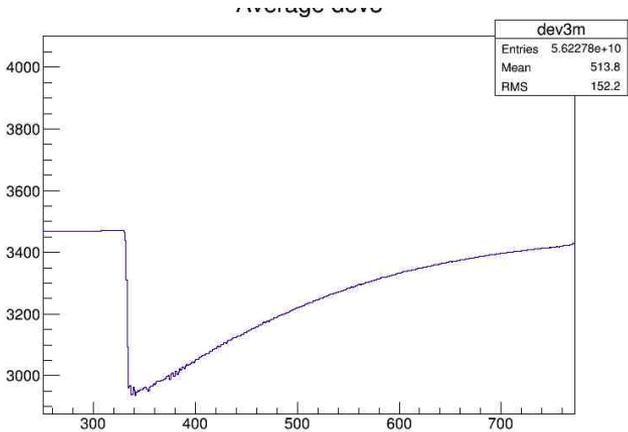


Stabilita del segnale di riferimento generato nel PM dal "pulser" $^{241}\text{Am}+\text{NaI}$

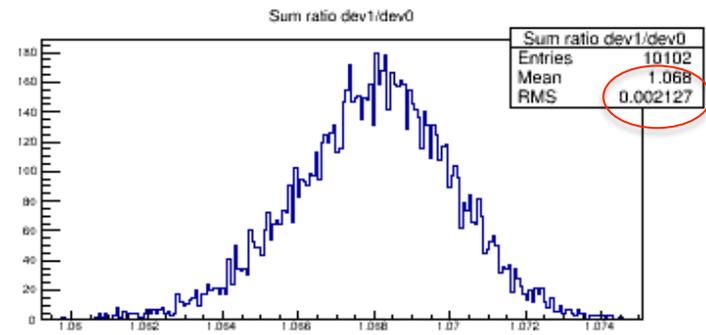
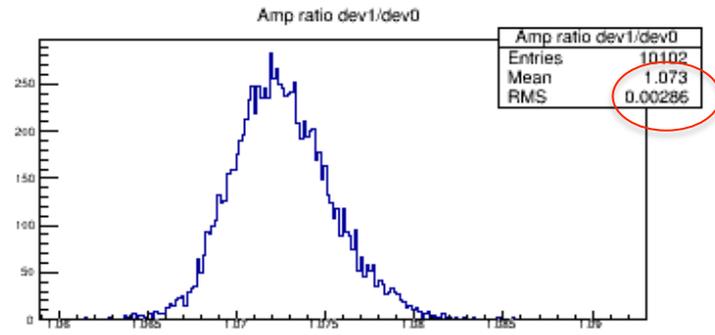
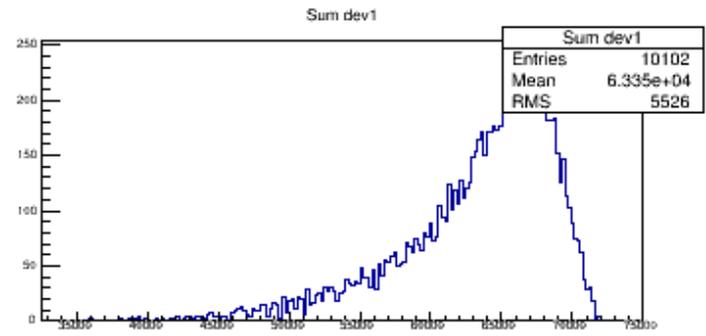
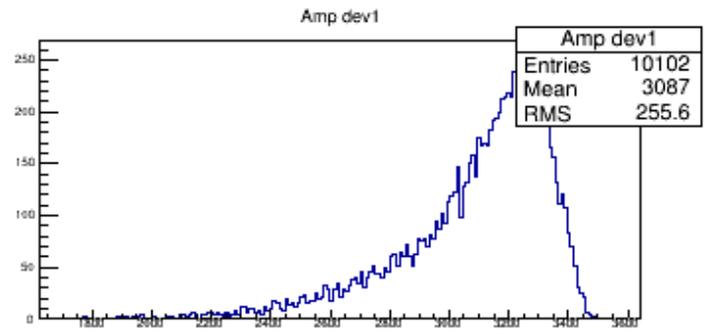
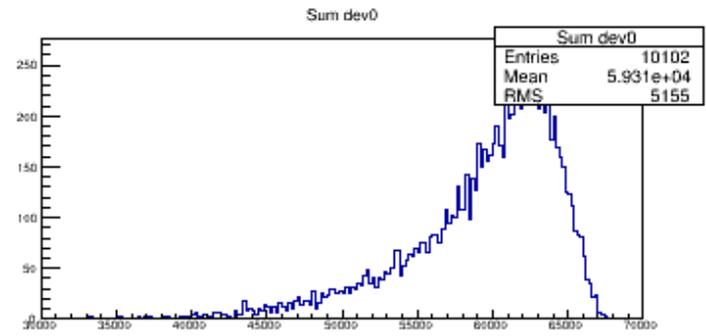
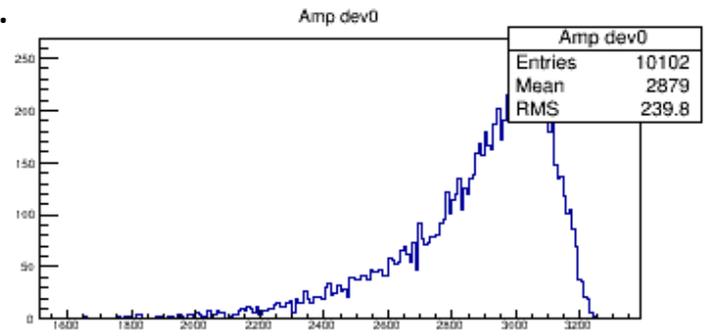
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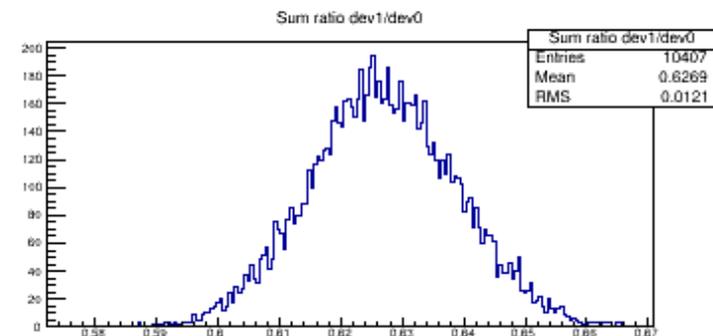
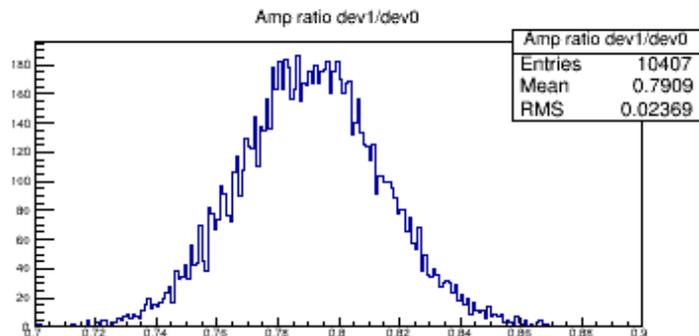
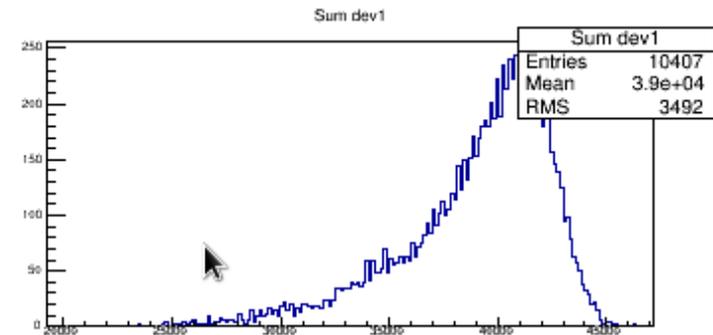
