RICH 2013 – Hayama, Kanagawa, Japan
2-6 December 2013

The RICH detector of the NA62 experiment at CERN

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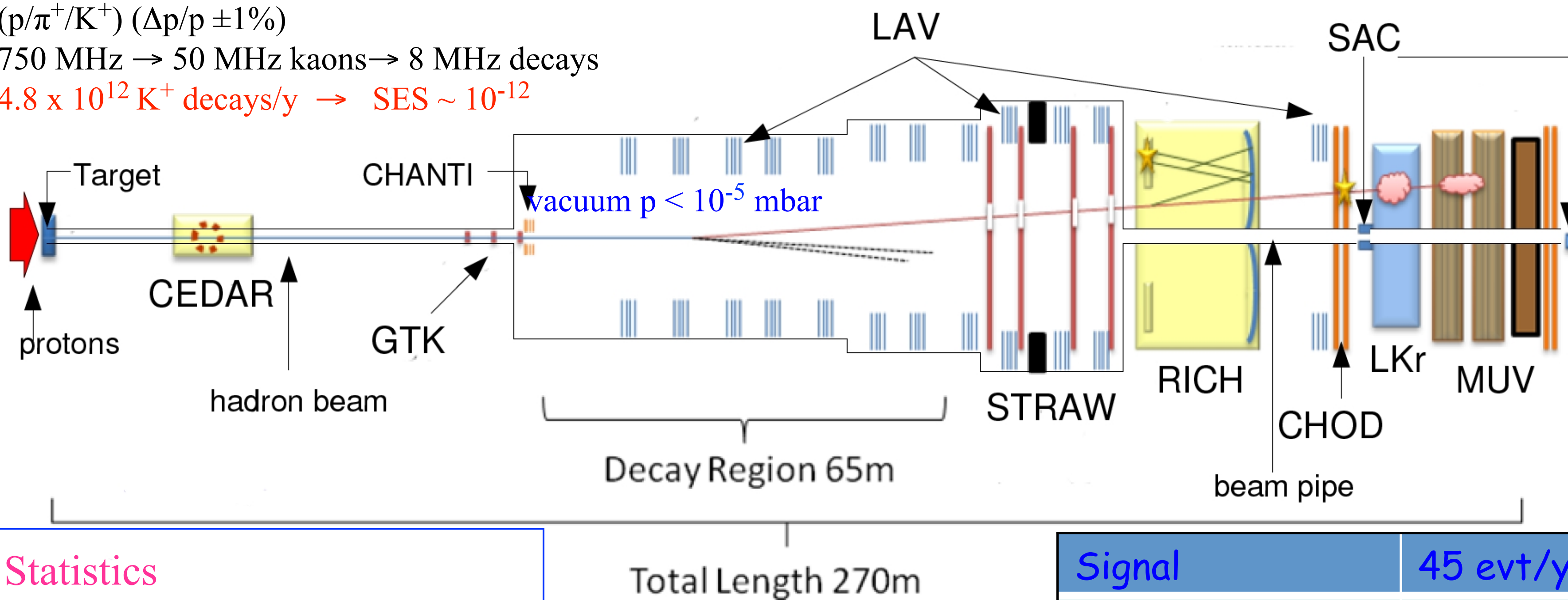
On behalf of the RICH working group of the NA62 experiment

Experiment layout & sensitivity

- 400 GeV/c SPS primary protons
- 75 GeV/c kaons unseparated hadron beam
- $(p/\pi^+/K^+)$ ($\Delta p/p \pm 1\%$)
- 750 MHz → 50 MHz kaons → 8 MHz decays
- 4.8×10^{12} K^+ decays/y → SES ~ 10^{-12}

Target: O(100) SM events for $K^+ \to \pi^+ \nu \bar{\nu}$



→ Statistics
- BR(SM) ~ $(7.8 \pm 0.8) \times 10^{-11}$
- Acceptance: 10%
- K decays: 10^{13}

→ Systematics
- $\geq 10^{12}$ background rejection
- $\leq 10\%$ precision on background measurement

Kaon intensity
Signal efficiency
Signal purity
Detector redundancy

New approach:
High momentum K^+ beam
& decay-in-flight technique

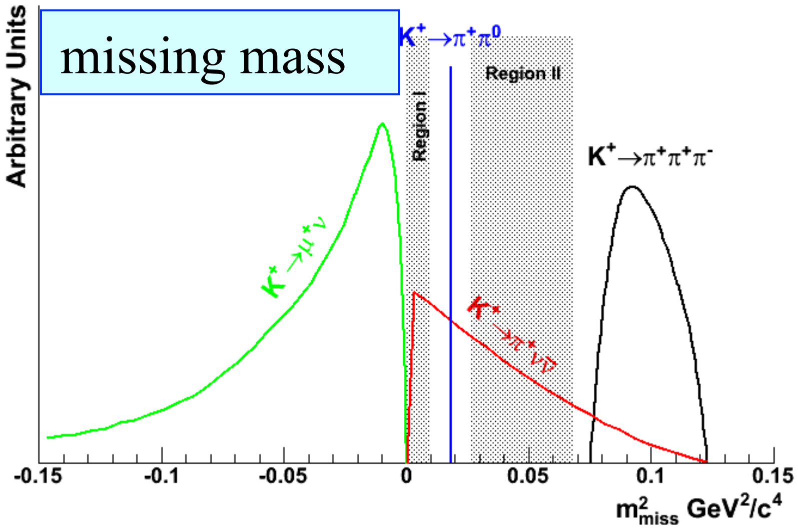
Signal	45 evt/y
$K^+ \to \pi^+\pi^0$	4.3%
$K^+ \to \mu^+\nu$	2.2%
$K^+ \to \pi^+\pi^+\pi^-$	< 4.5%
$K^+ \to \pi^+\pi^0\gamma$	~ 2%
$K^+ \to \mu^+\nu\gamma$	0.7%
total background	< 13.5%

Background and kinematics

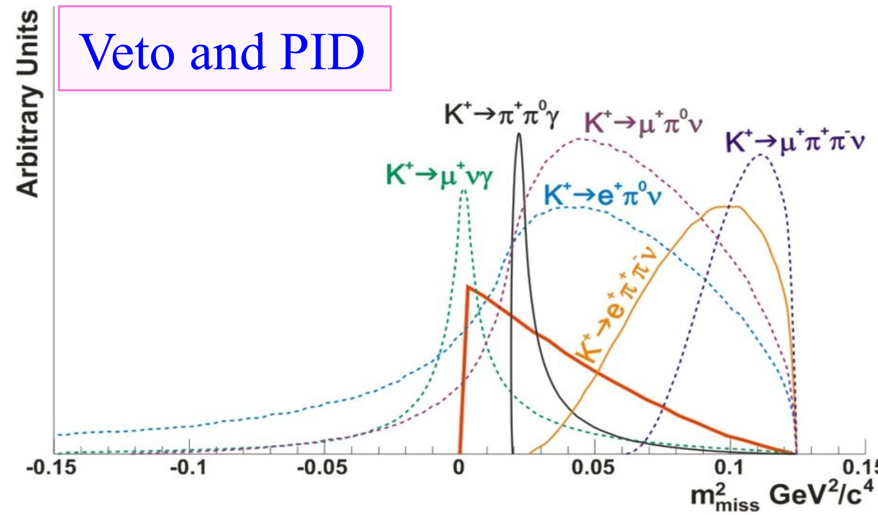
92% Bkg "separated" from signal by kinematic

8% not separated

missing mass



Veto and PID



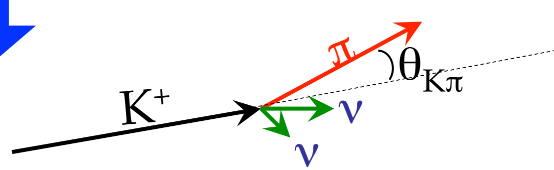
$m^2_{miss} = (P_K - P_\pi)^2$ defines low bkg signal regions separated by $K^+ \to \pi^+\pi^0$

decays extend in the signal region
kinematics doesn't help

- ✓ high resolution m^2_{miss} reconstruction
- ✓ measure precisely kaon and pion momenta
- ✓ keep multiple scattering as low as possible

- ✓ Reject offline decays with γ
- ✓ K^+ identification in the hadron beam
- ✓ 10^{-7} π-μ separation

Gigatracker (Kaon)
Straw chambers (pion)



$m^2_{miss} = (P_K - P_\pi)^2$

Photon veto system
Particle Identification

Background suppression

Decay	BR
$\mu^+\nu$ ($K_{\mu2}$)	63.5%
$\pi^+\pi^0$ ($K_{\pi2}$)	20.7%
$\pi^+\pi^+\pi^-$	5.6%
$\pi^0 e^+\nu$ (K_{e3})	5.1%
$\pi^0\mu^+\nu$ ($K_{\mu3}$)	3.3%

Very challenging experiment:

- Weak signature for signal decay
- Huge background →

$K_{\mu2}$ is the largest BR, a rejection factor $\sim 4\times10^{-13}$ is requested:

- Kinematics: 8×10^{-5} → Giga-Tracker + Straws
- Muon Veto: 10^{-5} → Muon Veto detector
- Particle ID: 5×10^{-2} → RICH ←

- Match a track (pion) seen by the STRAWS (10 MHz)
- with a track (kaon) seen by the GTK (750 MHz)
- Measure the track time, both upstream and downstream at **100 ps** level discriminating between pions and muons

