A RICH-like cosmic rays setup

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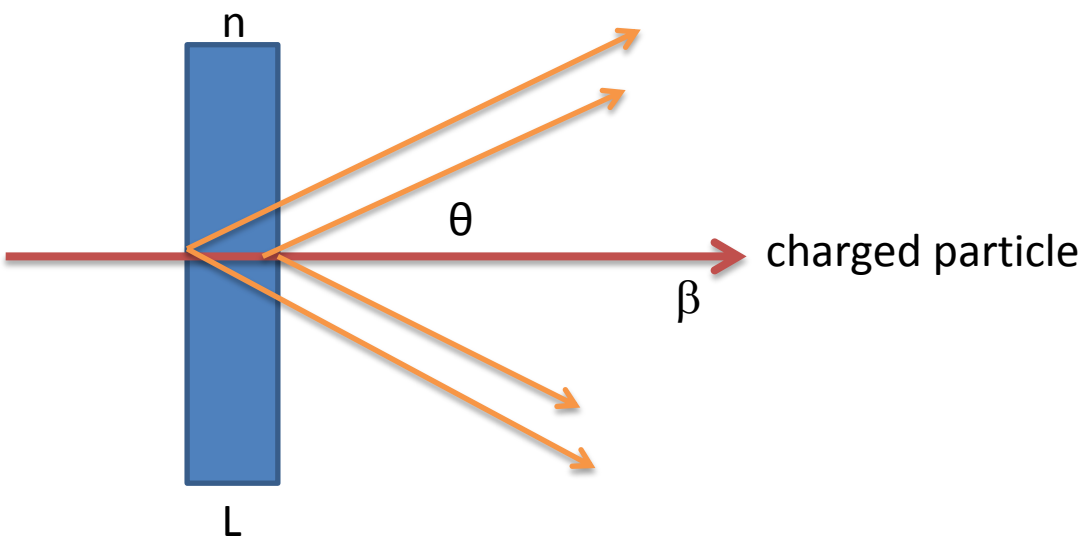
M.Lenti, S.Lami, F.Maletta, K.Xhani

Cherenkov effect in a nutshell



n: index of refraction
θ: Cherenkov angle
β: particle velocity (c=1)
L: radiator length

$\cos\theta = 1/n\beta$
$\cos\theta(\text{max}) = 1/n$
$\beta(\text{threshold}) = 1/n$

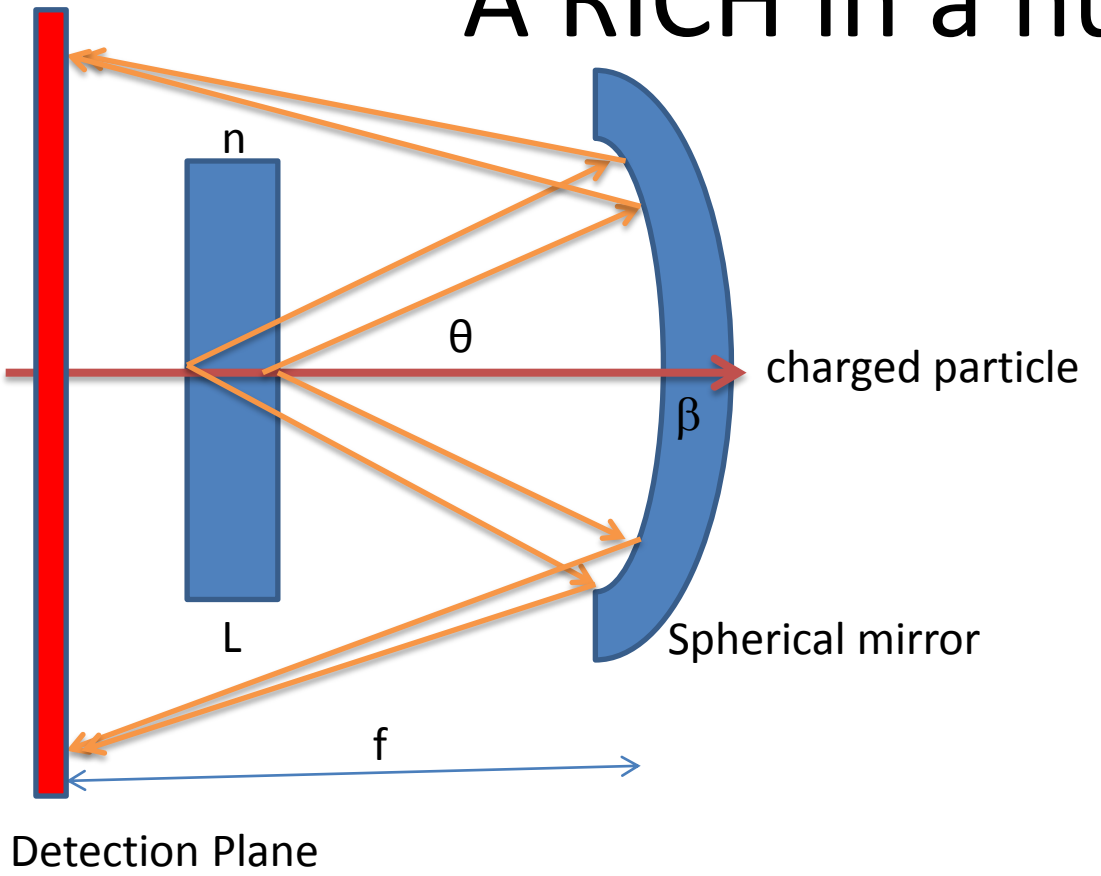
Frank-Tamm eq.:

$$\frac{d^2N_\gamma}{dEdx} = 370\sin^2\theta\ \text{eV}^{-1}\ \text{cm}^{-1};$$

$$N_{p.e.} = N_0\ L\sin^2\theta;$$

$$N_0 \approx 100\ \text{cm}^{-1}$$

A RICH in a nutshell



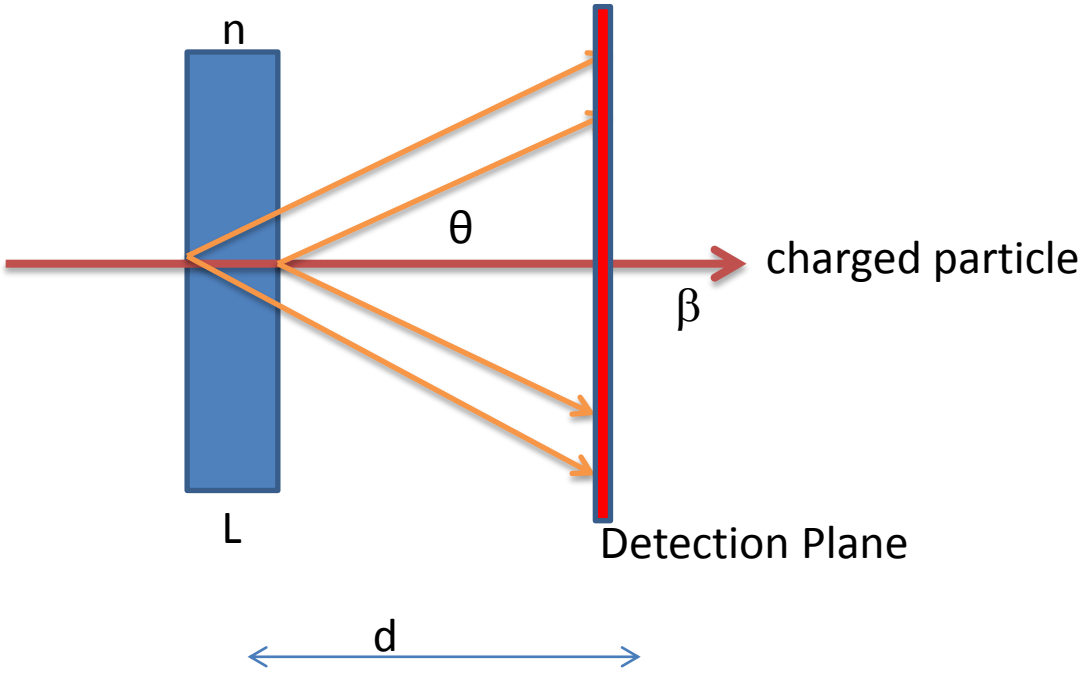
The Cherenkov cone is mapped (pure optical geometry) into a ring in the mirror focal plane

The sensors (PMT, etc) are placed in the mirror focal Plane

$$r_{ring} = f \tan\theta$$

Usually L≈f

A proximity focusing cherenkov in a nutshell



If L<<d an approximate Ring is formed on the Detection plane

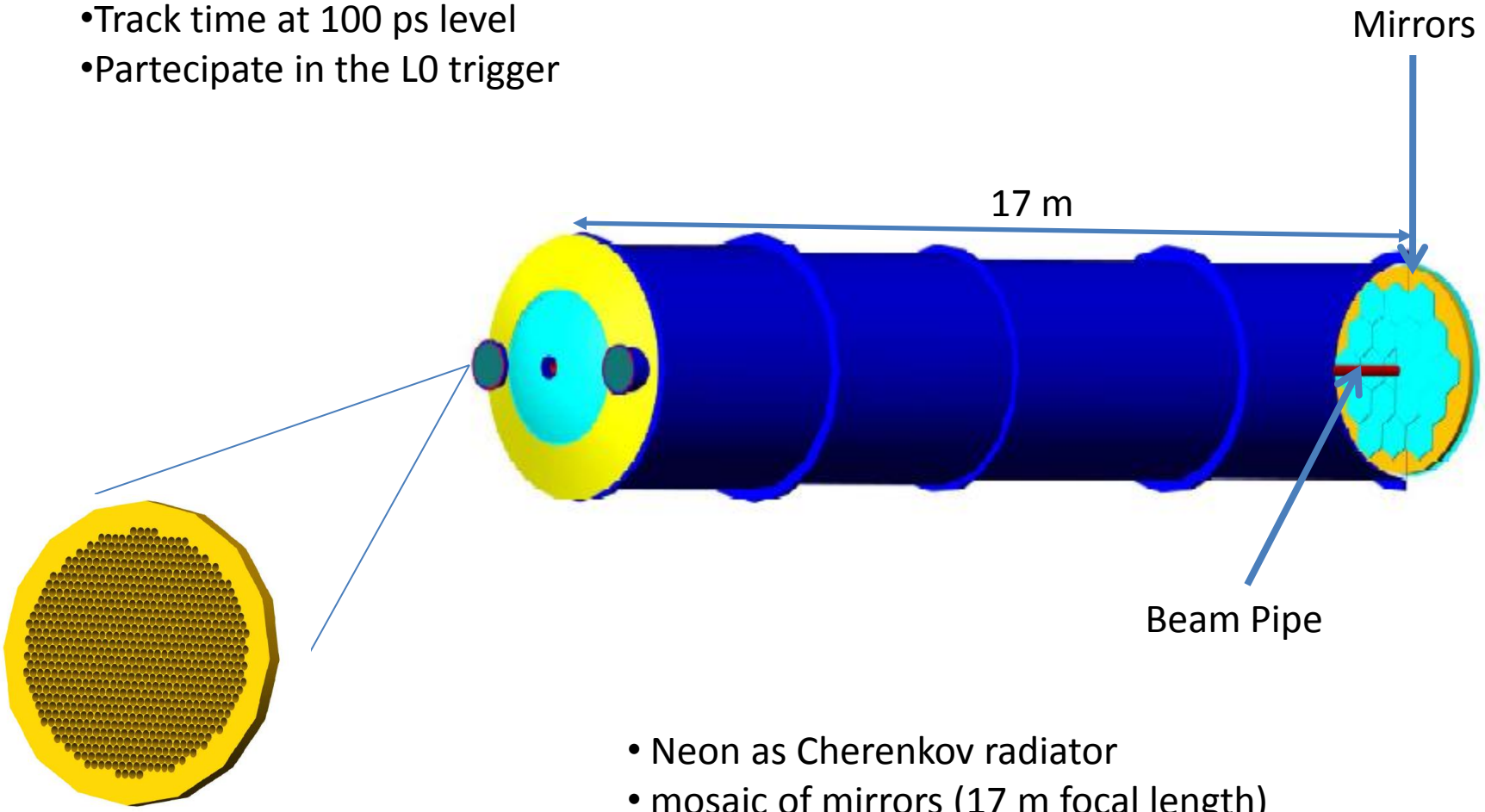
$$r_{ring} \approx d \tan\theta$$

The thickness of the ring depends on L

THE NA62 RICH

INFN Perugia
INFN Firenze
CERN

- Separate pions from muons <1% level between 15 and 35 GeV/c
- Track time at 100 ps level
- Partecipate in the L0 trigger