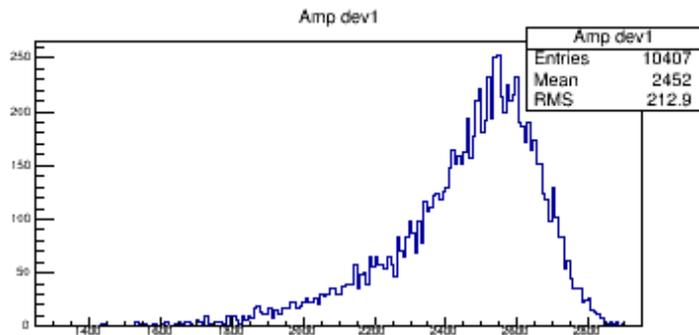
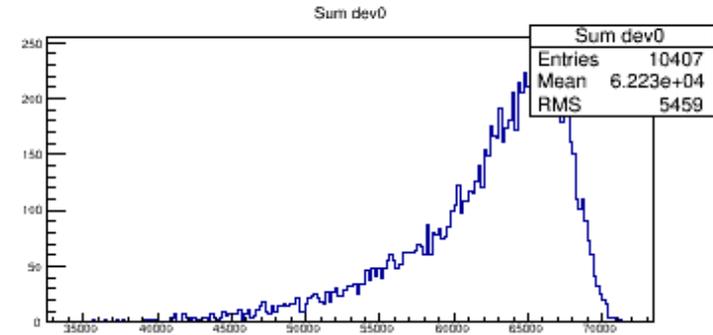
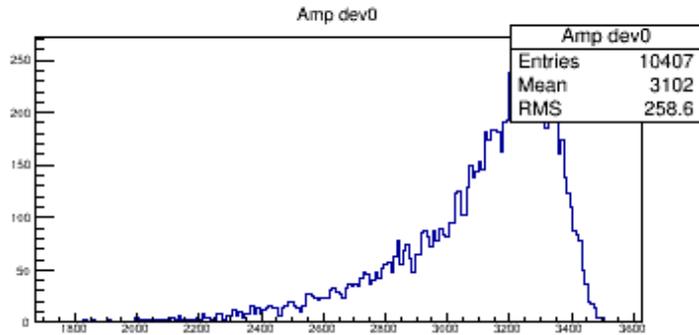
Le misure riportate in figura servono quale riferimento assoluto al 0.47%. Questo limite e' dettato dalla stabilita' dell'elettronica.



Shown here are amplitude, integral and R_{12} distributions. Note that $\sigma_{R_{21}} \sim 0.25\%$ **event-by-event despite the unusually large ($\sim 10\%$)** laser fluctuations seen in the distributions of the individual signals and that the Gaussian distribution is symptomatic of photostatistic dominance.