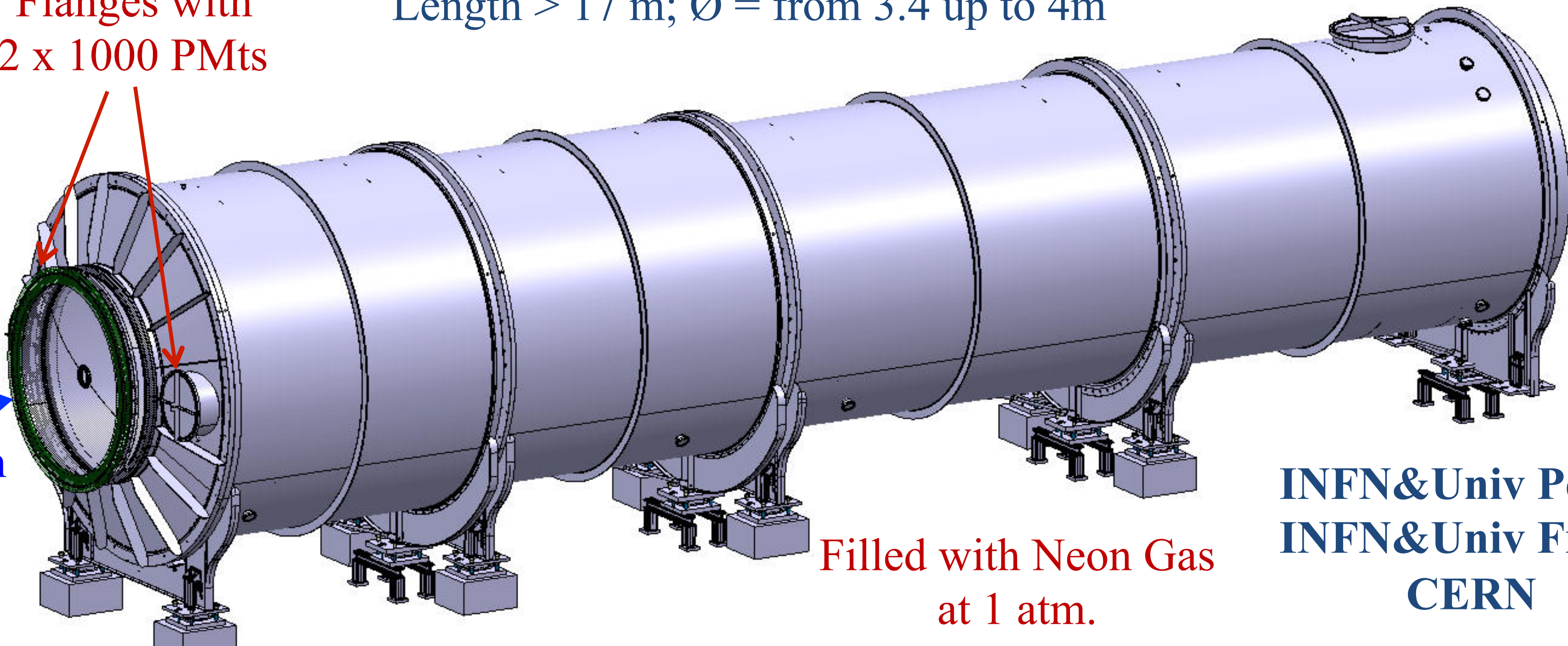
Momentum range for the pion: 15-35 GeV/c

The NA62 RICH

Length > 17 m; Ø = from 3.4 up to 4m

Flanges with
2 x 1000 PMts

Mirror mosaic



Beam

Filled with Neon Gas
at 1 atm.

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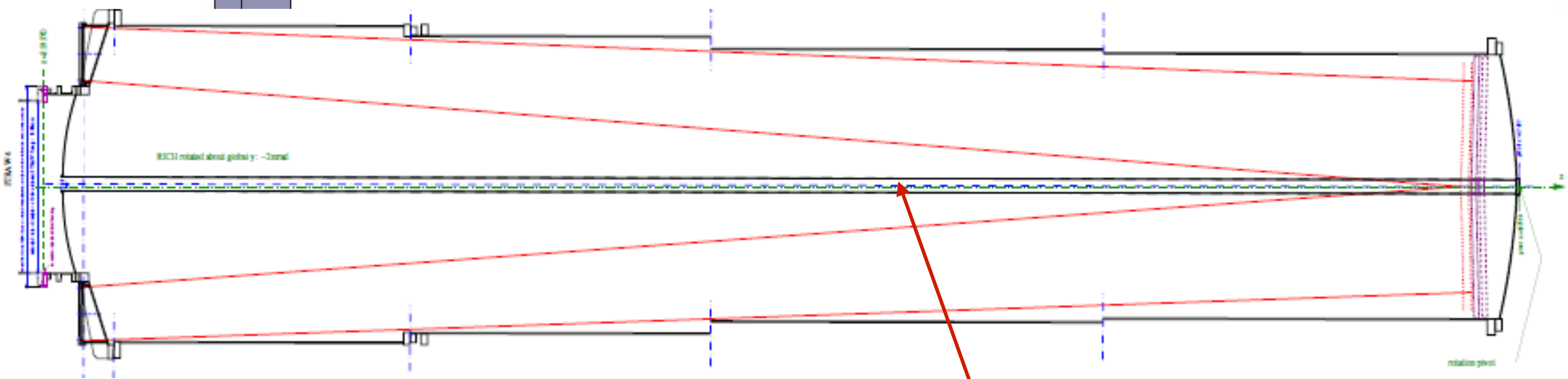
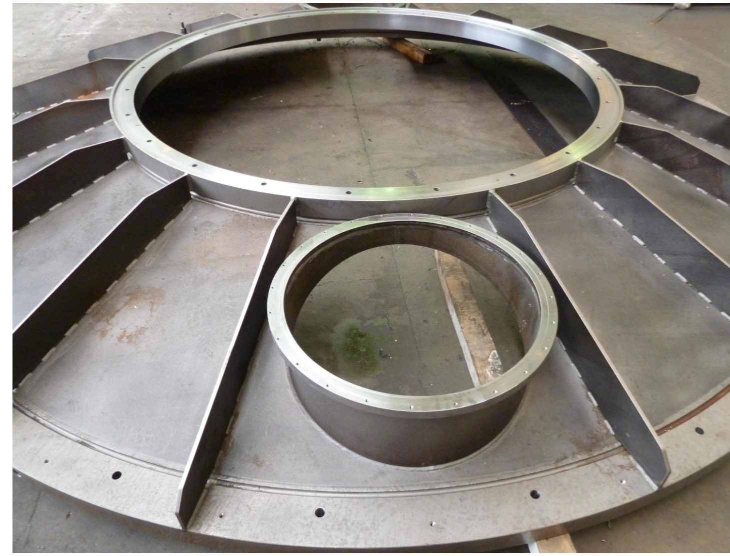


Beam Pipe

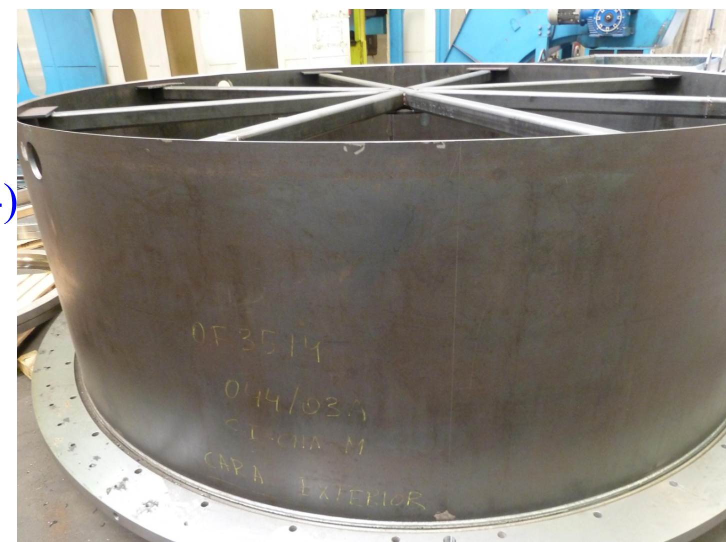
The Vessel

Support collars

Conical cap



Part of one section



- 17 m long vessel in steel, vacuum proof

(in construction, it will be delivered at the beginning of 2014)

- max overpressure: 150 mbar
- wide from 4 m (beginning) to 3.4 m (end)
- 4 cylindrical sections ("drums") and one conical cap
- beam pipe (Ø 157 mm) going through
- thin aluminium entrance and exit windows

The gas system

Čerenkov threshold for pions in Neon at atmospheric pressure is ~12.5 GeV/c, RICH will have good efficiency at 15 GeV/c

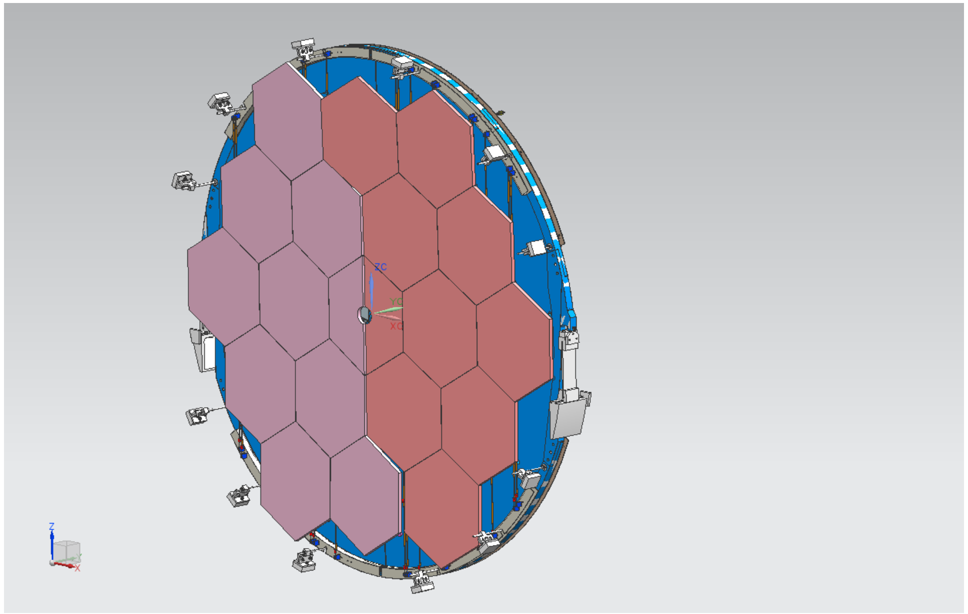
- Vessel volume: 200 m^3
- Neon at slightly above atmospheric pressure
- Neon density stability < 1%
- Contaminants < 1%

Procedure to fill the vessel:
The vessel is first fully evacuated, then fresh Neon is introduced in the vessel and finally the vessel is valve closed

The mirrors

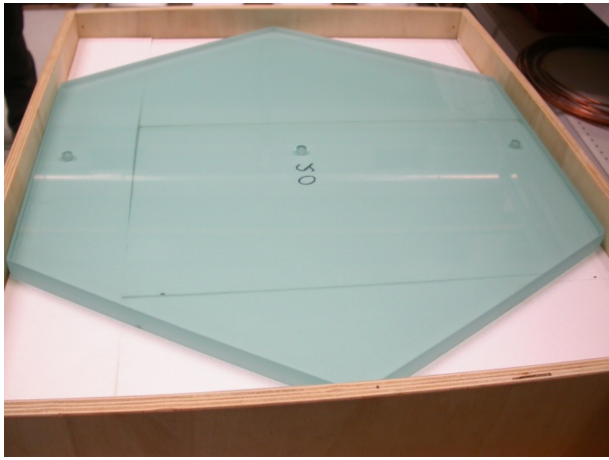
Two regions with different centers of curvature (to avoid beam shadow)