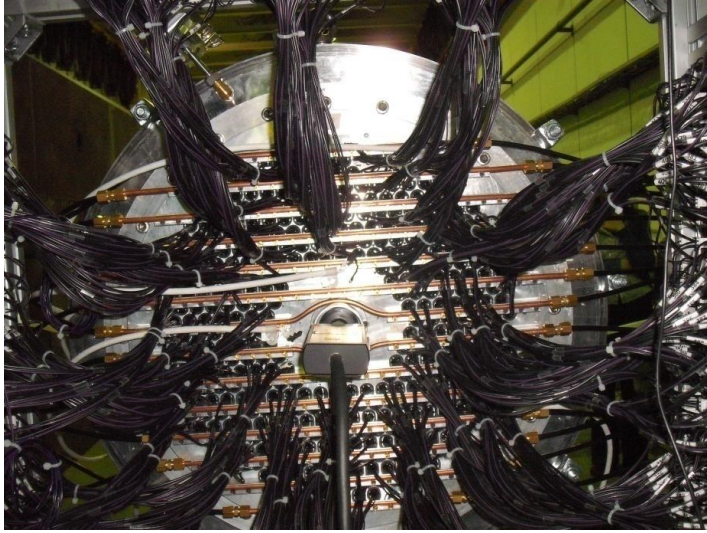
- Neon as Cherenkov radiator
- mosaic of mirrors (17 m focal length)
- two spots with PM (1000 PM per spot)
- beam pipe passing through

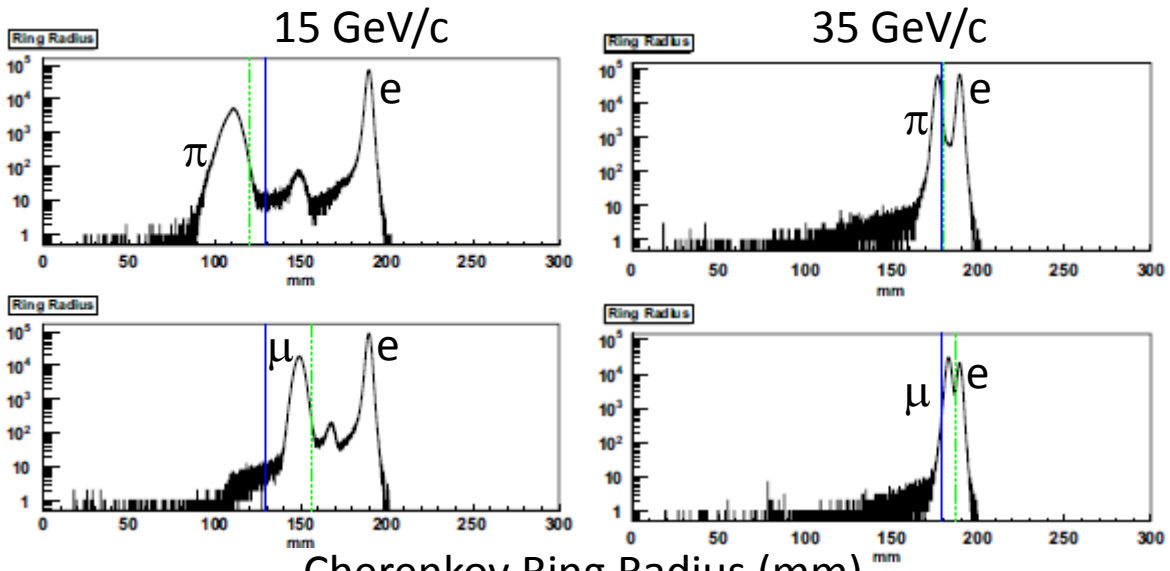
The NA62 RICH prototype

- A RICH prototype was built in 2007,
- Vessel: 17 m long, 0.6 m wide, filled with Neon
- Equipped with one mirror
- In a test beam in 2007 at CERN (TCC8) it was equipped with 96 PMTs, demonstrating the required time resolution
- In a test beam in 2009 at CERN (TCC8) it was equipped with 414 PMTs, demonstrating the required $\pi-\mu$ separation between 15 and 35 GeV/c
- 2 NIM papers published

NA62 RICH prototype publications

- "Construction and test of a RICH prototype", G.Anzivino et al, NIMA, v.538, p.314-318, 2008.
- "Pion-Muon separation with a RICH prototype for the NA62 experiment", B. Angelucci et al, NIMA, v.621, p-205-211, 2010

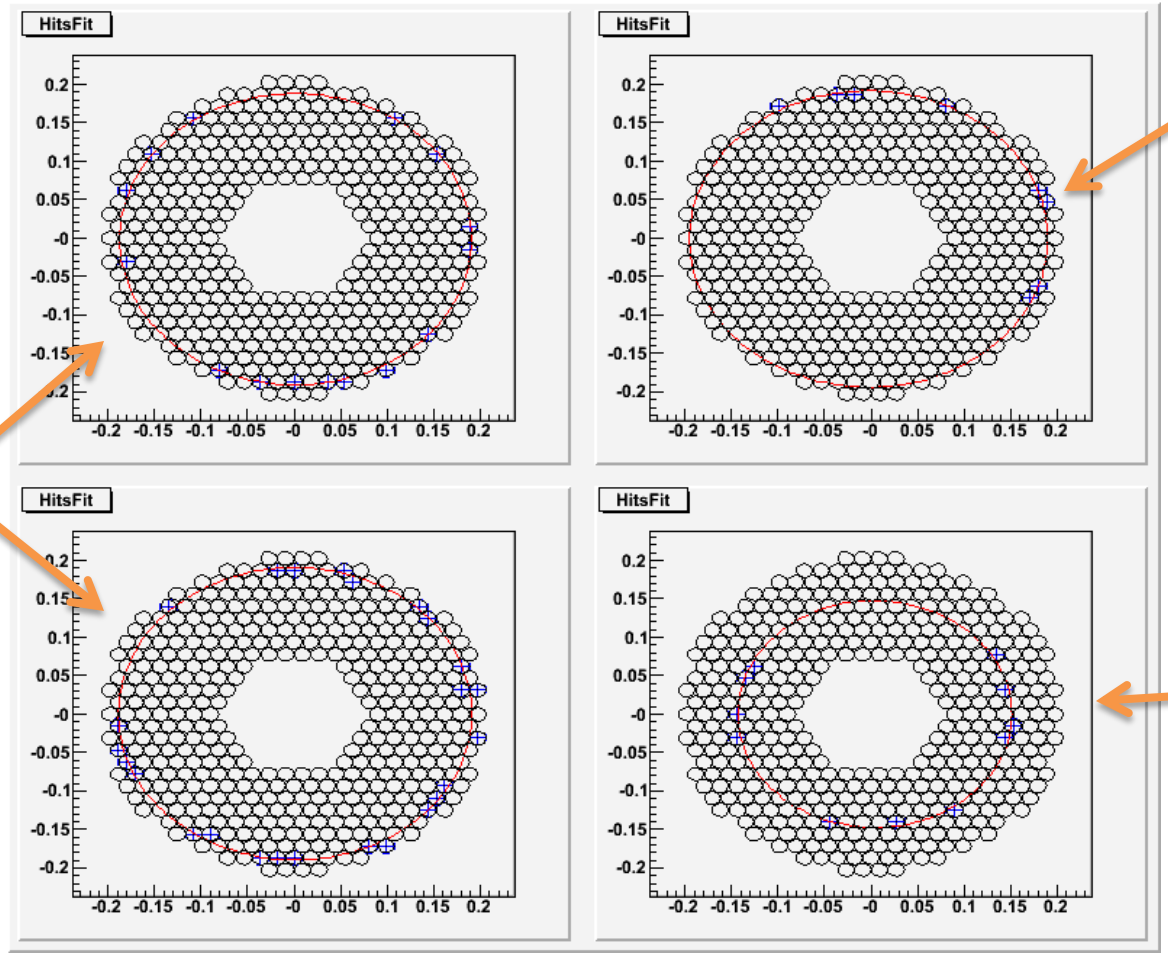




Cherenkov Ring Radius (mm)

NA62 RICH prototype: rings

20 GeV/c



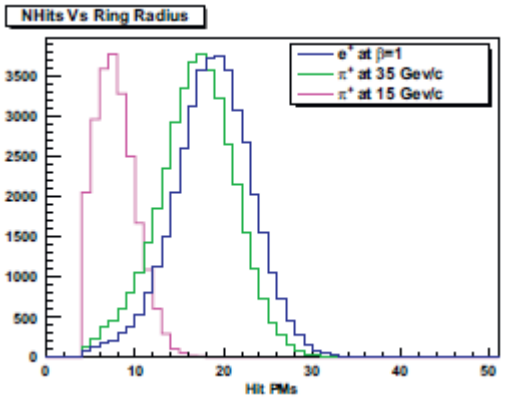
positrons

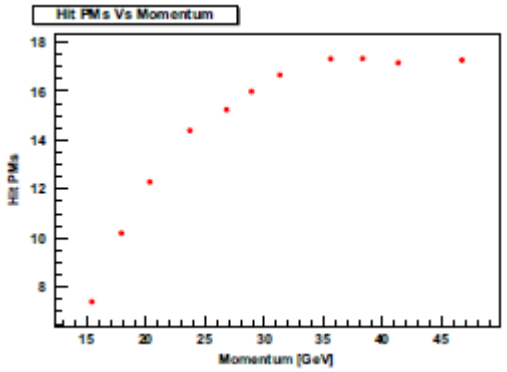
Hard to reconstruct ring…

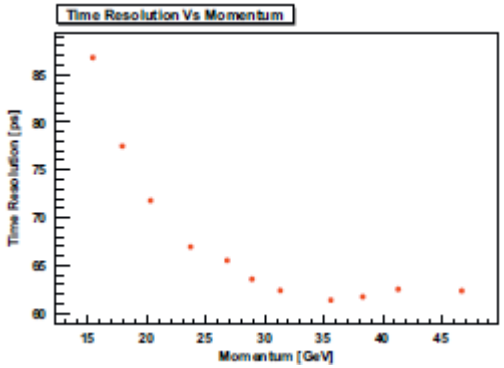
pion

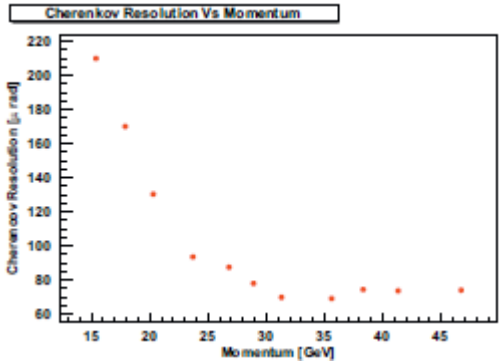
NIM A593 (2008) 314-318
NIM A621 (2010) 205-211

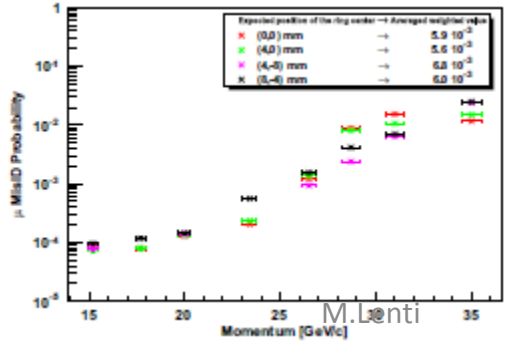
NA62 RICH prototype results





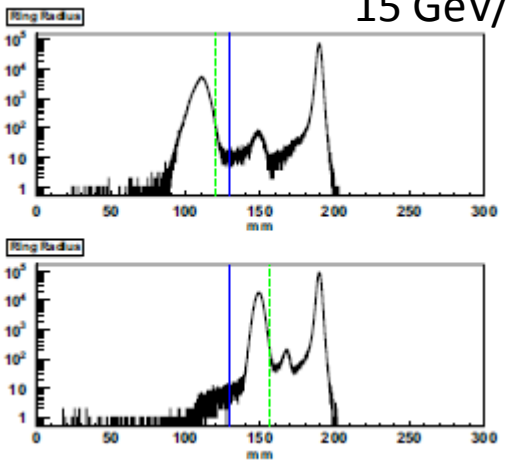




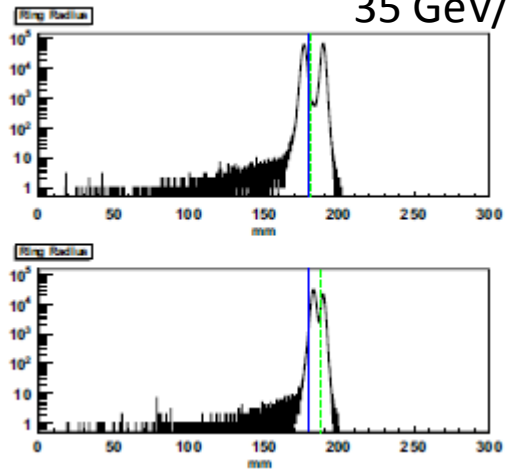


μ suppression: 0.7%
(15<p<35 GeV/c)