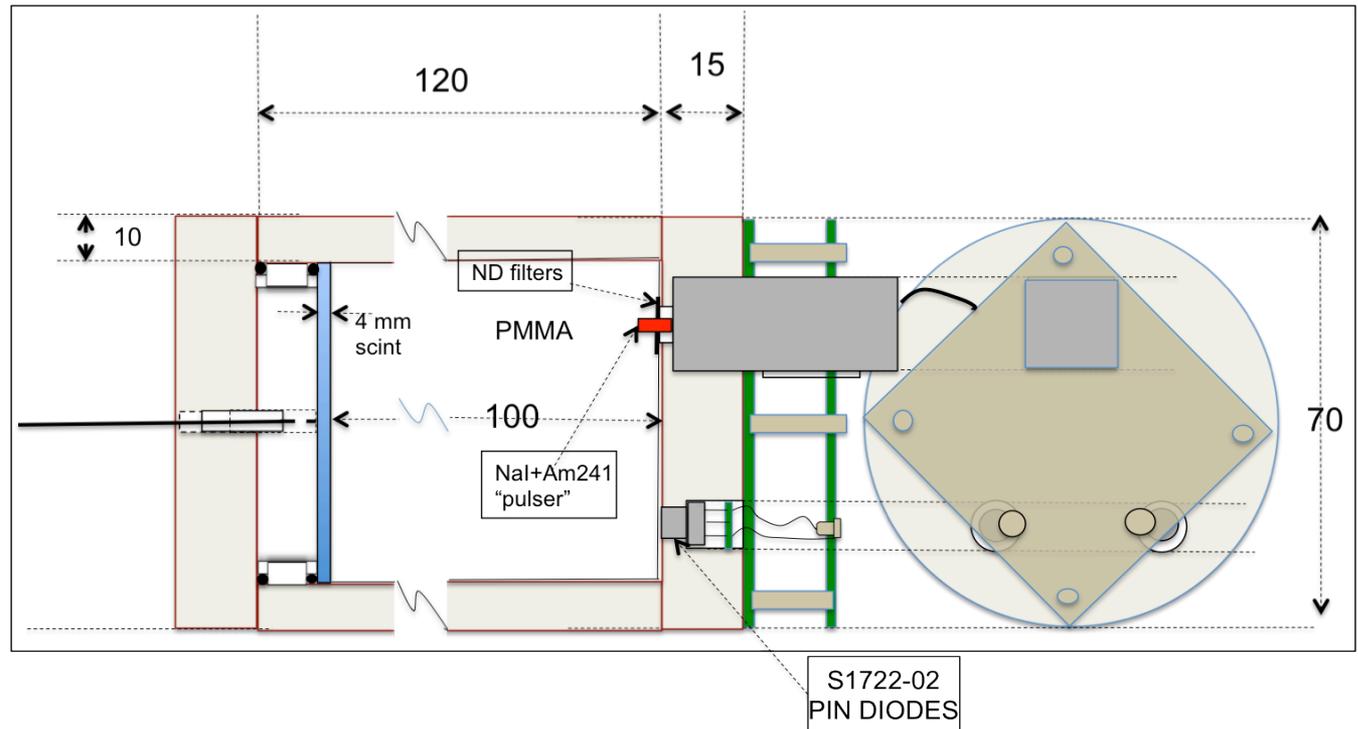
The associated σ_{R1} grows correspondingly to $\sim 1.6\%$. The situation is expected to be similar for the SiPM / PIN correlations. However, what matters is **the deviation of the mean** which varies as $1/(N_{\text{events}} - 1)^{1/2}$... to the degree that statistics dominate.



Short monitor prototype

Prototypes of two different lengths but the same basic characteristics were constructed. The shorter one is represented schematically below.

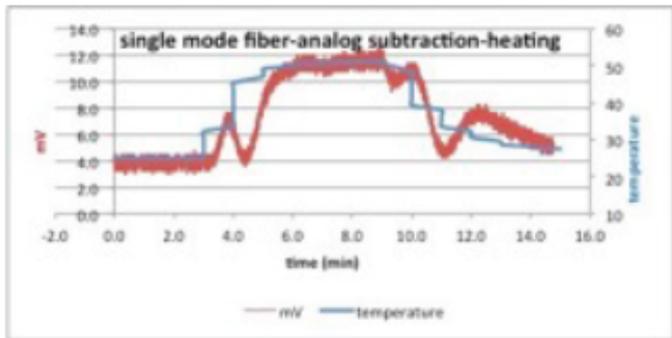
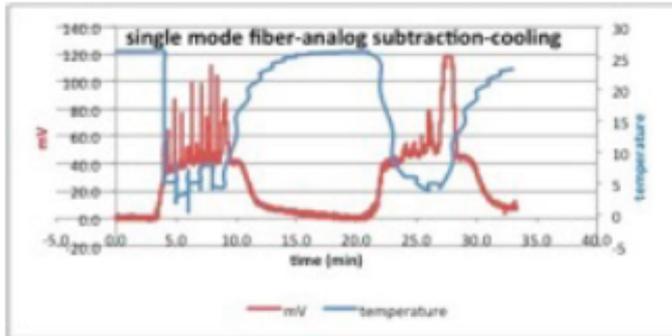
Laser light is injected by a quartz fiber on the left and excites a plastic scintillator which acts as an ideal diffuser because the emitted light is isotropic over 4π . The scintillator disk is faced up against a PMMA cylinder which acts a “mixer” .