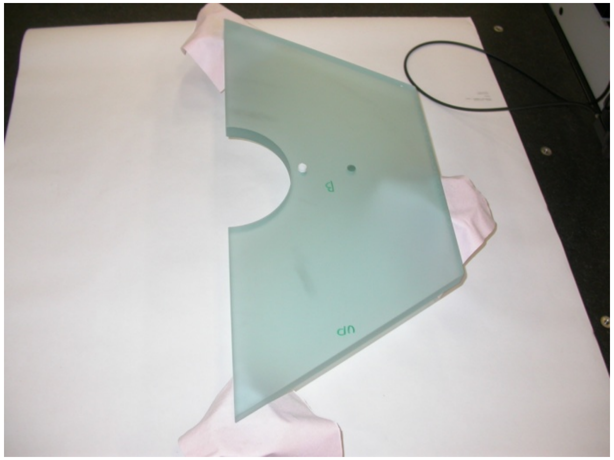
– 18 hexagonal mirrors
  (700 mm wide, 25 mm thick)
– 2 half mirrors around the beam pipe



Mirror Parameters + Quality:

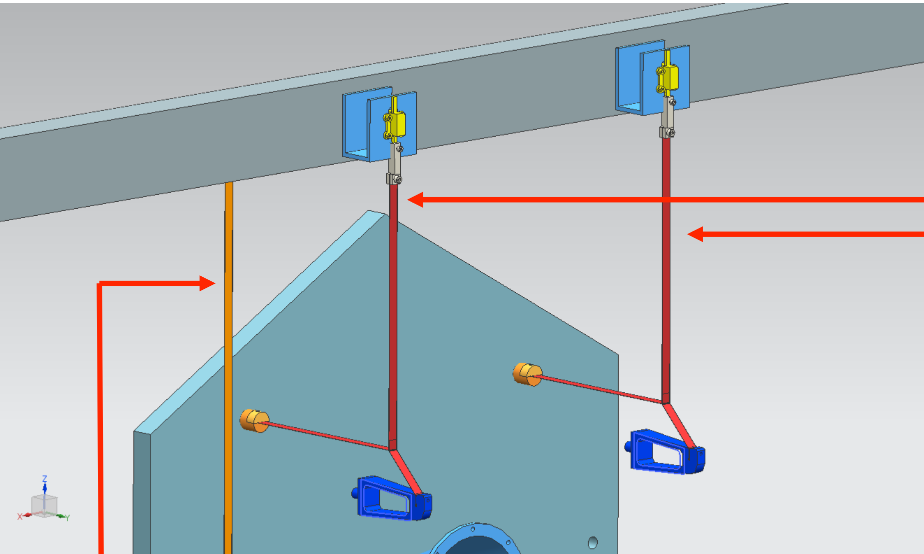
- Spherical mirrors f= 17±0.1 m
- Reflectivity > 90% (195 – 650nm)
- $D_o \leq$ 4mm
  (circle which collects 90% of the reflected light.)





Aluminization is now progressing at CERN

Mirror alignment



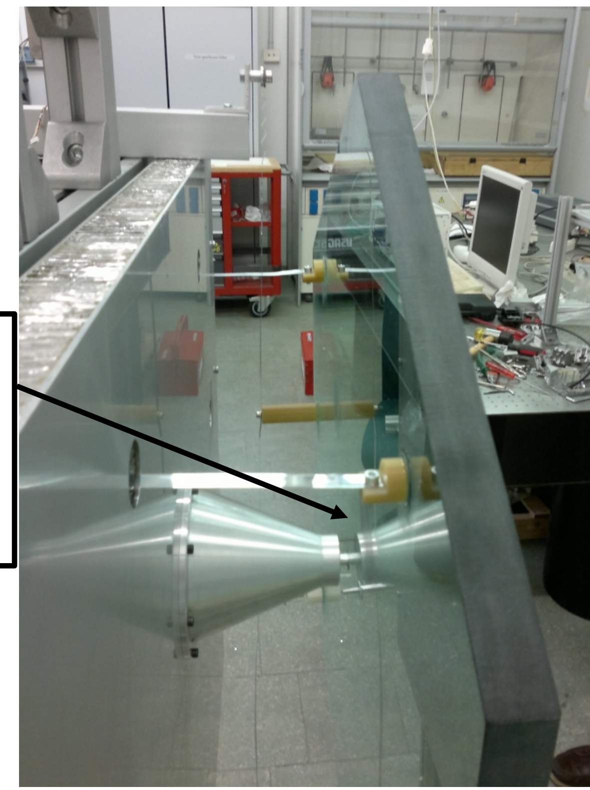
The orientation of the mirrors is remotely adjustable using piezo-motors

Aluminum ribbons 200 μm thick and 10 mm wide are used

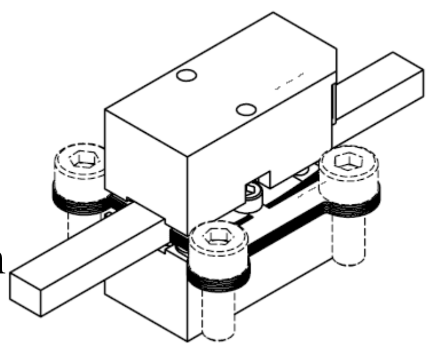
A third purely vertical ribbon is used to avoid mirror rotation

Mirror Support Prototype

Each mirror is supported by a dowel inserted in a hole drilled in the back of the mirror



Piezo Motors
20 Newtons
35 mm range
70 nm resolution



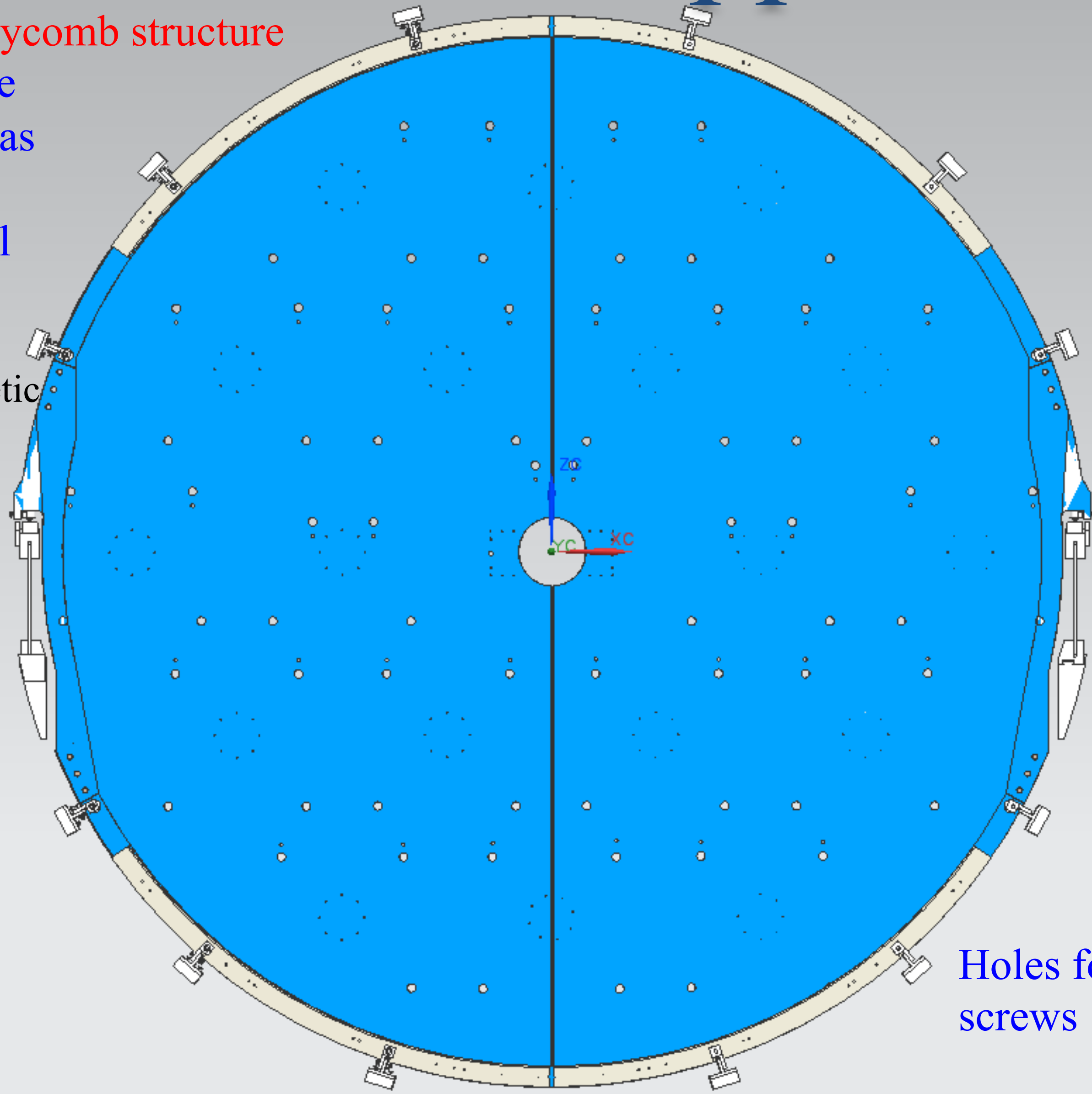
Mirrors support

Aluminium Honeycomb structure

When possible the material budget has been reduced to minimize the total radiation length

(RICH is in front of the electromagnetic calorimeter)