15 GeV/c



35 GeV/c

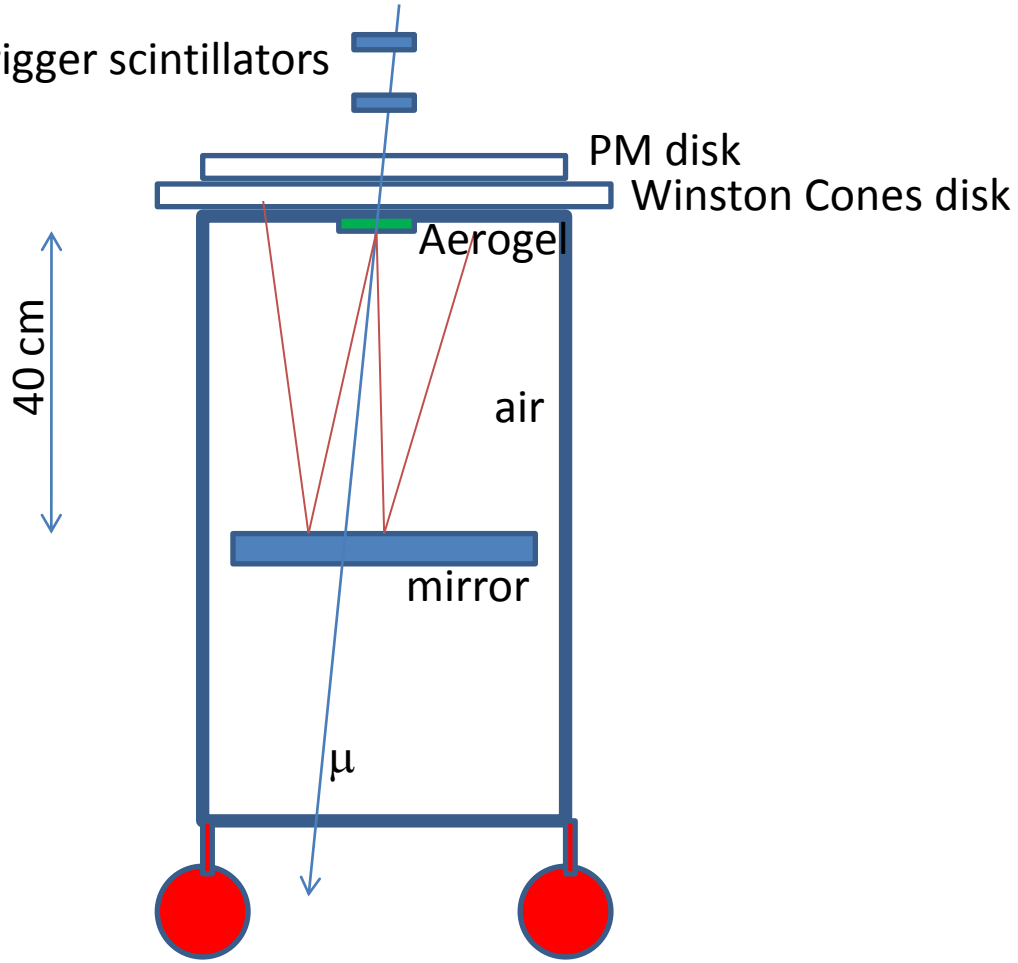


Cosmic rays setup

- Try to recycle part of the RICH prototype for a didactic cosmic rays setup
- Neon as radiator not practical for cosmics
- Use aerogel bricks as radiator
- Not a RICH but a proximity focusing Cherenkov detector
- Re-use the spherical mirror in “flat mode”

Cosmics rays setup: “COSMORICH”