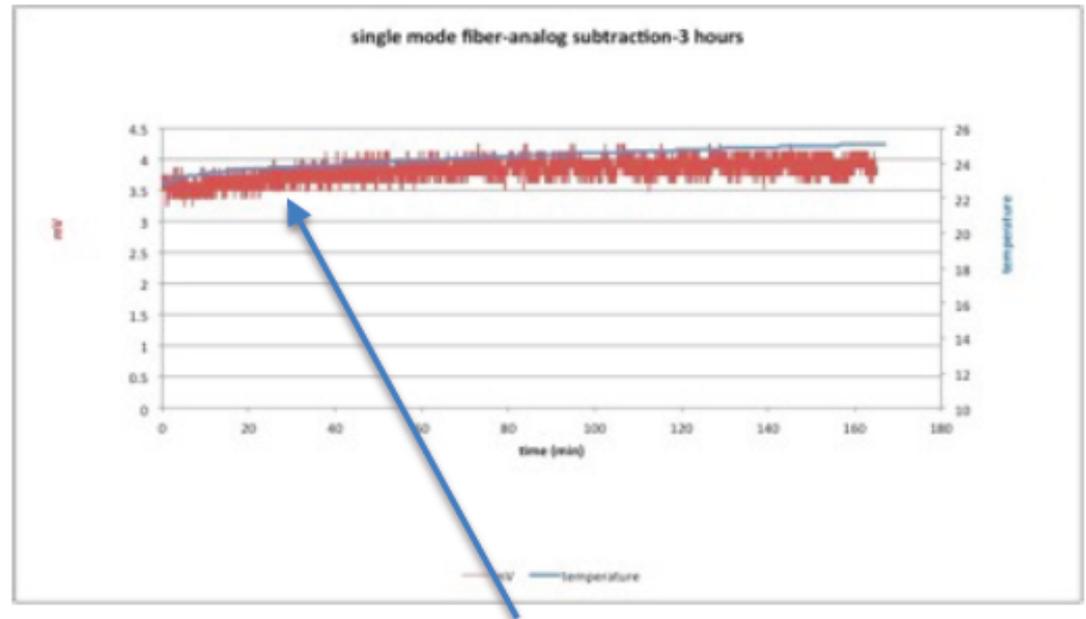
This combination should be effective in minimizing “pointing” fluctuatoons which could be produced by fluctuations in the emittance of the laser. These are improbable because the area of scintillator illuminated by the fiber is very nearly fixed a point source. The scintillation light illuminates the photodetectors faced up against the other end of the PMMA mixer.

Differenza analogica (mod. 2) - fibra singolo modo

PD2 - ciclo di raffreddamento (sopra) e di riscaldamento (sotto)



Prova di stabilità su 3 ore di misura



Sensibilità su 30 minuti:
 $3.6 \text{ mV} / 650 \text{ mV} = 0.5 \%$

il Pin Diode e' seguito da un preamplificatore di carica, necessario per lo storage della carica dell'evento e da un sistema di feedback controllato da due switch necessari per il reset dell'integratore alla fine della lettura dell'ADC.