Front view

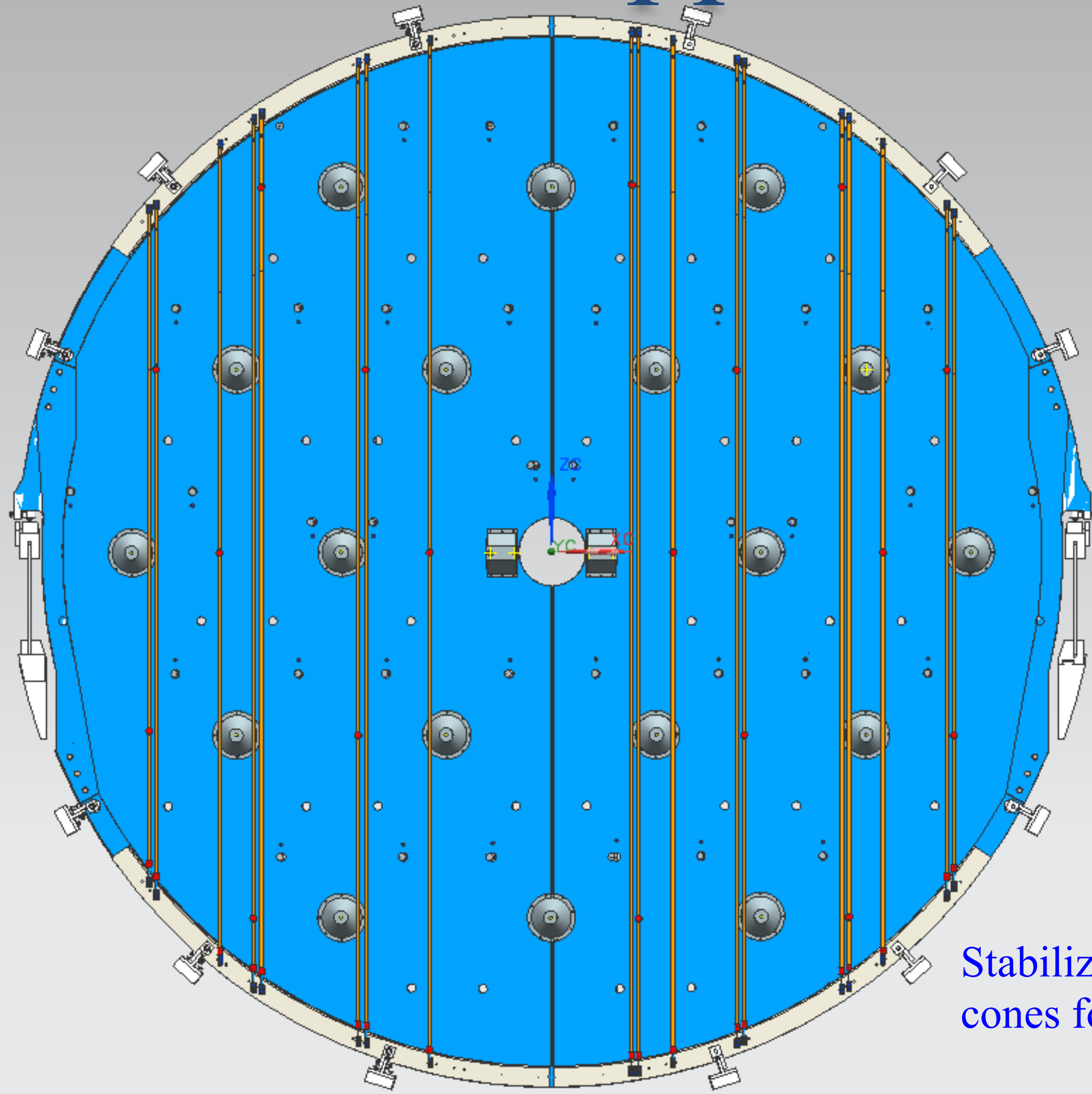


Working drawing completed, order is going on

Holes for service and screws

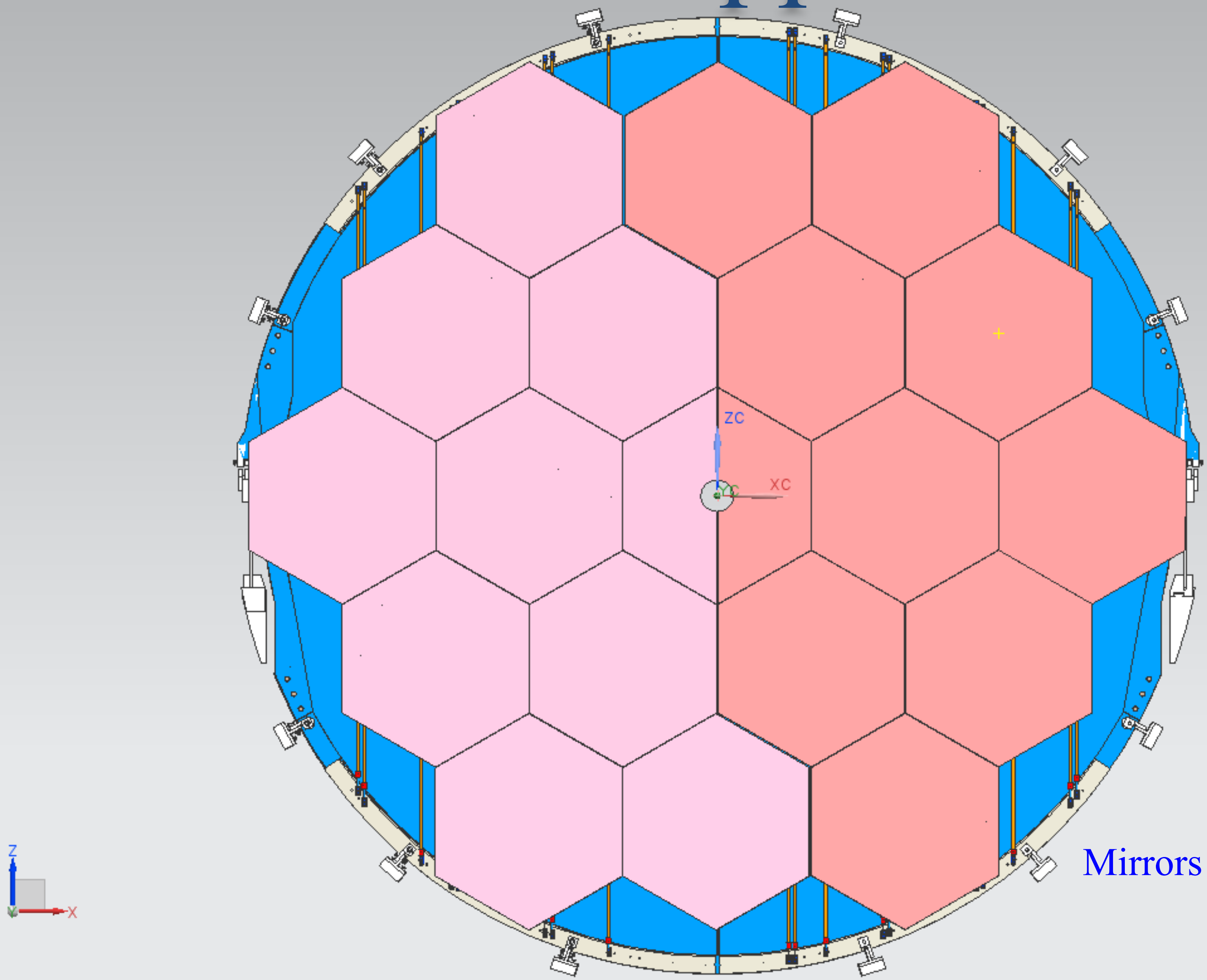
Mirrors support/II

Front view



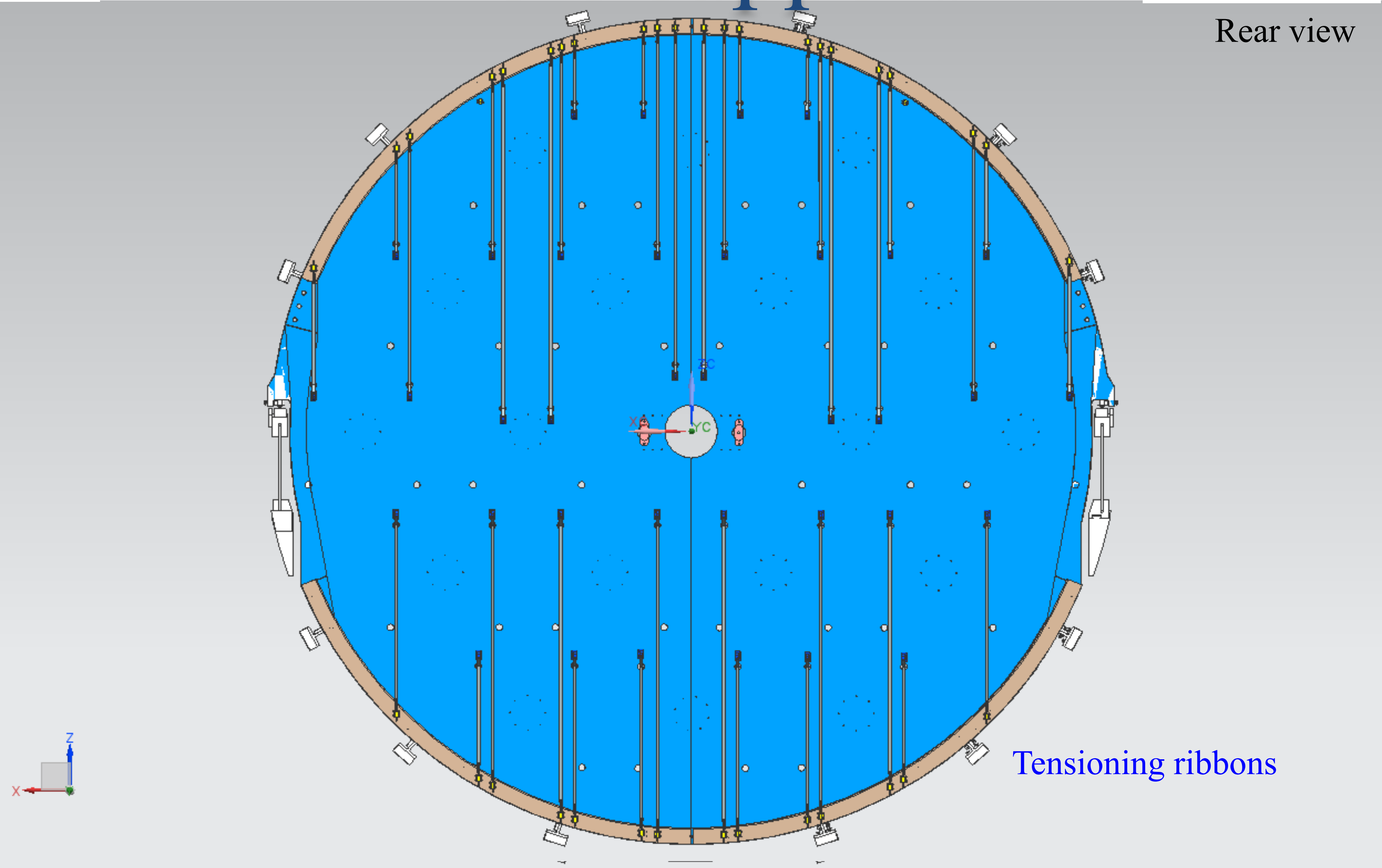
Stabilizing ribbons &
cones for mirrors support