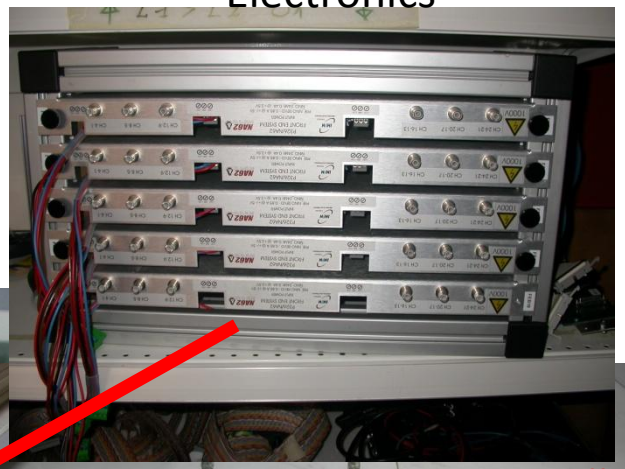
“vessel” light tight,
not gas tight



Preparation

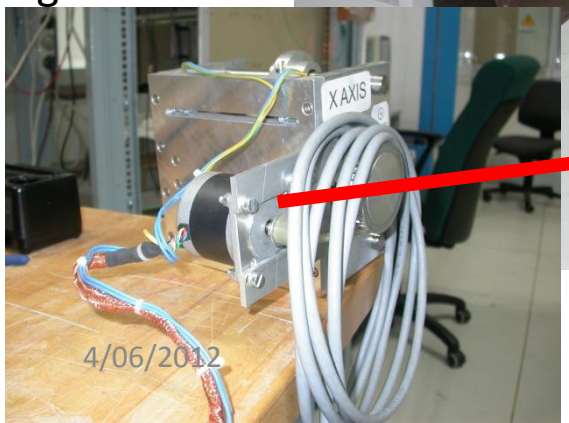
PM disk

Electronics



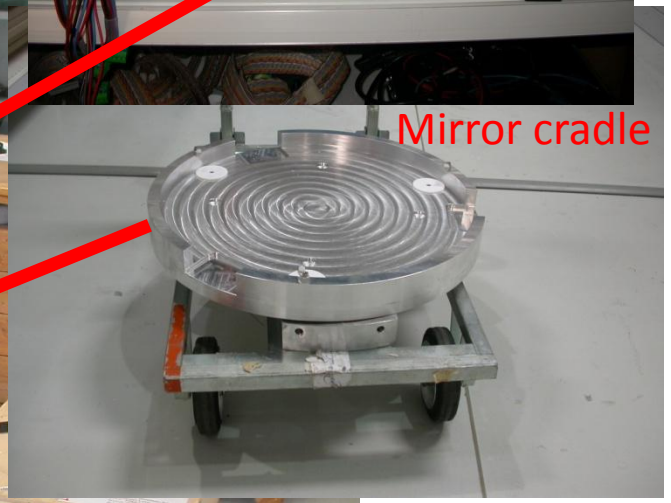
Winston Cones

Align motor

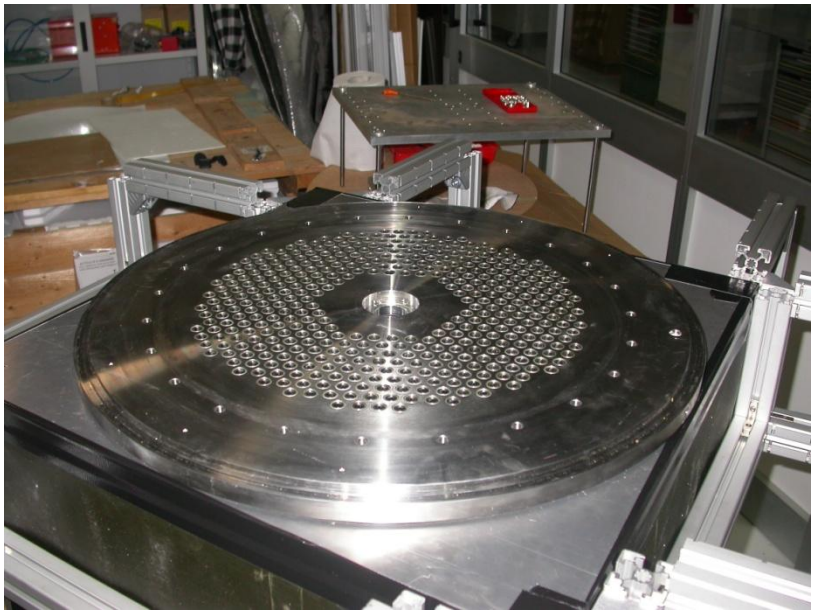


Cosmic chariot

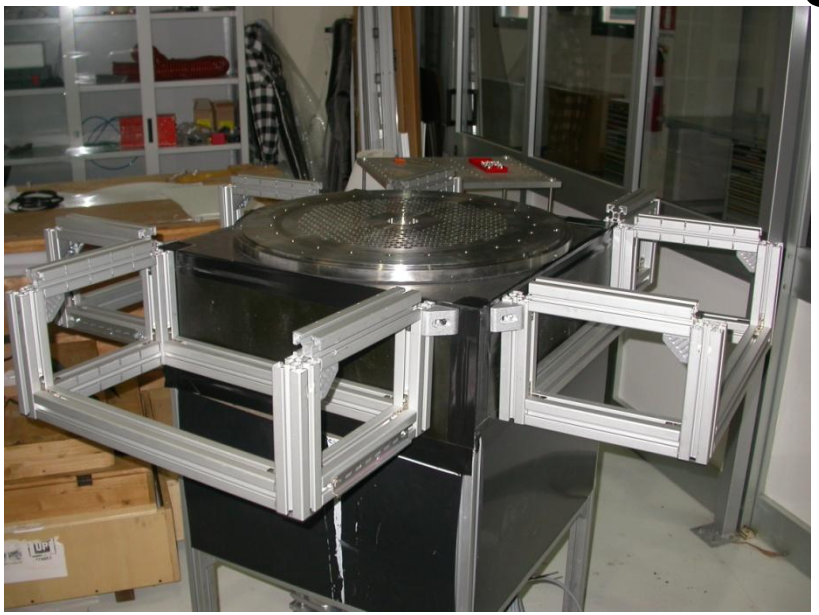
Mirror cradle

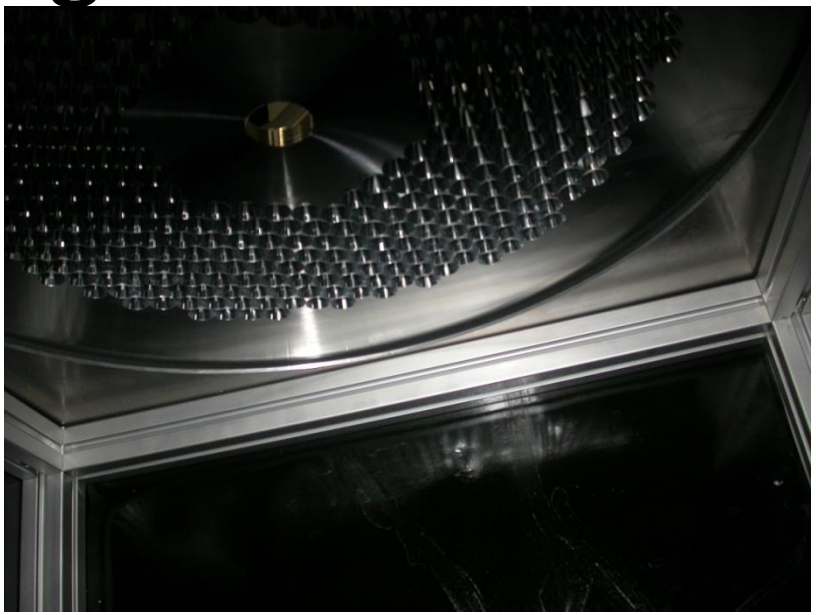


Closing flange



Progressing…



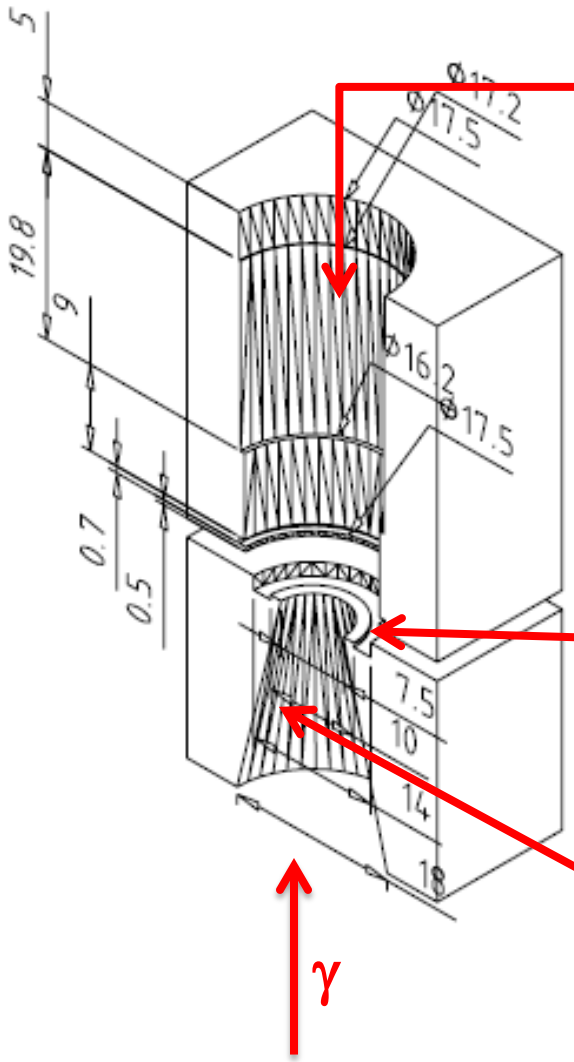


View from inside

Light Collection

PMT: 16 mm Ø
Active region: 8 mm Ø
Packing: 18 mm step

Need a light collection system from 18 mm Ø to 8 mm Ø:
Winston Cone



PMT location

PMT Lodging Disk

Quartz window

Winston Cones Disk

Aluminized Mylar to improve light reflection in the Winston Cone

Quartz windows

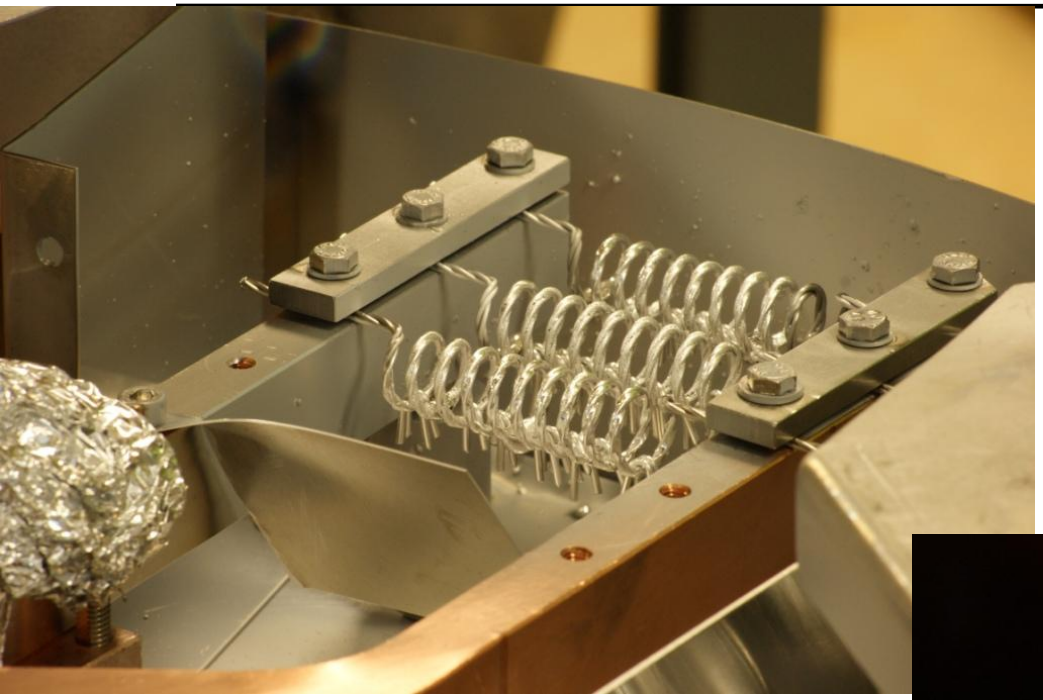
- Praezisions Glas & Optik GmbH
- Windows made of UV-grade Quartz Glass:
  - double side polished
  - diameter. 12.7mm (+/-0,1)
  - thickness 1mm (+/-0,1)
  - ground edge, unbeveled
- Necessary to separate air from Neon with good UV transparency
- Not necessary for the cosmic ray setup…..

NA62 Mylar reflective coating with Al/MgF2

Fixation in the evaporator:
The clamped Mylar foil is fixed to the rotating plate in the upper part of the evaporation plant

Quality Control samples:
For each process (foil) we add a glass sample to assure the quality control of the process. An extra sample is cut out of the Mylar foil to document the result on the foil.

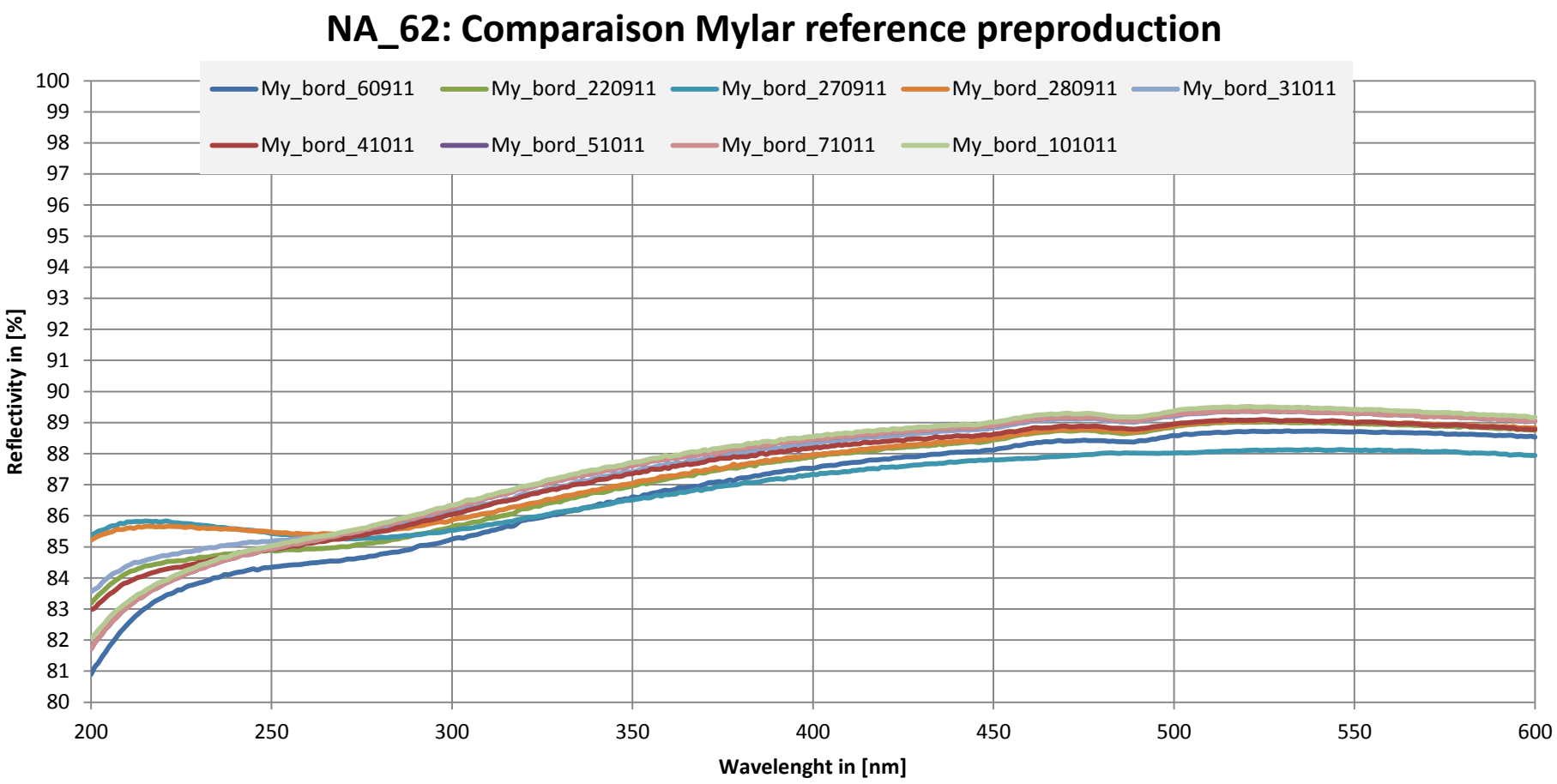
NA62 Mylar reflective coating with Al/MgF2



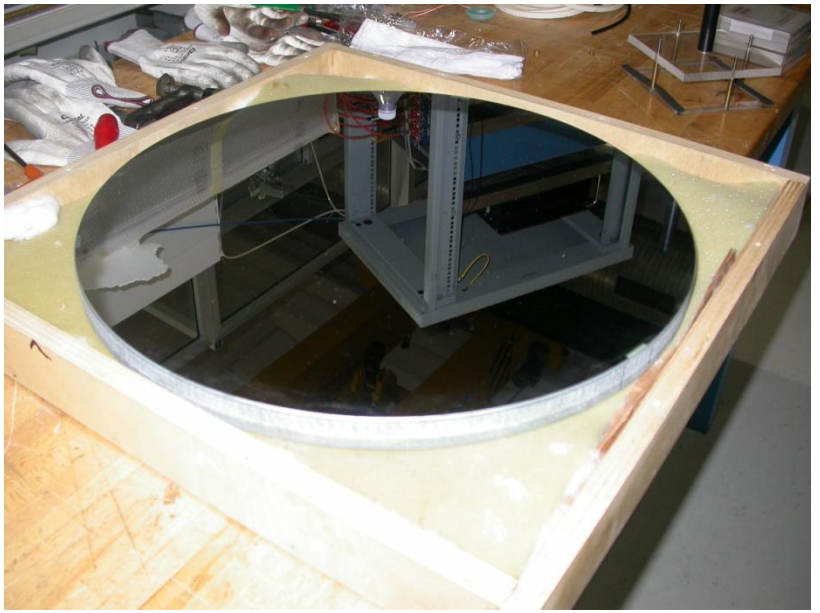
Aluminium evaporation:
Tungsten filaments are charged and pre-melted with pure Aluminium.

Via resistive heating (joule effect) the Aluminium is evaporated to the rotating substrate (Mylar foil). The vacuum during the process is in the order of 10^{-6} mbar.

NA62 Mylar reflective coating with Al/MgF2

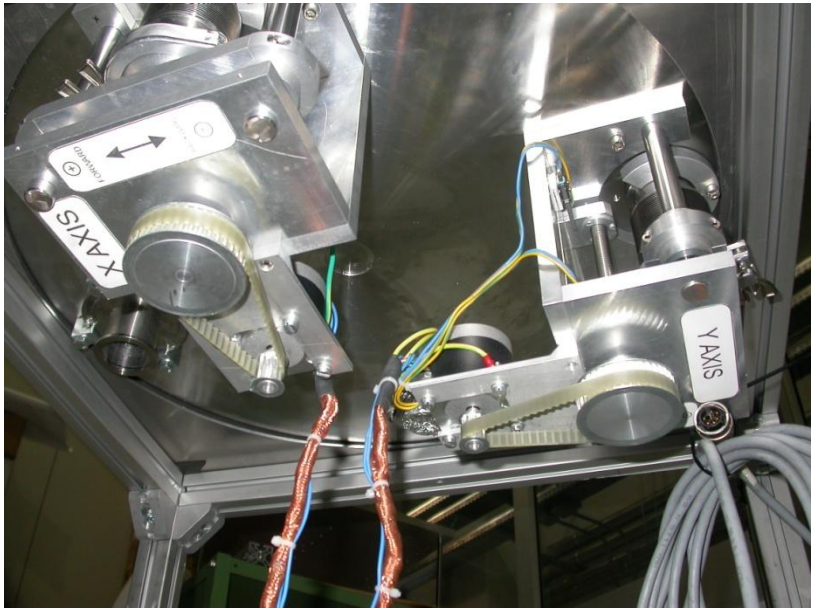


Reflectivity scan of some coated Mylar foils (scan from 200nm-600nm)



The mirror

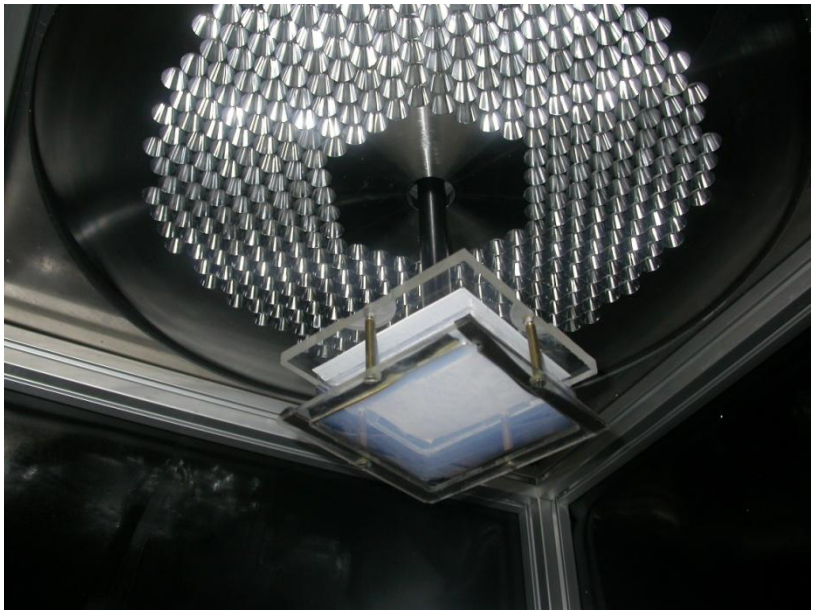
Back to preparation….