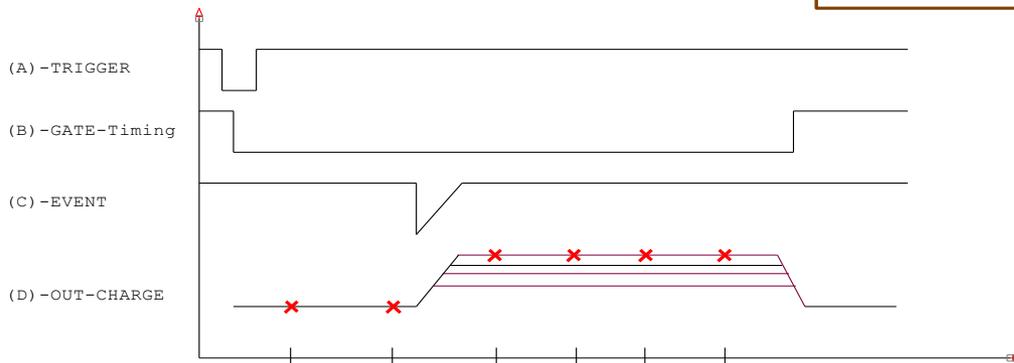
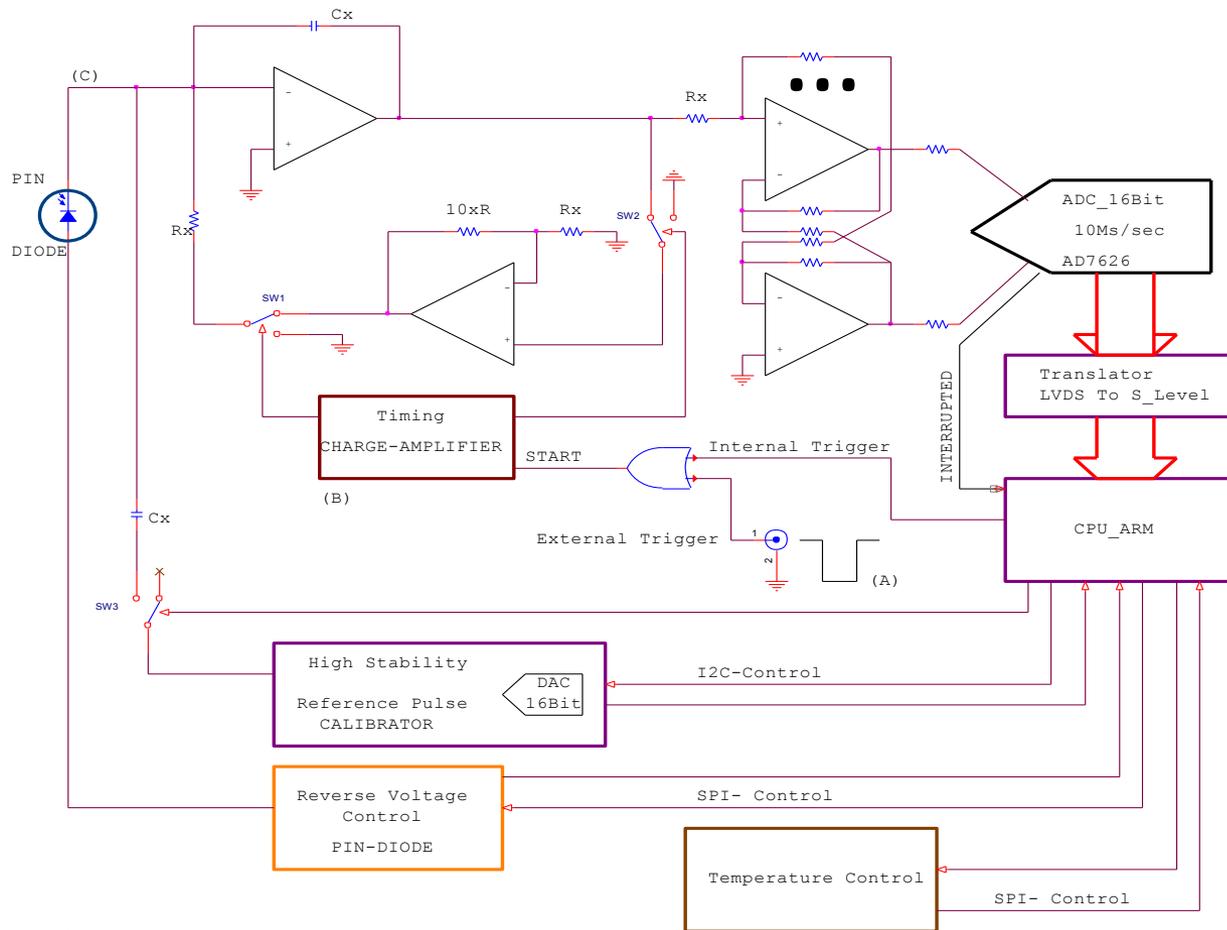
Il preamplificatore di carica, richiede un circuito di temporizzazione, per la scarica del condensatore di accumulo.

I segnali di uscita del ADC, in LVDS, dopo essere stati adattati in livello, vengono inviati alla CPU ARM, che ne fa la lettura

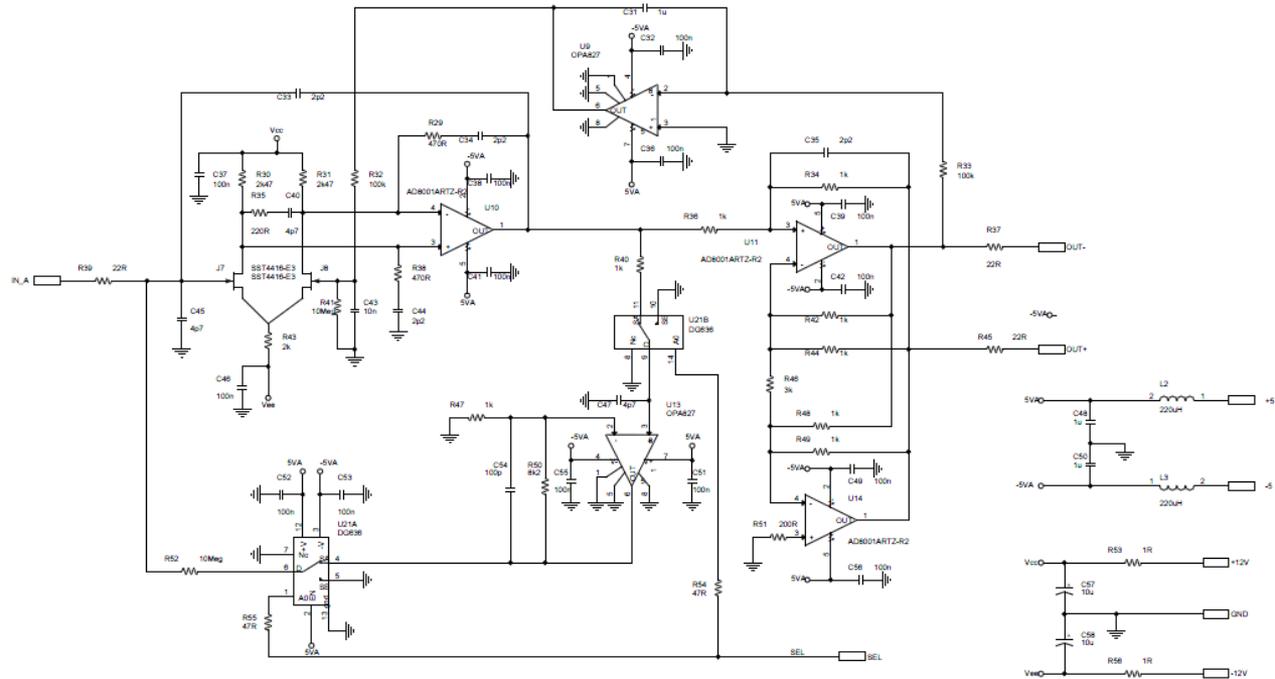
La CPU-ARM esegue la sincronizzazione con il segnale di trigger e controlla le operazioni di test e calibrazione tramite bus Ethernet.