Mirror supports/III



Mirrors surface

Mirrors support/III

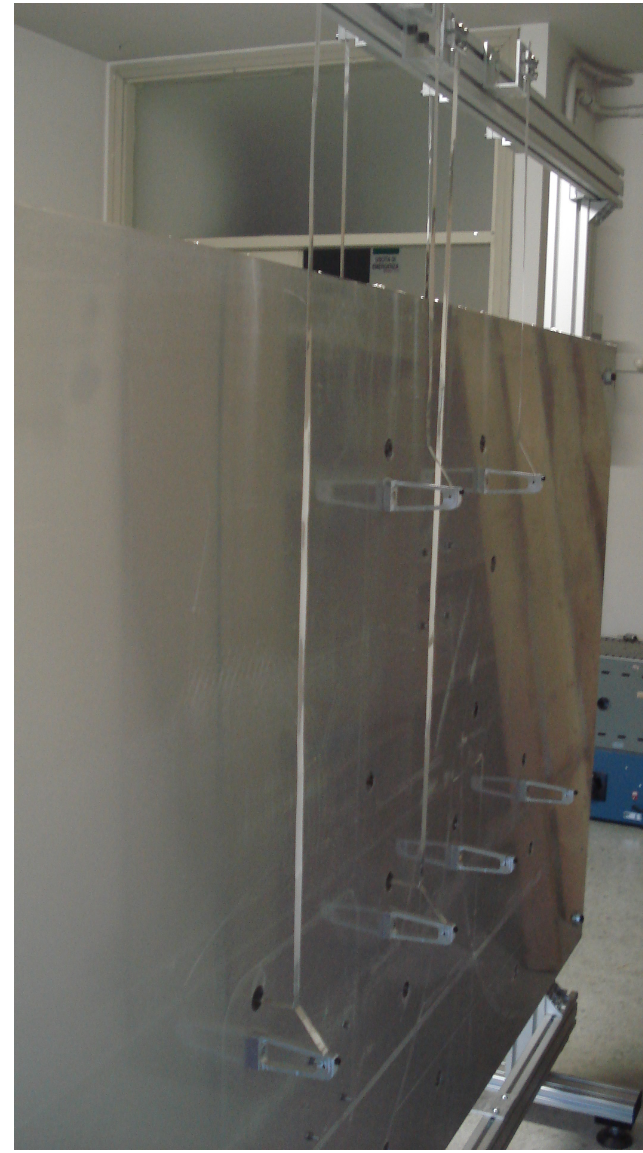


Prototype for support

A prototype of the support with 3 mirrors is under construction

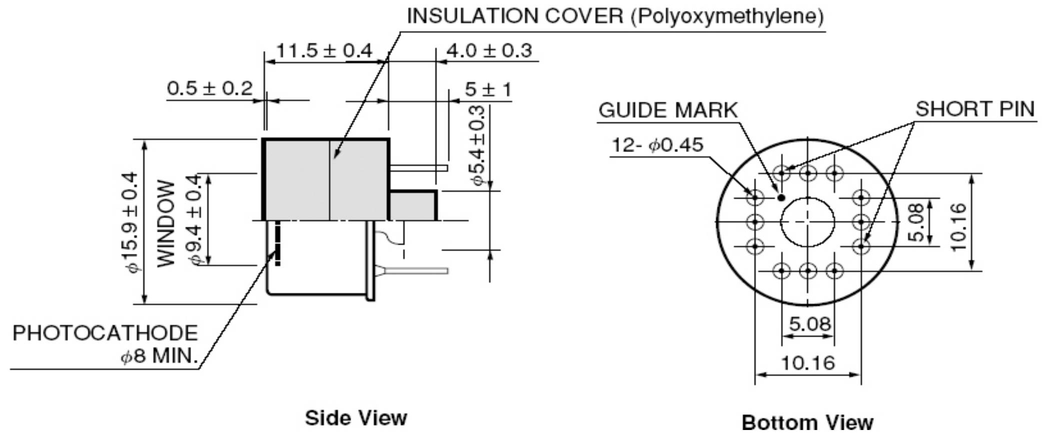
Fundamental to establish the best procedure for the installation of the mirrors in the final support

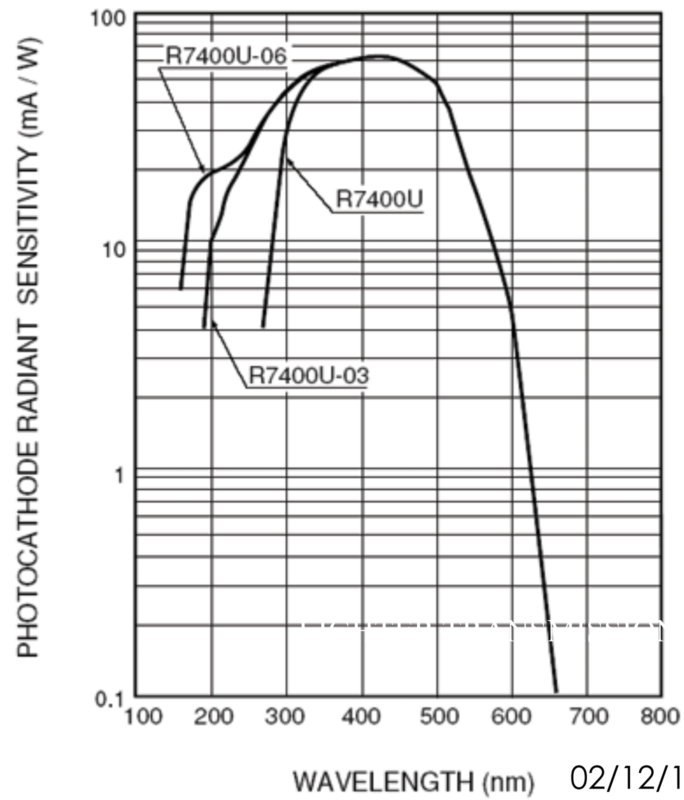
Also important to understand the ability on mirror orientation



The photomultipliers

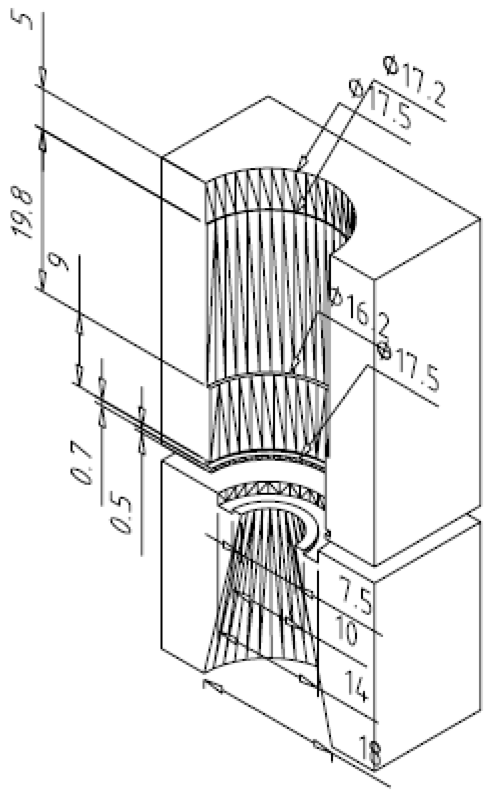
- Hamamatsu R7400U-03
- UV-glass, bialkali, 8 dyn
- 16 mm wide (8 mm active)
- Gain 1.5 10^{+6} @900 V
- 280 ps time jitter (FWHM)
- 185-650 nm response (420 nm peak)
- Q.E. around 20% on peak
- PM output (1 p.e.): 240 fC, peak at 200 μA or -10 mV (50 Ω)
- Rise time: 0.78 ns, fall time~1.6 ns



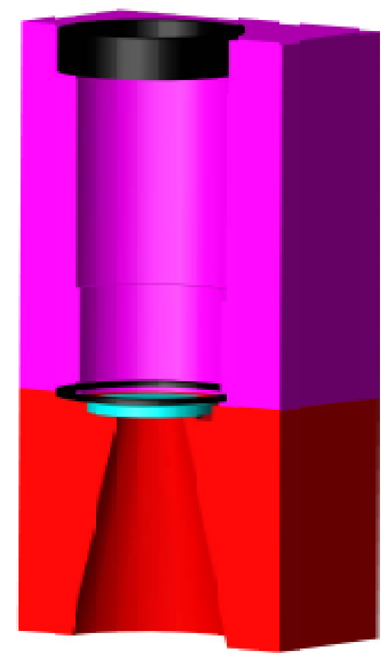


Winston cones

- 976 PMs packed per spot (18 mm min dist.)
- Light collection: Winston cones with aluminized mylar foil
- Quartz window to separate Neon from air
- O-rings for light tightness and thermal contact