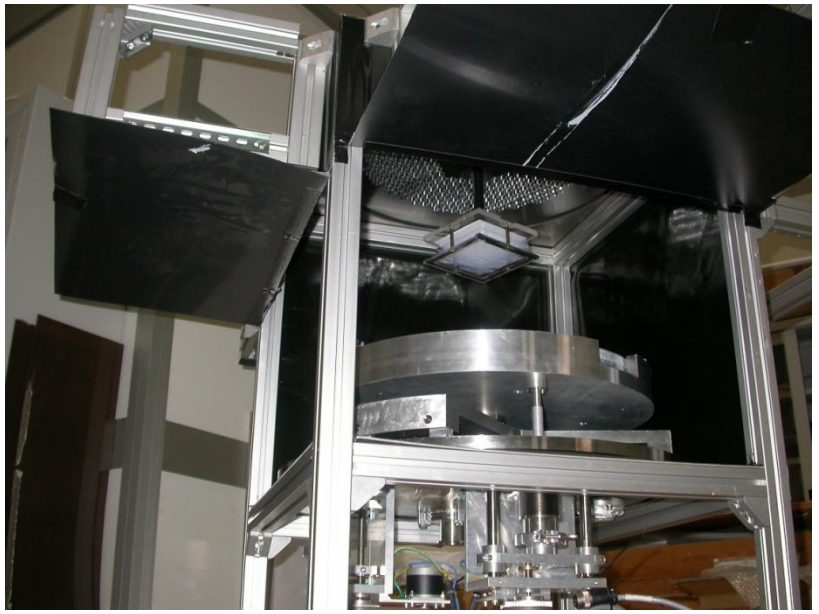
Aerogel bricks

Aerogel

- Matsushita SP-30 (courtesy of **Clara Matteuzzi** from LHCb), hydrophobic
- 3 bricks of 12x12x1 cm^3 each
- n=1.03 (θ_{max} = 250 mrad, p_μ(thresh)=440 MeV/c)
- Dist aerogel-mirror ≈ 40 cm
- R_{ring} (β=1)≈ 2x40x0.250 ≈ 20 cm (as in test beam)

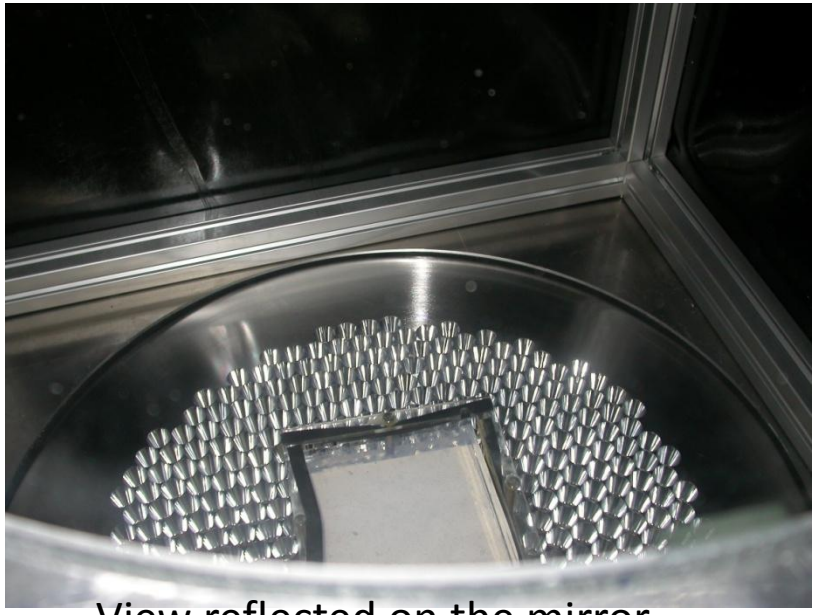


Inserting aerogel…



Again…

Final position



View reflected on the mirror

RICH PMT: Hamamatsu R7400U-3

Figure 11: Dimensional Outline and Basing Diagram (Unit: mm)

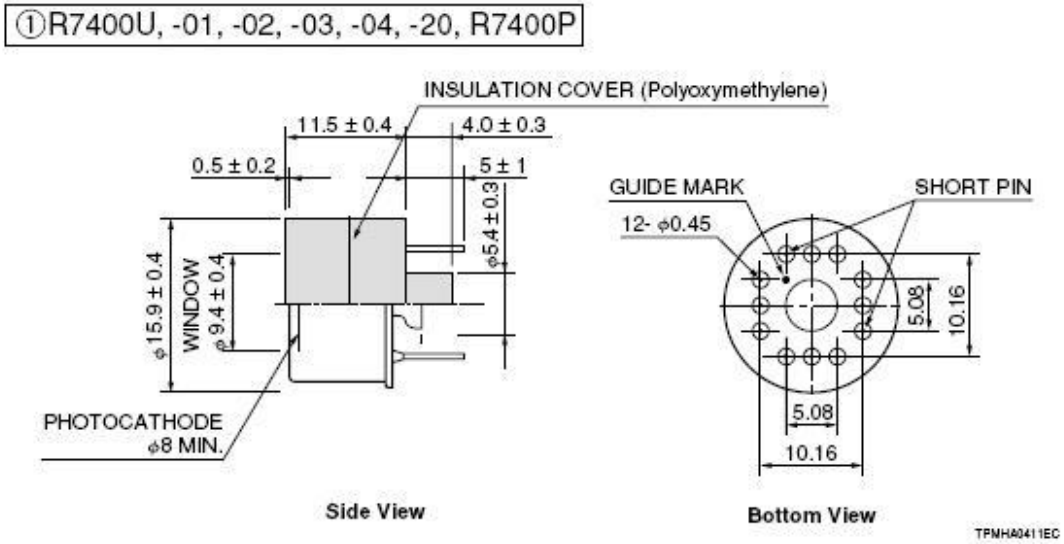
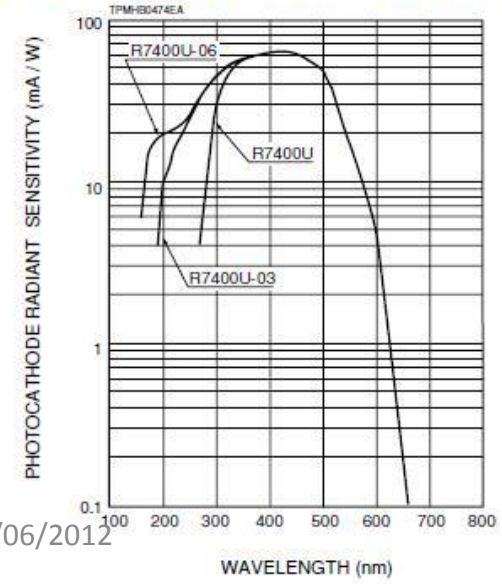


Figure 2: Typical Spectral Response (Bialkali)

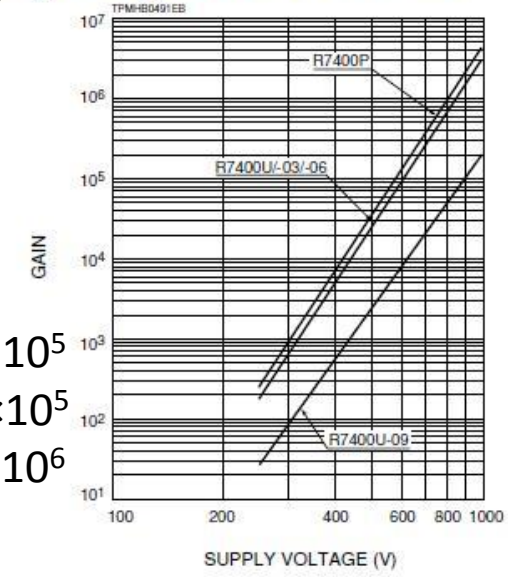


Fast, low noise, single anode PMT, 8 dynodes,
G ~ 1.5 10^6 @ -900 V

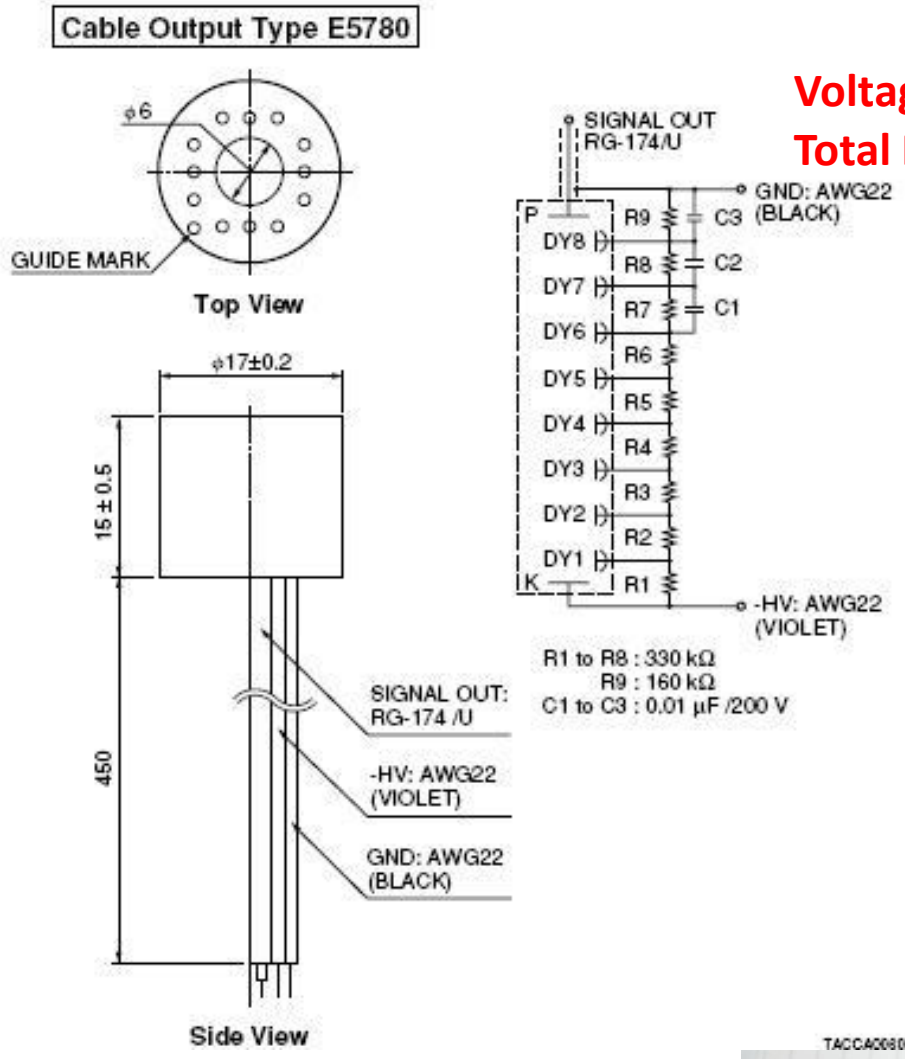
~2000 PMTs tested in Perugia/Firenze

normal: gain @ 800 V > 1×10^5
good: gain @ 800 V > 5×10^5
best: gain @ 800 V > 1×10^6