Il blocco di calibrazione, all'ingresso del preamplificatore fornisce un impulso di carica noto, programmato con un DAC a 16 bit

Il blocco di controllo tensione, fornisce una tensione di polarizzazione stabile al Si-Pin. Il blocco di controllo della temperatura mantiene stabile la temperatura di funzionamento della scheda di front-end. Tutti i registri di controllo sono visibili sul nodo Ethernet.

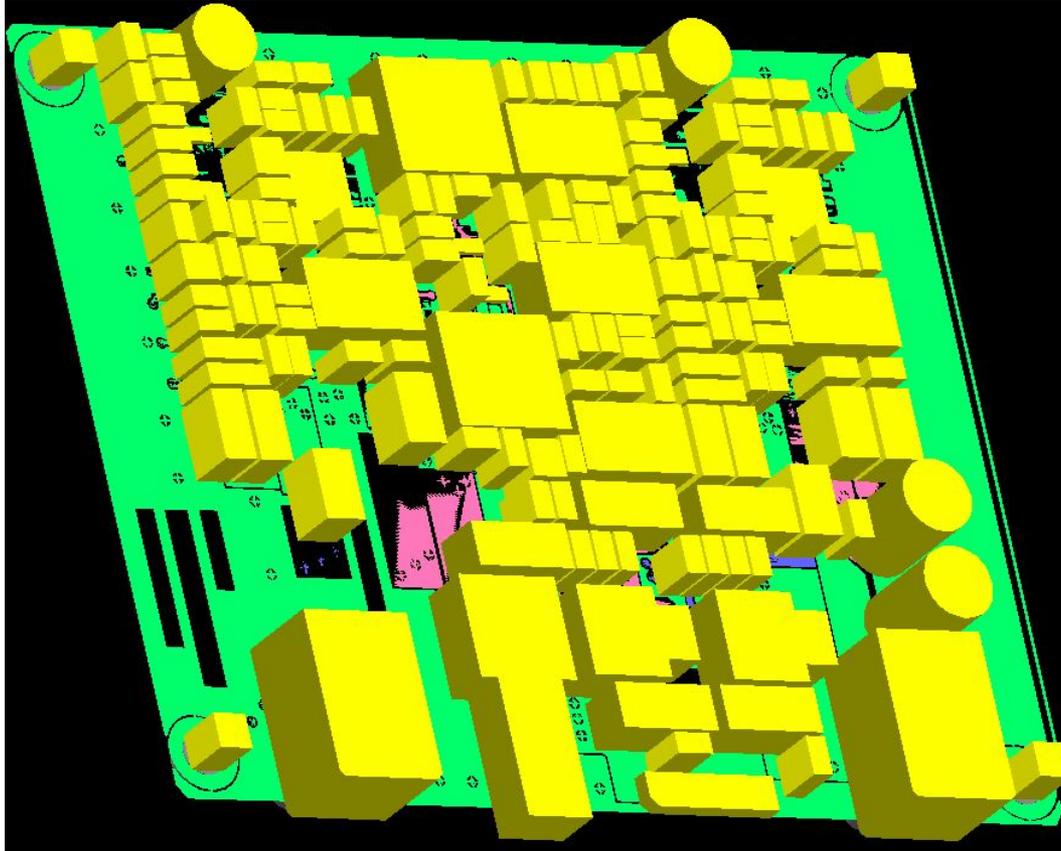


scheda di front-end di TEST



schema generale della scheda di front-end che abbiamo in TEST

Layout 3D



Layout 3D tramite editore CADENCE

Sistema di Calibrazione (baseline): Valutazione Aggiornata dei costi

3 laser sources (two+one spare): $15\text{kE} \times 3 = 45 \text{ kE}$

2x8 FTB (Fused Bicon Tapered) fiber splitter: 4kE

8 Sphere or Beam expander+mixer: $1\text{kE} \times 8 = 8 \text{ kE}$

8 fibers 15 mt for the primary distribution: $0.7 \times 8 \sim 6 \text{ kE}$

24 Bundle of 60 fibers 2mt, 3x60 fibers per secondary point (sphere/beam exp) = $24 \times 4 = 96 \text{ kE}$

24 monitors, one per bundle = $2 \times 24 = 48 \text{ kE}$

24 monitoring electronic boards = $24 \times 0.4 = 10 \text{ kE}$

1300 Optical elements to route fibers to crystals: $35 \text{ E} \times 1300 = 45 \text{ kE}$

Drive Source board, DAQ, etc... $\sim 10 \text{ kE}$

Optical Table 2 kE

Other Optical Material (collimators, mechanics, etc...)= 30 kE

Total $\sim 300 \text{ kE}$

- 2 Laser potrebbero non essere sufficienti
- Possibile necessita' di collimatori

Il costo puo' cambiare a seconda delle scelta e del numero dei componenti (Sfere invece dei Beam Expander)