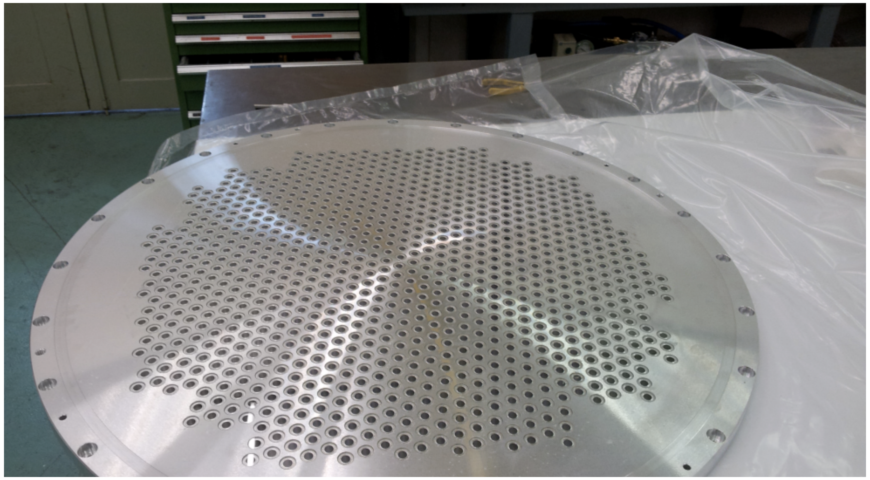


2 separated parts

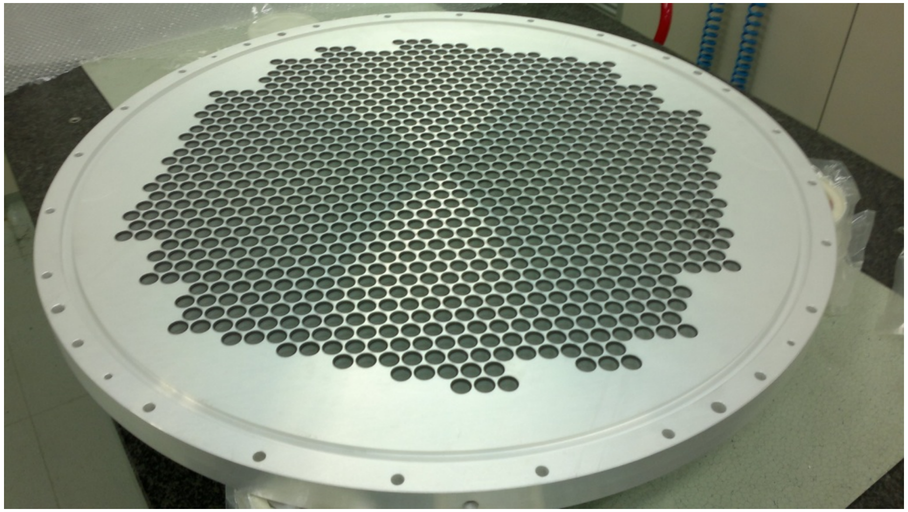


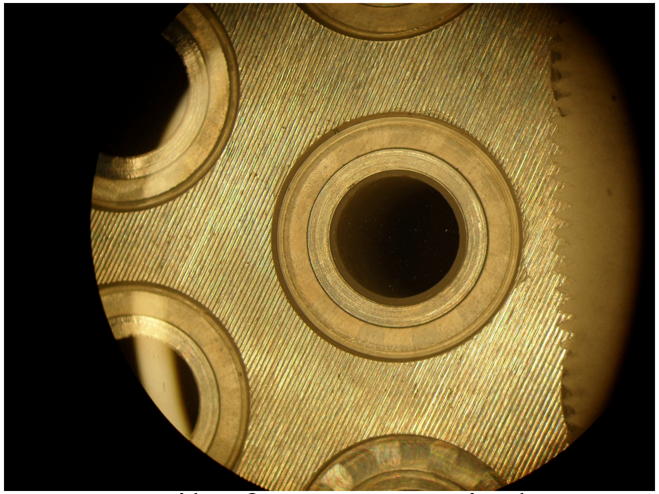
Flanges

Neon-air separation disk (Quartz window side)



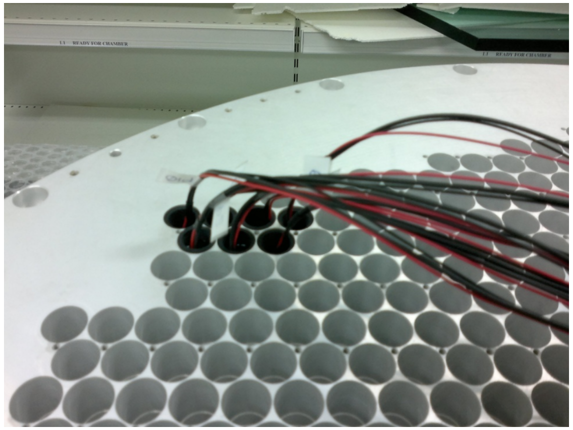
PM lodging disk (PM “face” side)





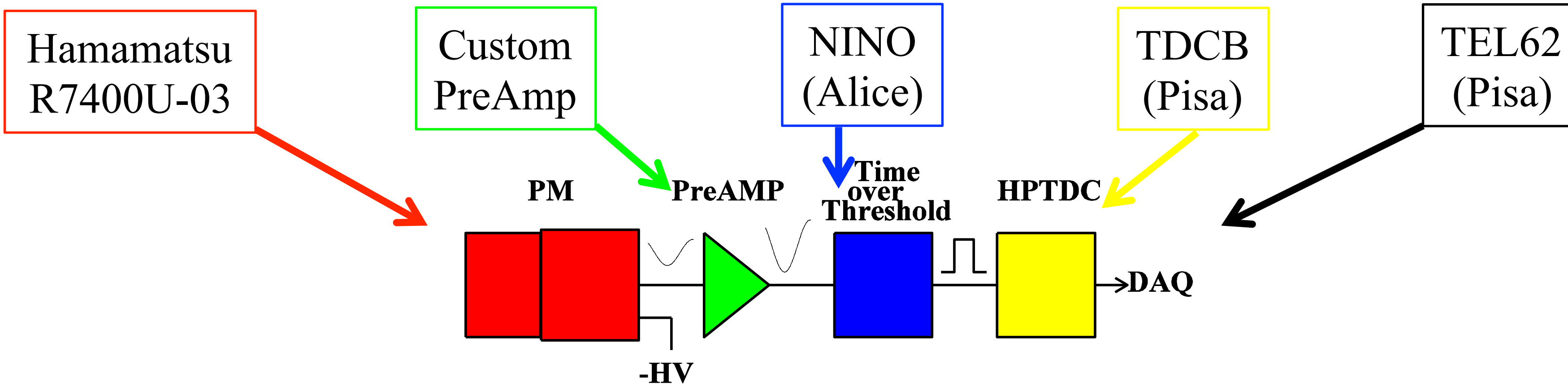
Detail of a quartz window

Detail of Winston Cones
with and without Mylar foils



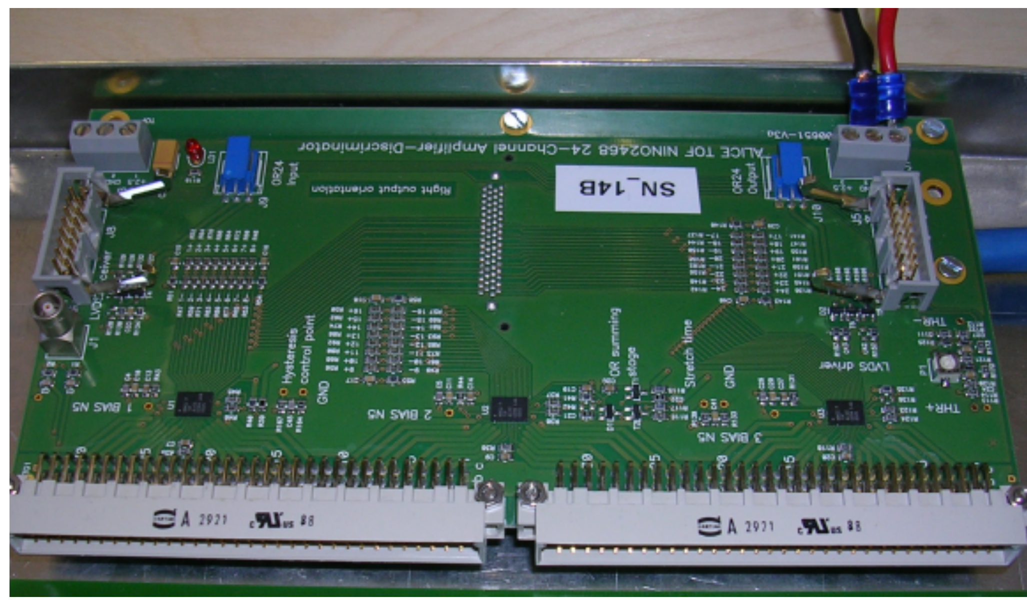
PM “rear” side: detail
Few PMs inserted

Readout electronics



The contribution of the FE electronics and of the DAQ to the time resolution is lower than 50 ps

NINO ASIC (from ALICE) as fast discriminator operating in Time over Threshold

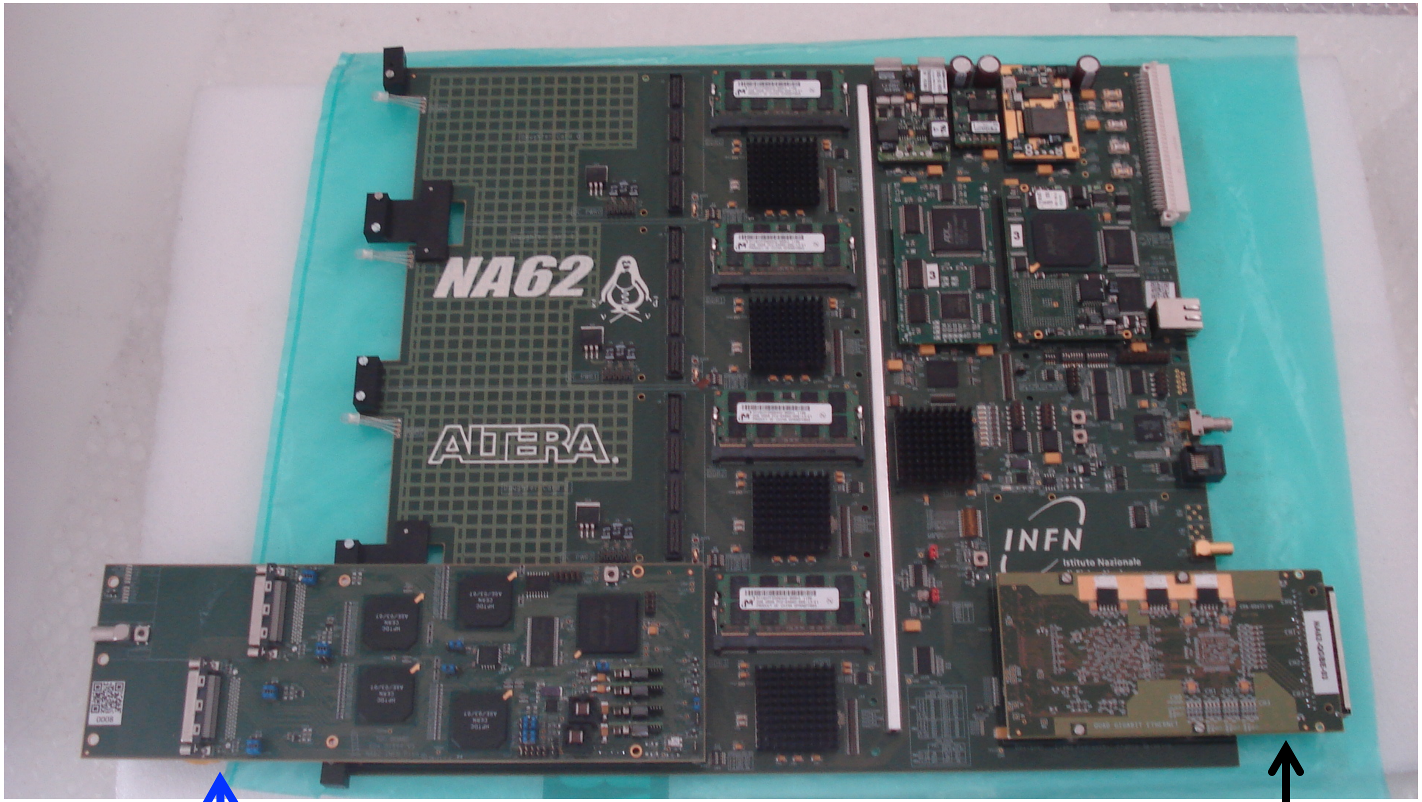


new board including custom preamplifiers in development

Read electronics /II

TEL62, developed by Pisa group (evolution of the LHCb TELL1), housing 5 FPGAs for data processing and production of trigger primitives, a Credit Card PC running Linux also included