Figure 4: Typical Gain Characteristics

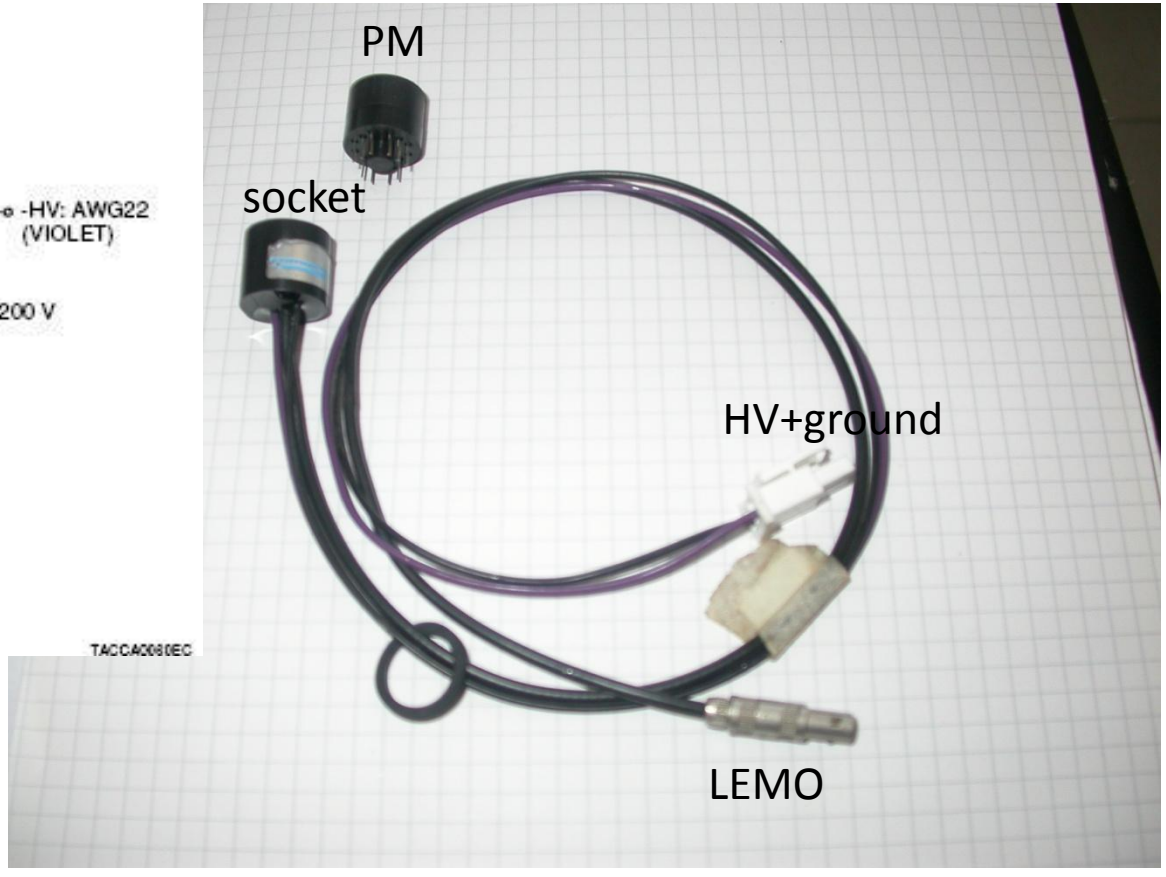


Hamamatsu E5780 Socket Assembly



Voltage Divider Circuit

Total Resistance 2.8 MΩ



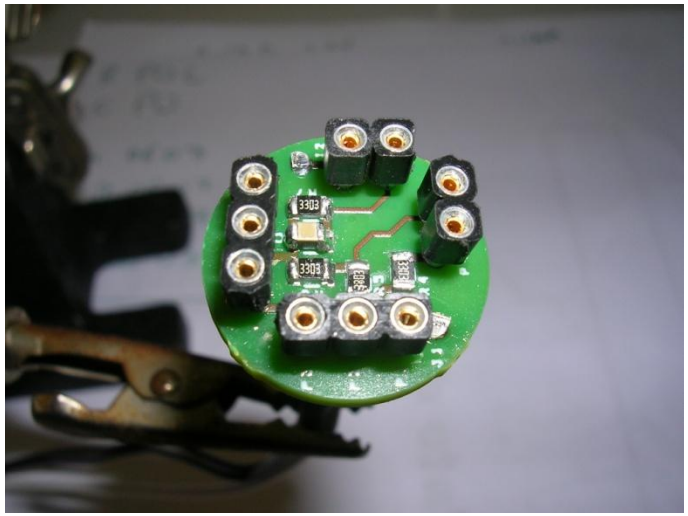
Systematic tests w. different resistors

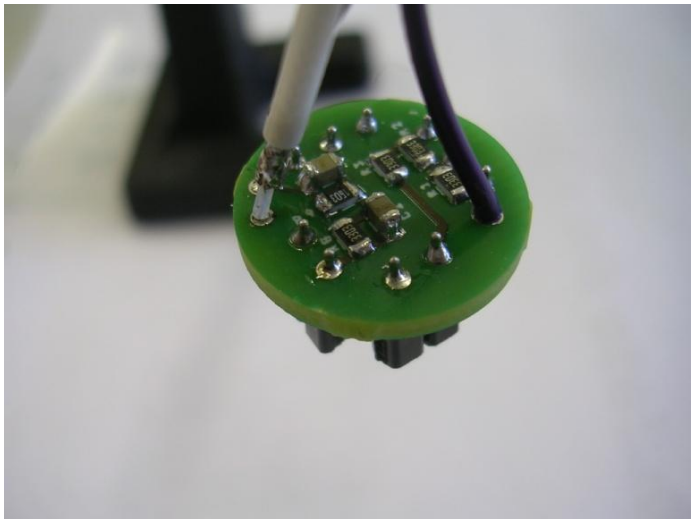
2m long cables.
Molex connectors.

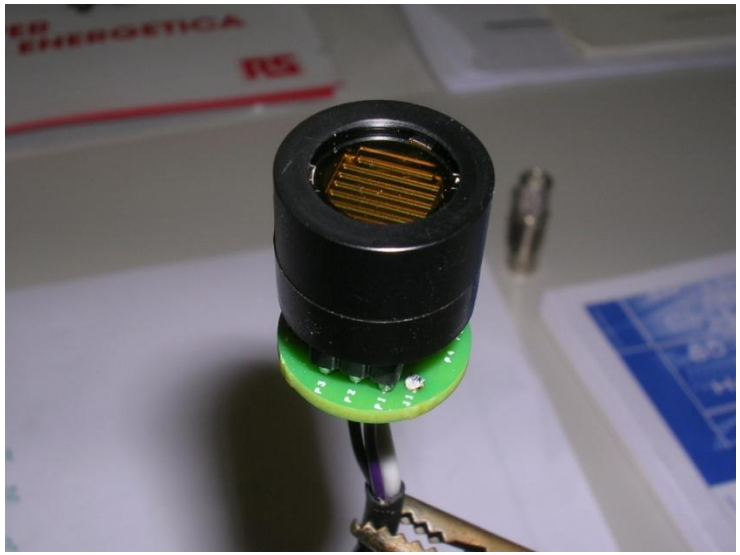
Comparison Hamamatsu - INFN dividers with 3x, 5x, 6x, 8x and 10xR.

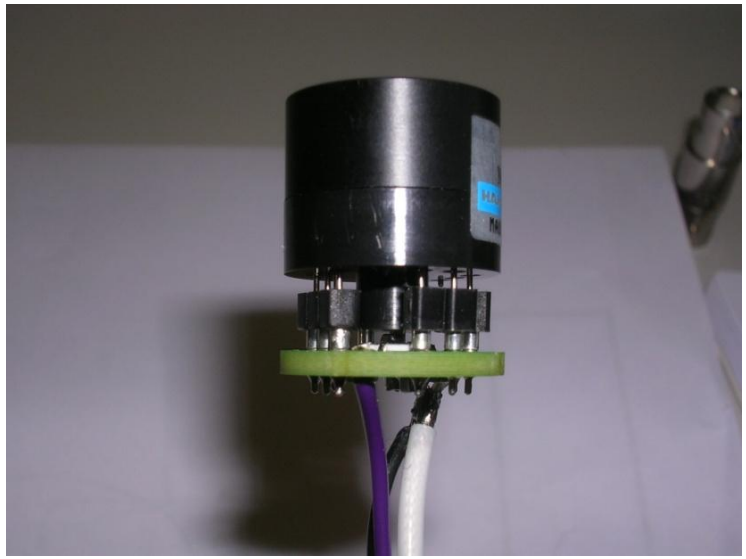
Tests with laser illuminating 2 PMTs at the same time, one kept fixed at 900V as a reference, to monitor laser fluctuations.

INFN – Firenze Socket Prototype







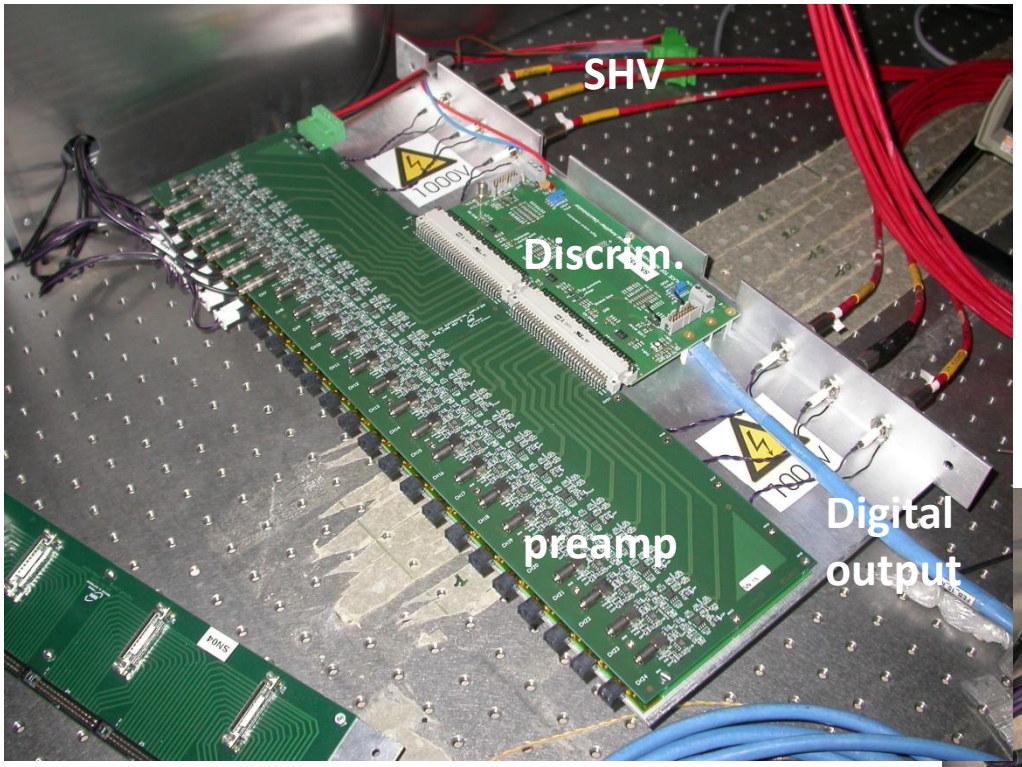


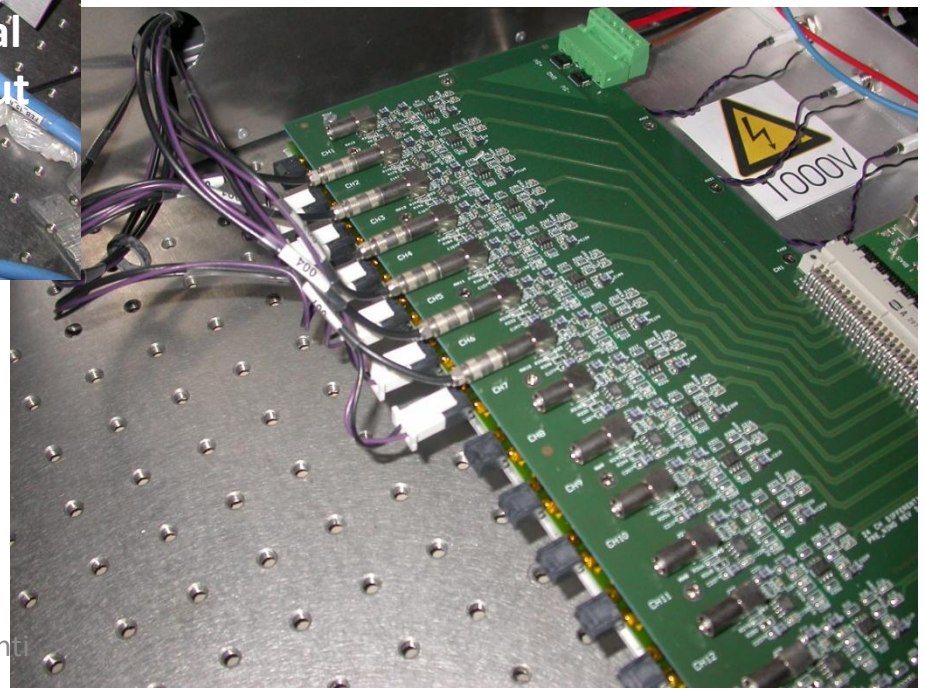
HV power supply

- mainframes CAEN SY1527 (16 slots each, 8U high)
- boards CAEN A1733N (12 ch, 1slot, 6U high)
- boards CAEN A1535SN (24 ch, 2slots, 6U high)

In the lab:
1 SY1527
14 A1733N (9 used)