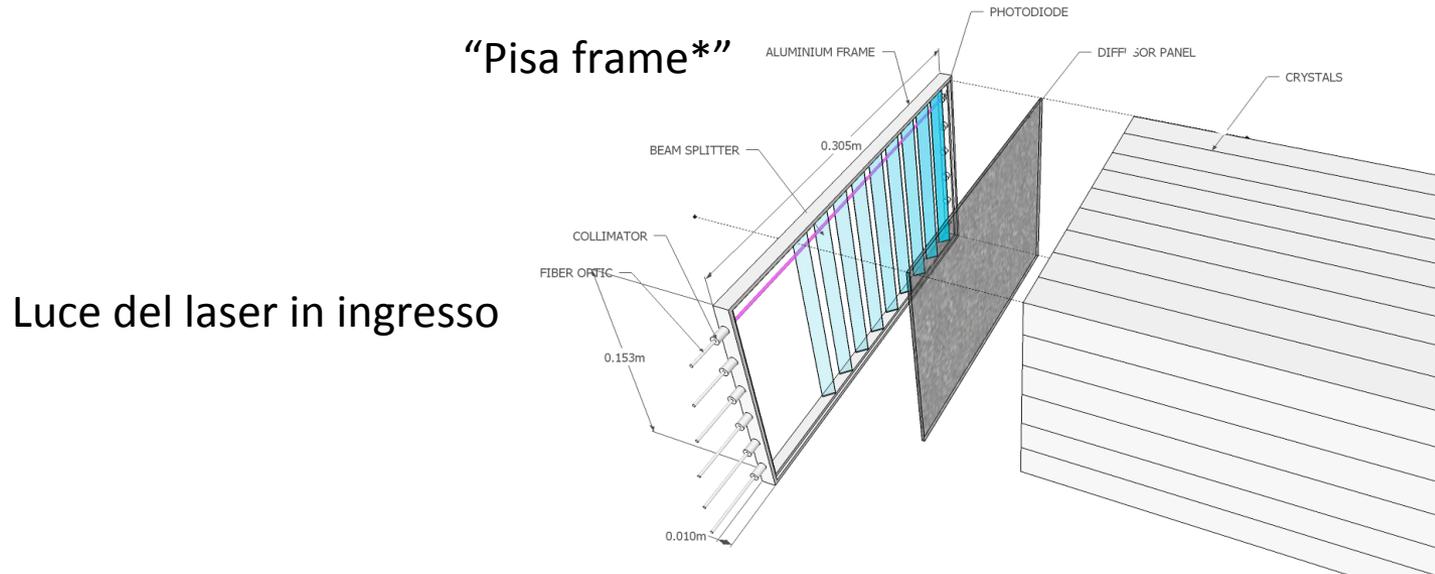
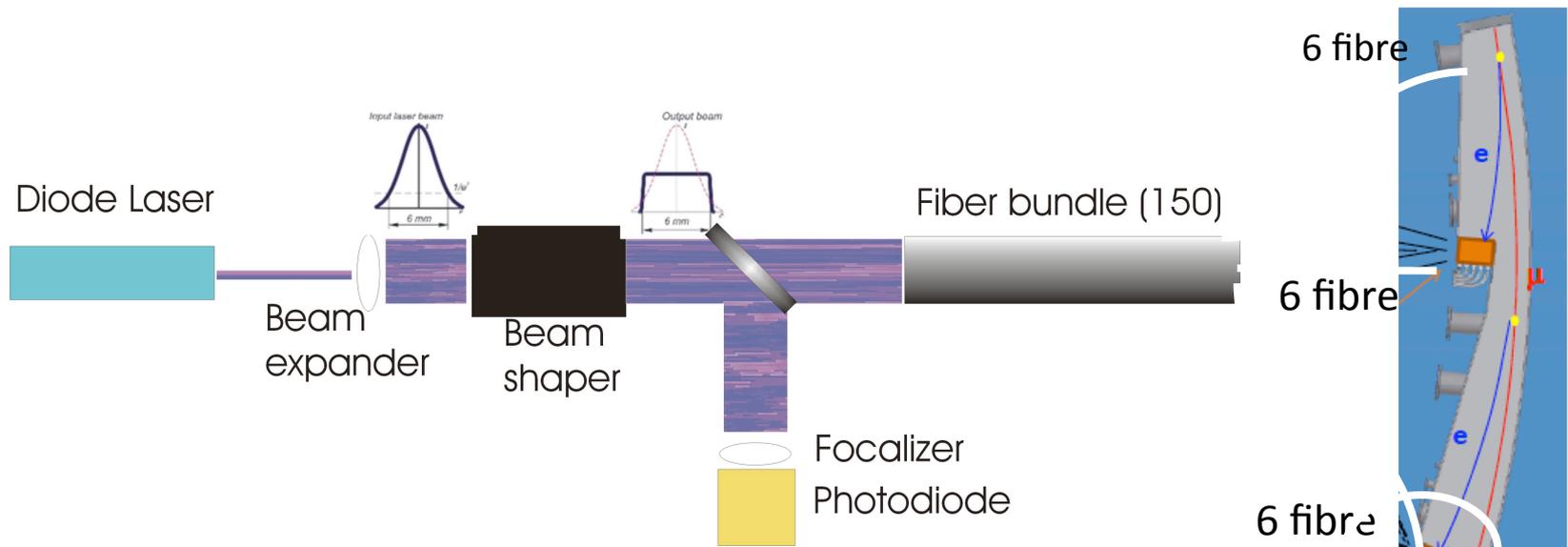
Richieste aggiuntive 2014