In total each TEL62 is able to read 512 channels



10 MHz of events from beam

<1 MHz after L0

~100 KHz after L1

$\mathcal{O}(10)$ KHz after L2

TCDB (developed by Pisa), housing 4 HPTDC (Cern) for 32×4=128 channels (100 ps lsb)

4 Gb/s Ethernet card:

- 2 links to PC farm for data acquisition
- 2 links to L0TP to send trigger primitives

RICH tests

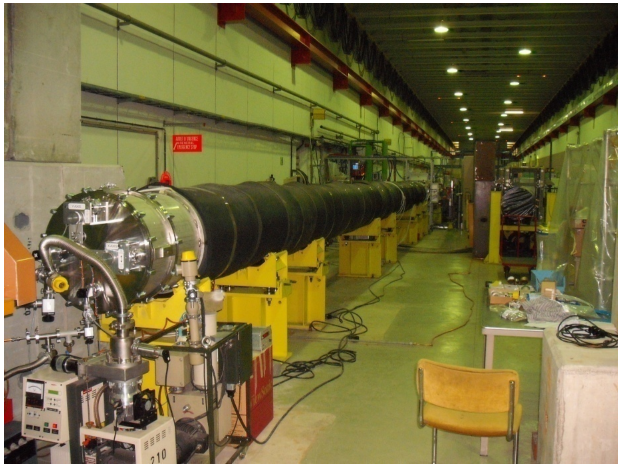
Since 2007 R&D started to validate the chosen approach with prototypes

2007 Test Beam, RICH100, prototype with 96 PMs to study:

- Time resolution
- Number of photons (multiplicity)
- PMs choice

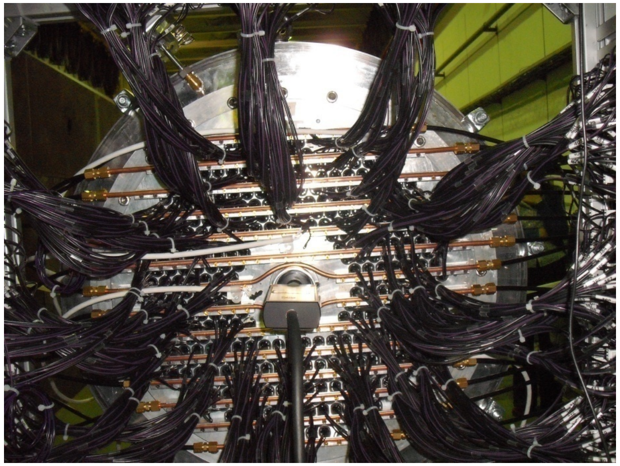
2009 Test Beam: RICH400, prototype with 414 PMs to study:

- $\pi-\mu$ separation
- Readout system
- Neon pollution

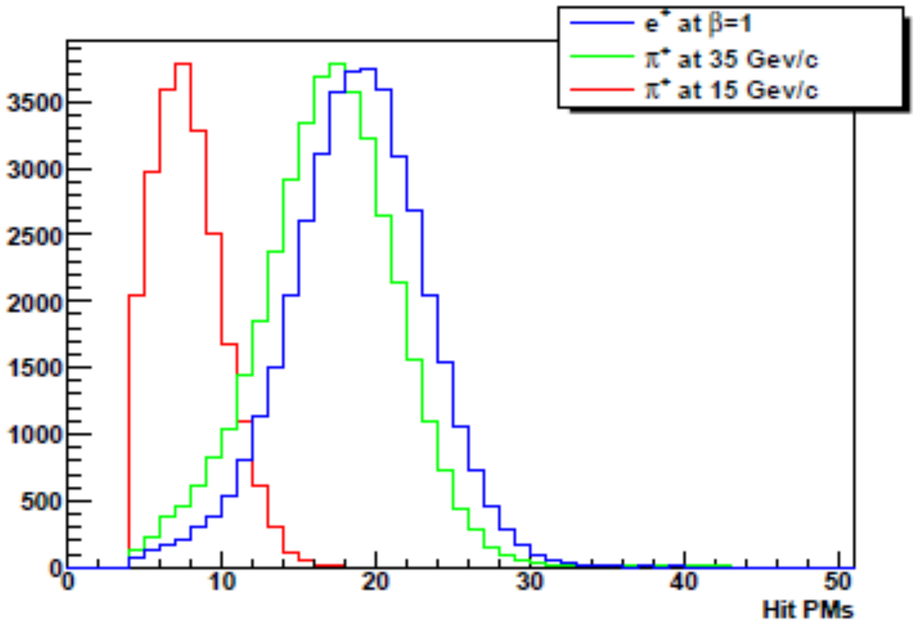


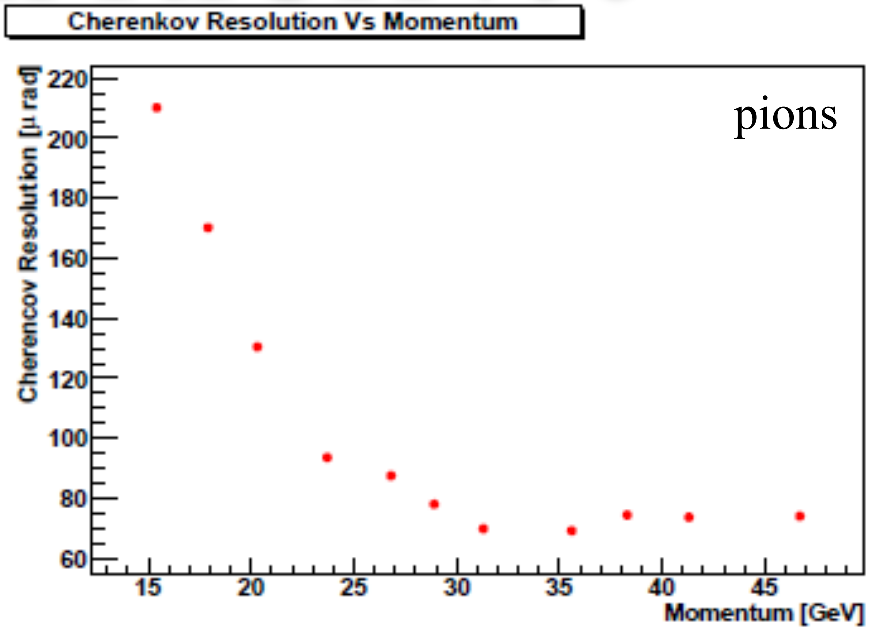
Full length prototypes

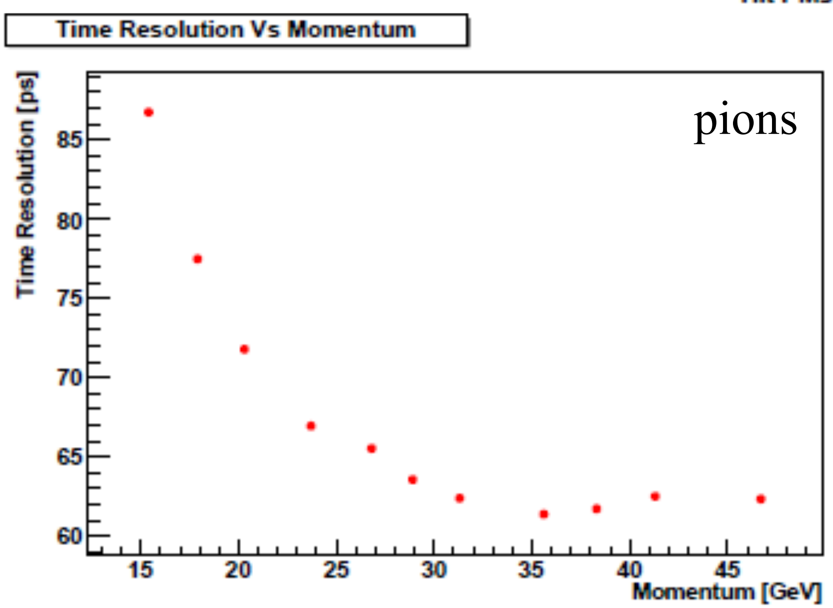
NIM A 593 (2008) 314-318
NIM A 621 (2010) 205-211
IEEE TNS 60 (2013) 265-269

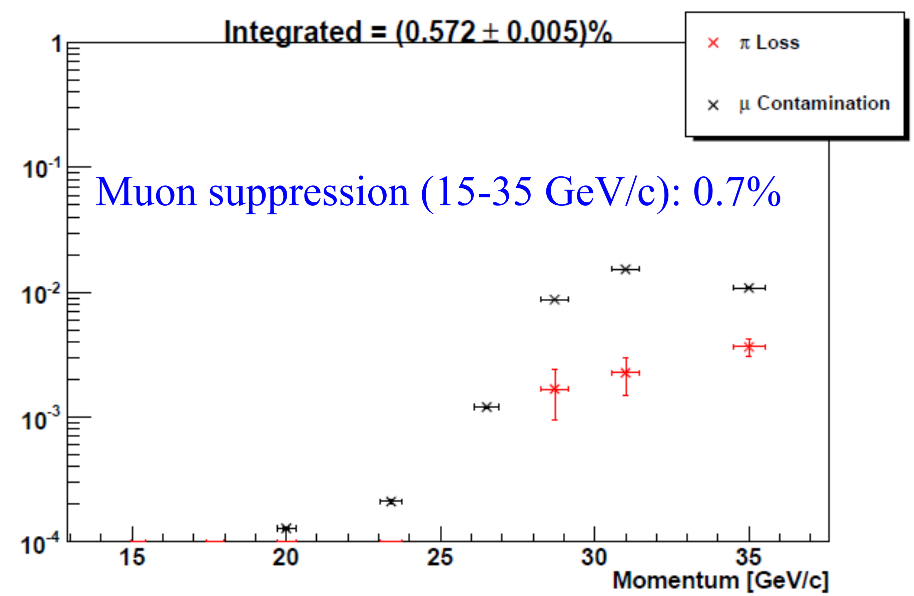


Results from RICH400









Conclusions

The NA62 RICH is a far demanding object, it will be fundamental to reduce backgrounds with a muon in the final state and it will measure the flight time of charged particles with a resolution better than 100 ps.