RICH prototype FE board

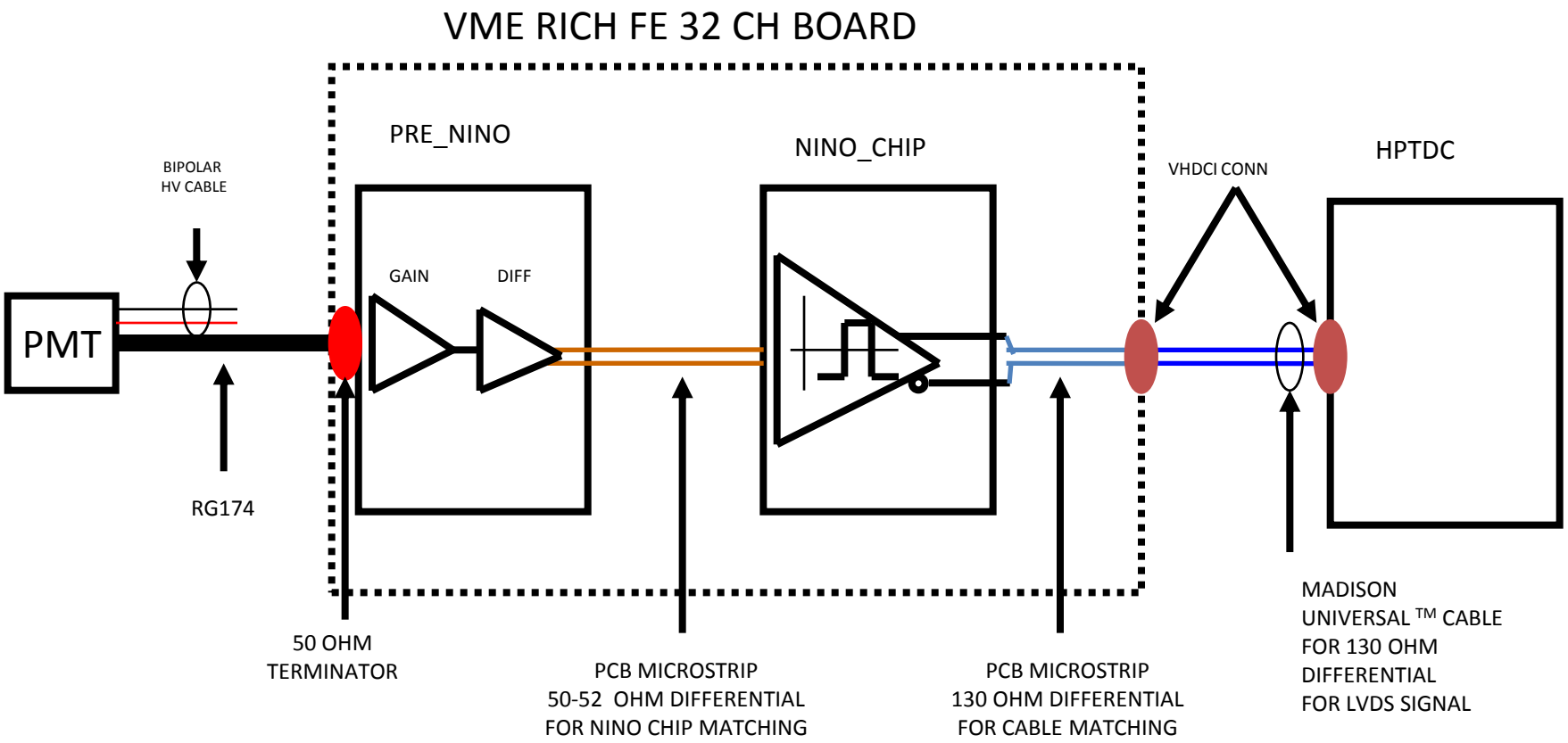




Prototype version: 24 channels
FINAL version: 32 channels

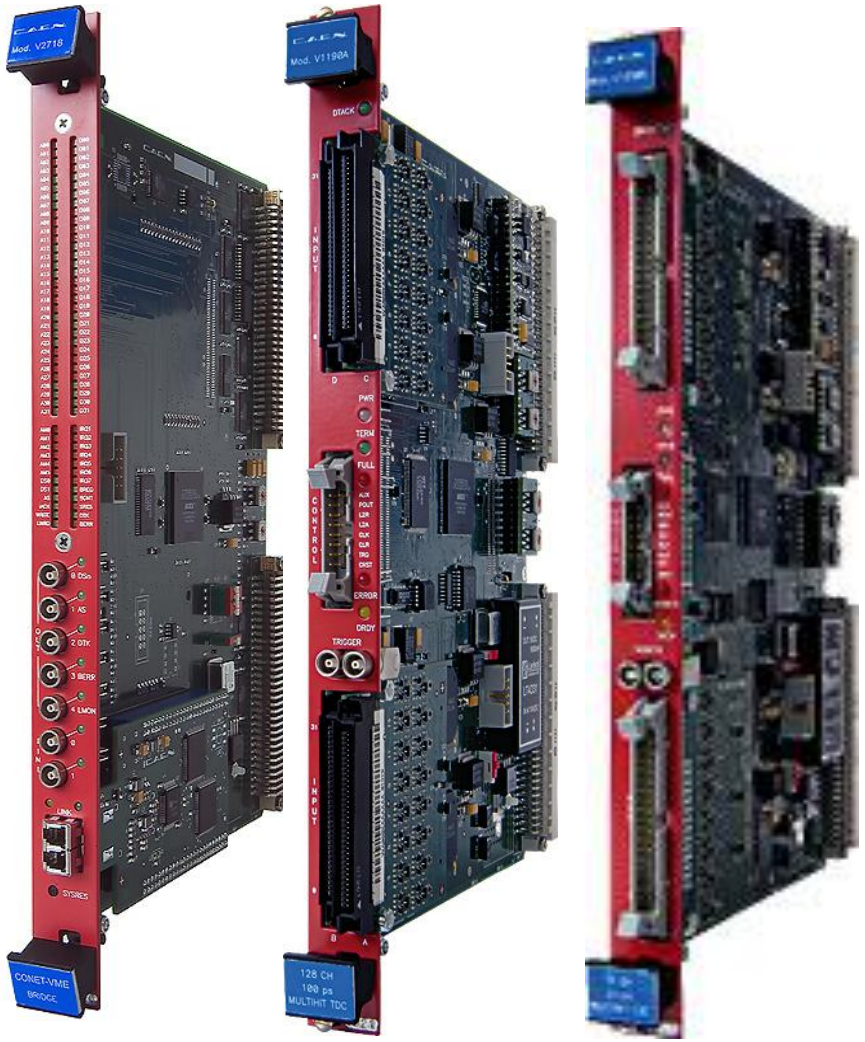
NA-62

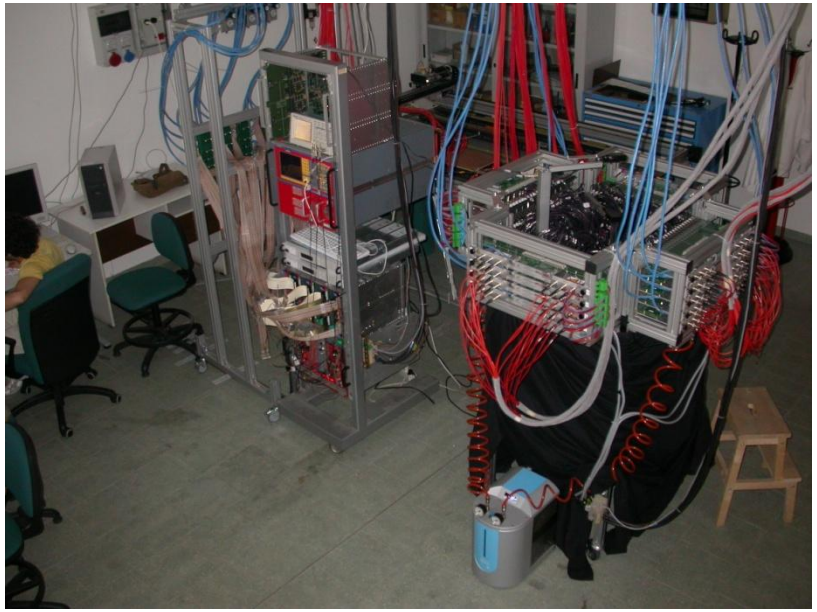
SIGNAL CHAIN OVERVIEW



DAQ

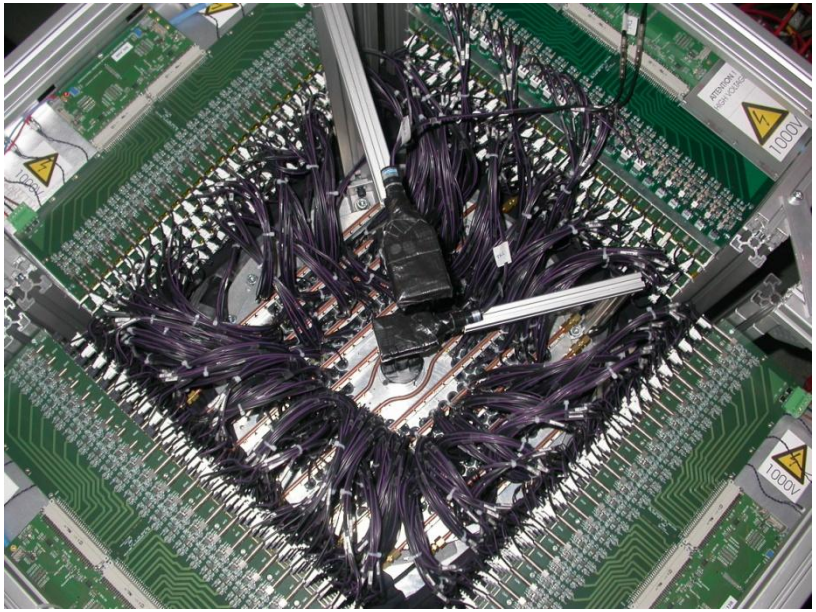
- Crate VME
- 1 bridge V2718: controller and optical link to PC
- 3 TDC V1190A (128 ch), LSB:100 ps, 40 MHz clock
- 1 TDC V1290 (32 ch), used with LSB:100 ps, 40 MHz clock
- 2 PC for control (start daq), data transfer, analysis, etc