MISSIONI	kE	CONSUMI	kE	Inventaria bile	kE	RICH TOT kE
- TB SLAC (4m.u.+8 viaggi) - Meet Coll 1.5 m.u.+8 viaggi - Dottorando a FNAL (1m.u.) - Metabolismo Sezioni	26 14 5 5	- sfera 1 inch+ ottica varia (collimatori, beam splitters..) -Componenti diffusore / Monitor (lenti, beam splitters, etc..) -Virtex -Scheda Monitoring -Sipm -Costruzione Pisa Frame (meccanica)	3 5 2 4 2 4	Unita' di bassa tensione stabilizzata	2	
TOTALE	50		20			
Rimanenza (Assegnazioni 2014)	20		6			
Richiesta	30		14		2	46
		-Anticipi 2015				
		: 2x8 fiber splitter; - Fotodiodi pisa frame	4 4	Laser picoquant Oscilloscopio veloce	15 15	

Richieste aggiuntive 2014 divise per Sezioni

	MI (kE)	CONS (kE)	INV (kE)
TS/UD	14	8: 4-Monitor+Diffusore (UD) 4-Pisa Frame (mecc) (TS)	2: (UD) Unita' di bassa tensione stabilizzata
LNF	12	4: 2-sfera 1 inch+ ottica varia 2-Scheda monitoring	
NA_DTZ	2	2: Virtex	
RM2_DTZ	2	-	
TOT	30	14	2

Sistema di Calibrazione: "Pisa Frame"



*= Idea di Carlo Ferrari e Stefano Veronesi, CNR Pisa

Per il Pisa Frame non abbiamo fatto una valutazione dettagliata dei costi, perché vorremmo prima fare dei test su prototipi.

Un primo test potremmo iniziare a farlo con le richieste per il 2014 ed eventuale anticipo di 4 kE sul 2015 (vedi slide 4)

Richieste finanziare (2105/16)

- 2015: Prevediamo una richiesta simile a quella del 2014 . (~100kE consumo +50 Missioni+50 Costruzione Apparato (SJ))
- 2016 prevediamo richieste principalmente per costruzione del sistema completo e invio a FNAL, manutenzione, debugging, (eventuali) turni. Ad oggi prevediamo ~250kE in costruzione apparati+100kE in missioni.



Stato dell'Esperimento



Calibration signal: Statistics

$$R = \frac{Q_{SiPM}}{Q_{mon}} \sim \frac{C_{V \rightarrow ADC}^i G \epsilon_{PDE} S_{\gamma}^i}{C_{V \rightarrow ADC}^0 \epsilon_{PD} A_{mon} S_{\gamma}^0}$$

S_{γ}^i = Intensity of laser pulse to i-channel

S_{γ}^0 = Intensity of laser pulse to the monitoring

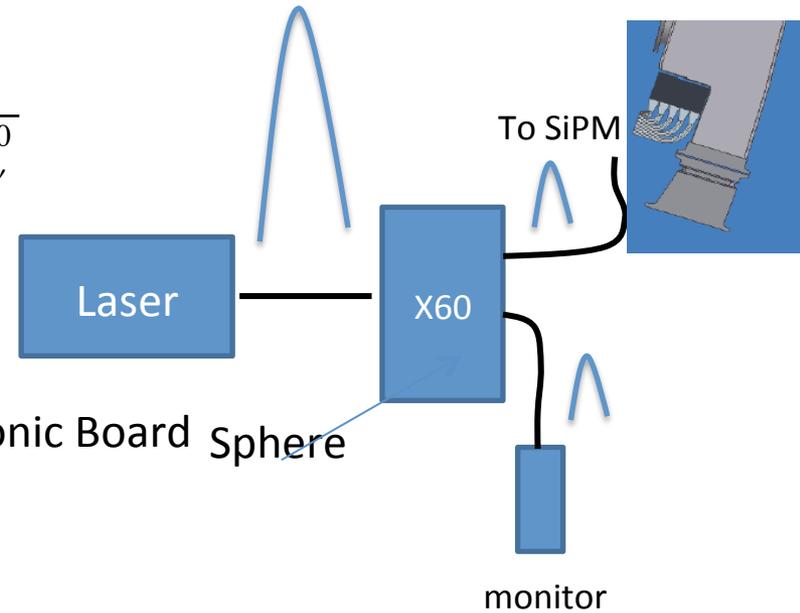
$G \epsilon_{PDE}$ = SiPM Gain x efficiency

$C_{V \rightarrow ADC}^i$ = Charge-amplitude Conversion factor (Electronic Board Sphere and WFD)

A_{mon} = Light coll efficiency of Monitor

ϵ_{PD} = Pind Diode eff

$C_{V \rightarrow ADC}^0$ = Charge-amplitude Conversion factor (Electronic Board)



$$\sigma_R^{stat} = \sigma_{phe, SiPM} + \sigma_{phe, PD} + \sigma_{elect noise} + (1 - \rho) \sigma_S^{stat}$$

$$\sigma_R^{stat} \rightarrow \sigma_{phe, SiPM} \sim 1 / \sqrt{3000} \sim 2\%$$

Statistical error: dominated by the photostatis of SiPM. can be brought to 0.04% by taking 2000 pulses

σ_S^{stat} = Fluctuation of the Source (beam pointing) and uniformity, can be neglected if they affect in the same way SiPM and Monitor