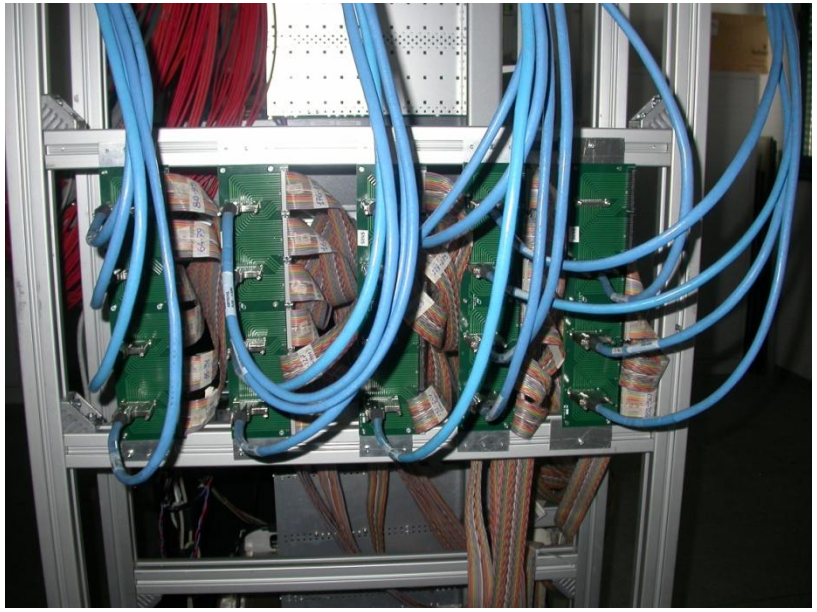


Bird eye view

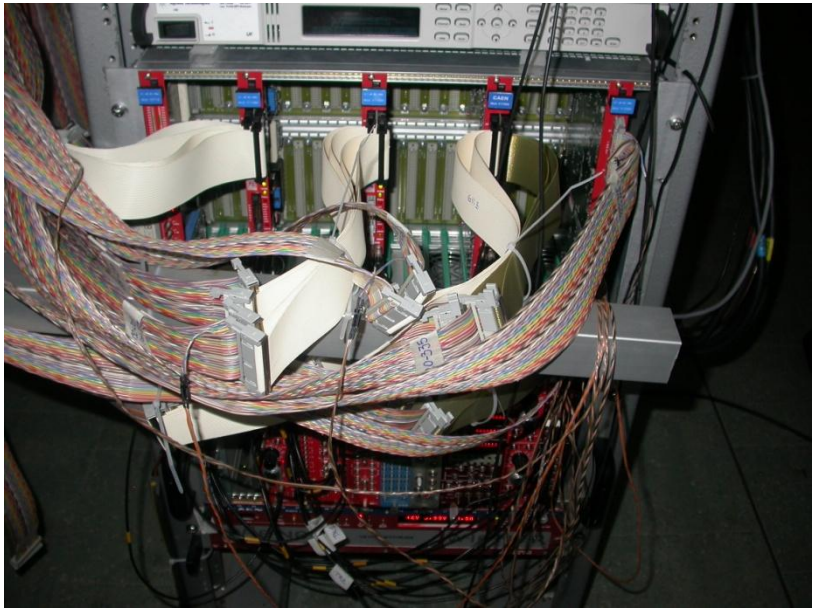
lab



Trigger Scintillators, PMTs, FE

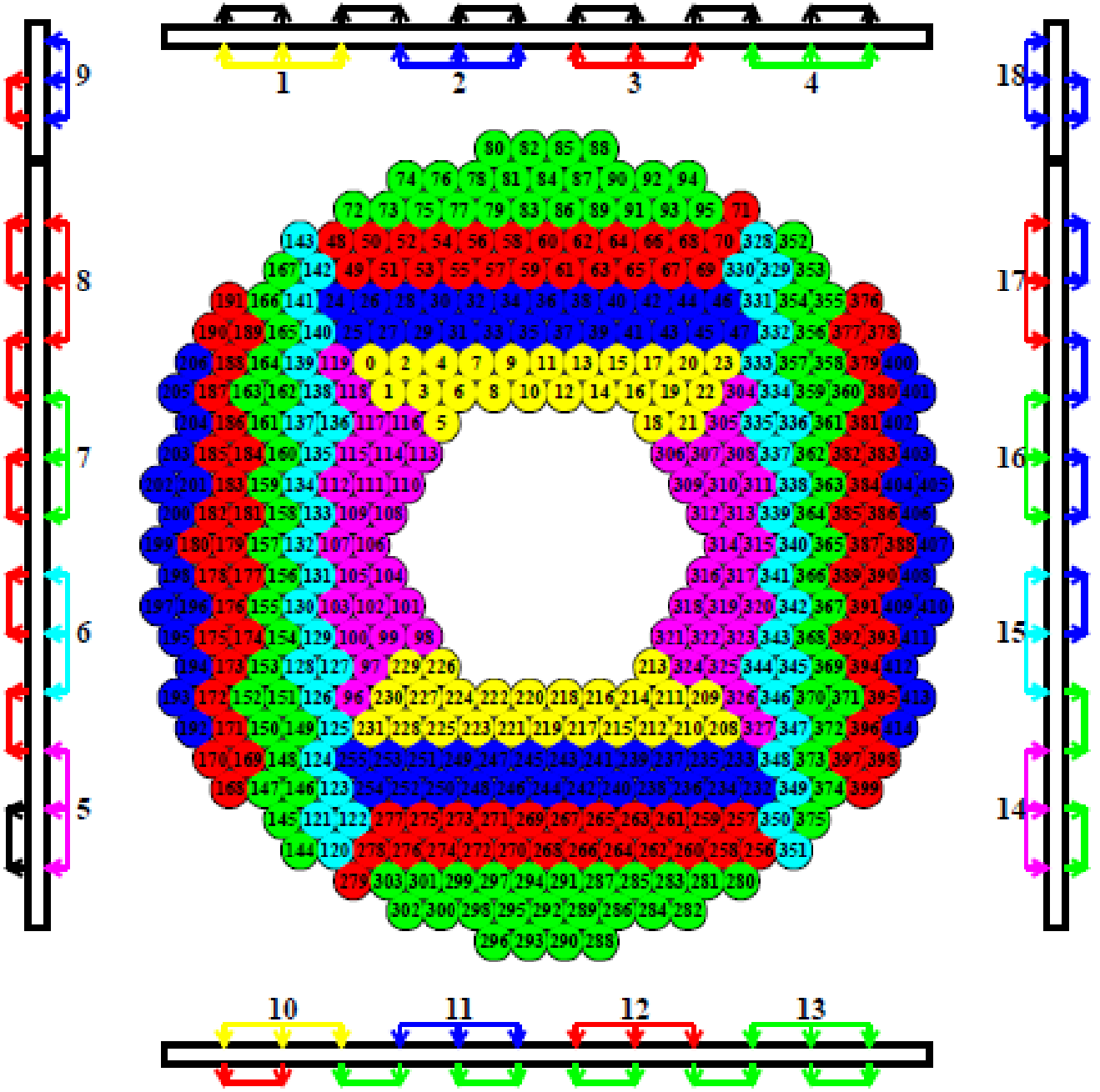


Patch panel



DAQ

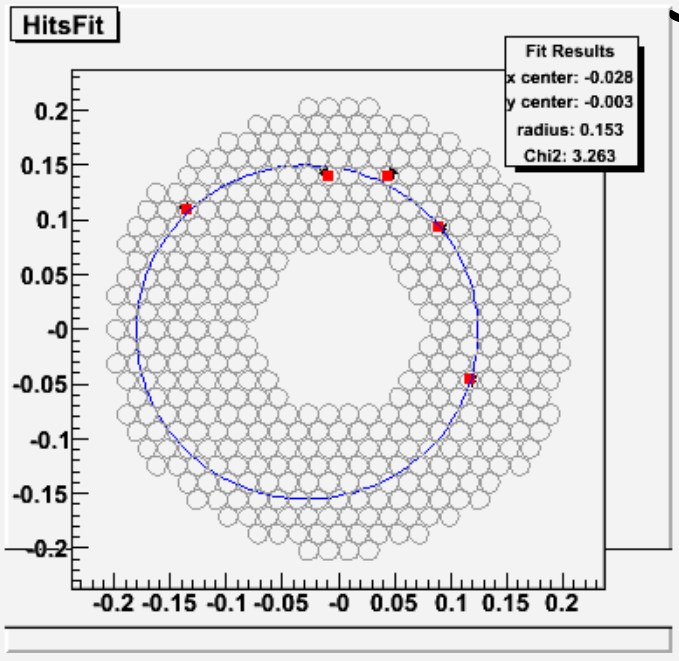
Channels and FE-boards map

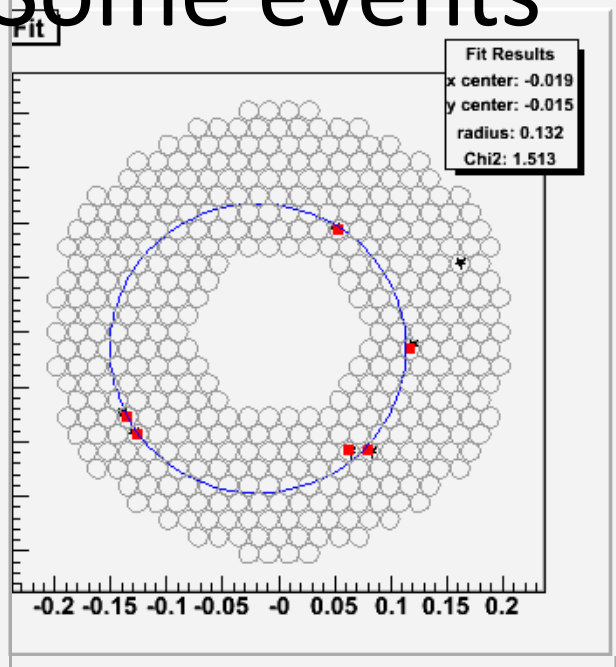


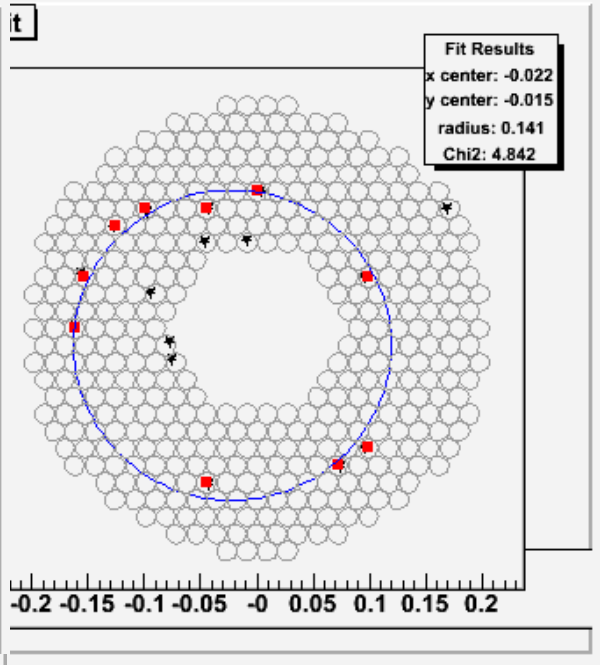
In the lab….

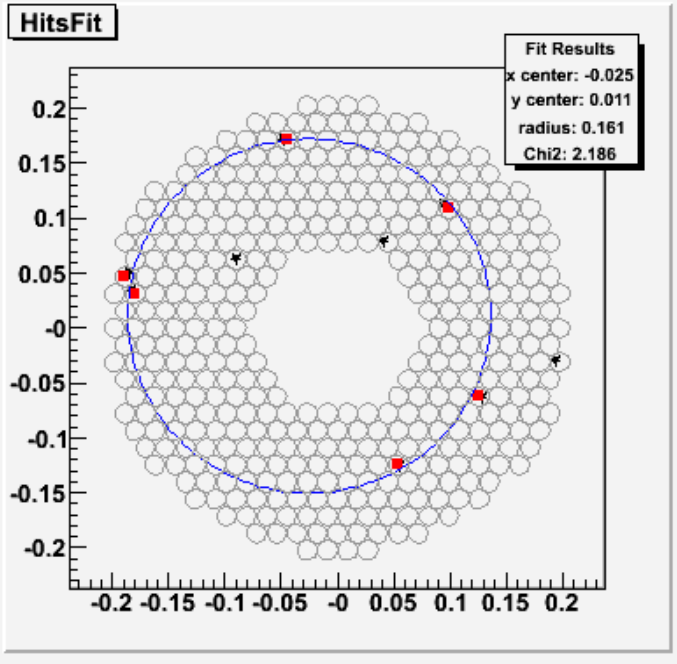
- Trigger with a couple of scintillator
- TDC operated in Trigger Matching Mode
- TestBeam-like daq: enable for 7 secs (“spill”), disable for 3 secs (“interspill”)
- Each cycle is a “burst”
- Raw data produced….
- Make a true data acquisition
- Make offline data analysis
- Reconstruct cosmic rays induced Cherenkov ring
- Fit the ring (with a circle but it is an ellipse…)

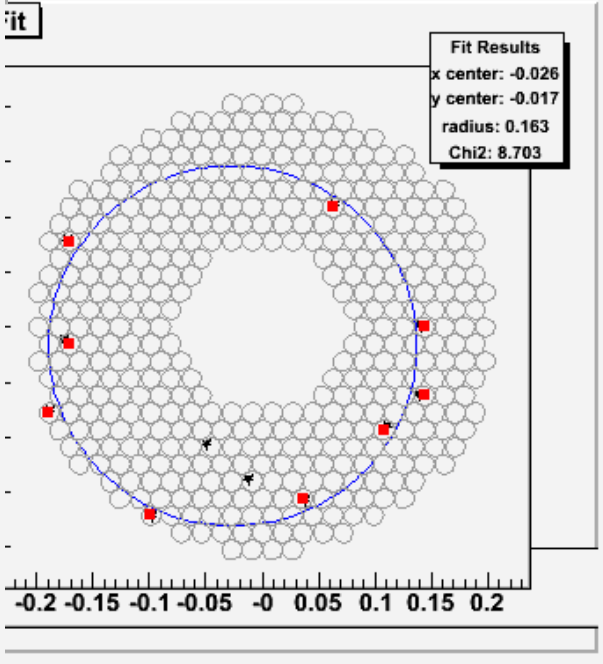
Some events

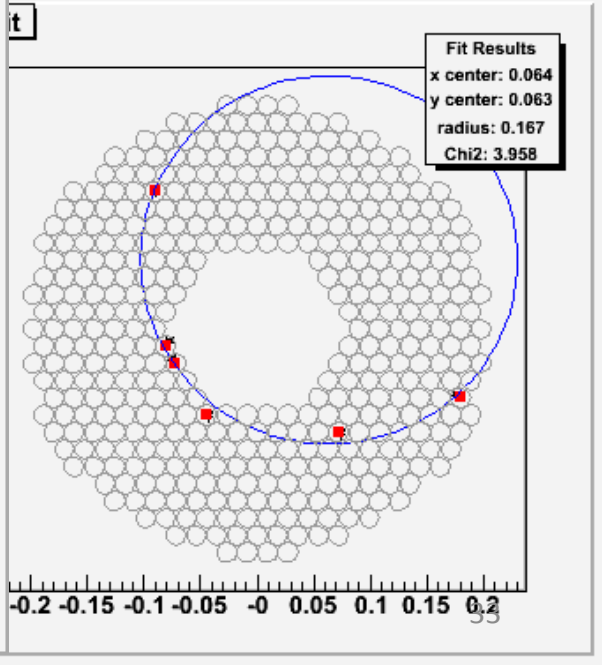

HitsFit
Fit Results
x center: -0.028
y center: -0.003
radius: 0.153
Chi2: 3.263


Fit Results
x center: -0.019
y center: -0.015
radius: 0.132
Chi2: 1.513


Fit Results
x center: -0.022
y center: -0.015
radius: 0.141
Chi2: 4.842


HitsFit
Fit Results
x center: -0.025
y center: 0.011
radius: 0.161
Chi2: 2.186


Fit Results
x center: -0.026
y center: -0.017
radius: 0.163
Chi2: 8.703


Fit Results
x center: 0.064
y center: 0.063
radius: 0.167
Chi2: 3.958

Conclusions

- COSMORICH ready downstairs
- Enjoy the lab