RICH will be also used to generate the L0 trigger signal for charged particles (see G. Lamanna talk)

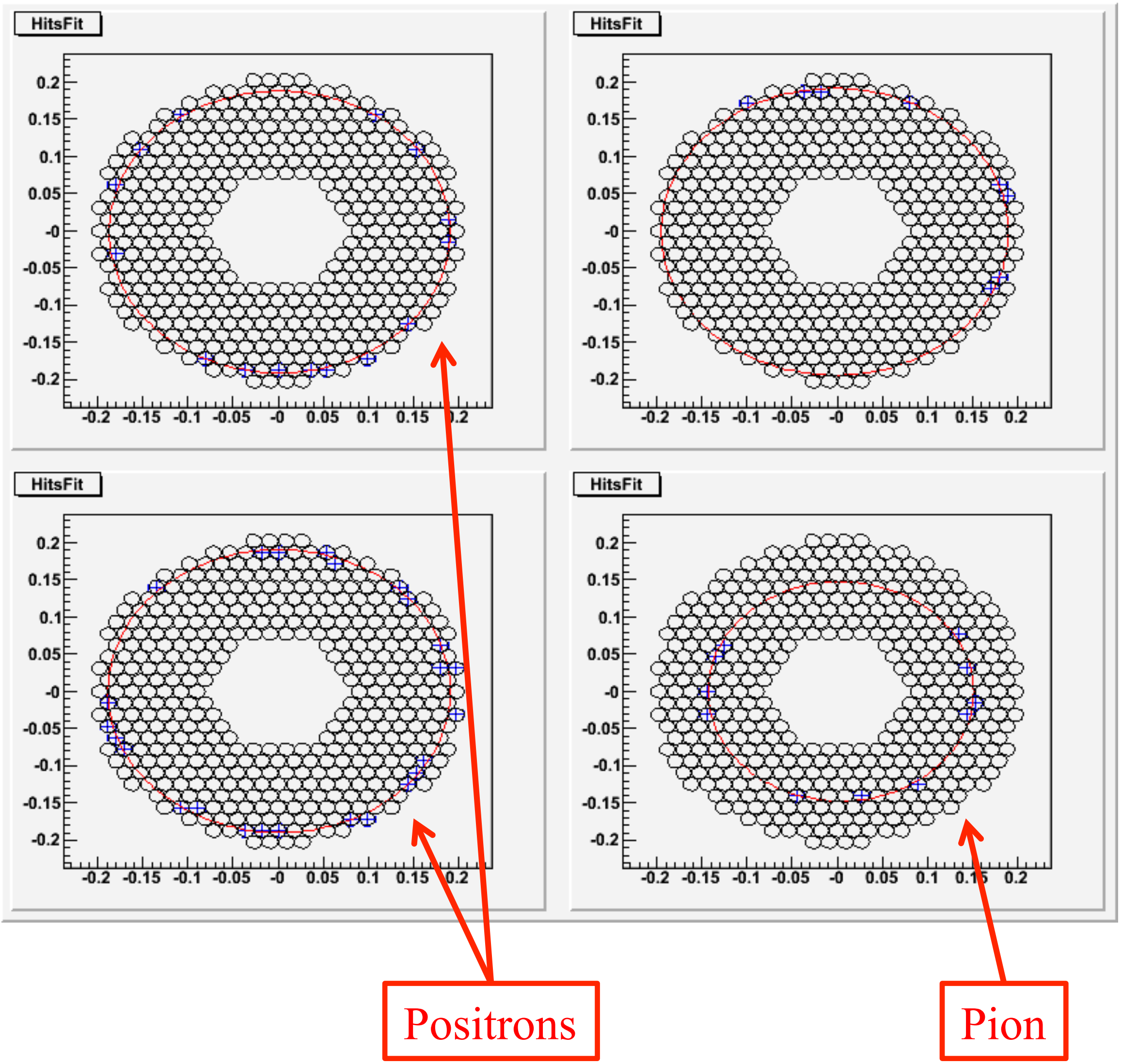
R&D and tests up to now have validated the project

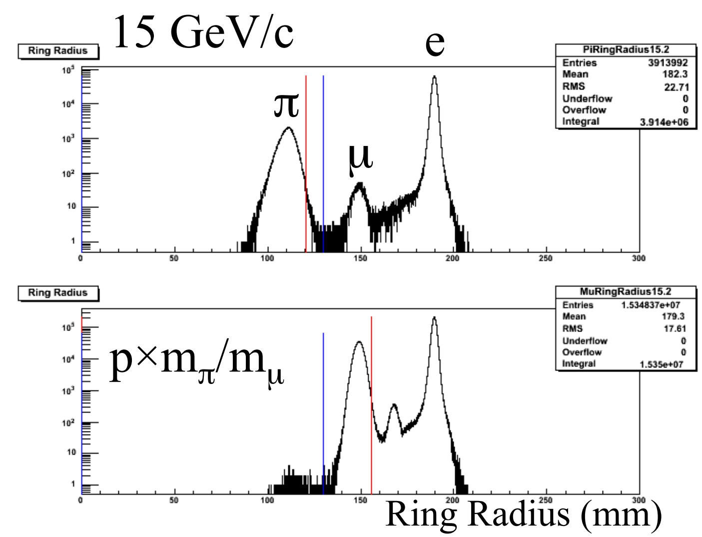
Installation schedule:

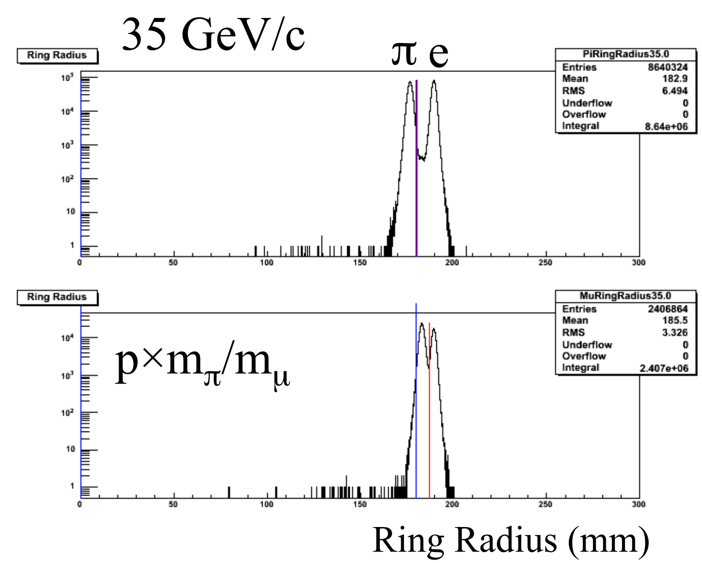
- Jan 2014: RICH vessel delivery
- Jun 2014: Mirrors Installation completed
- Aug 2014: PM installation completed
- Sep 2014: Gas filling completed
- Oct 2014: RICH commissioning and first physics run of NA62

SPARES

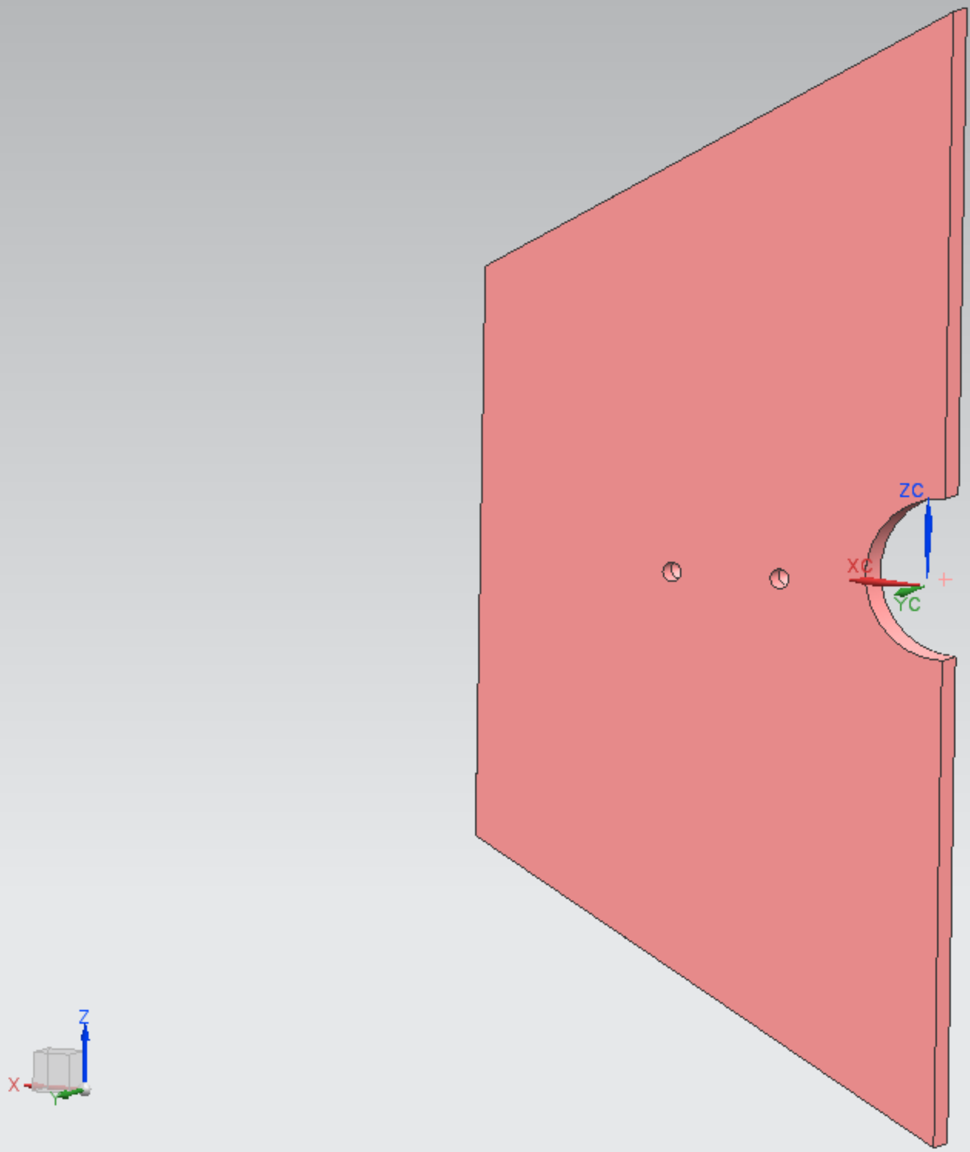
Plots from RICH400



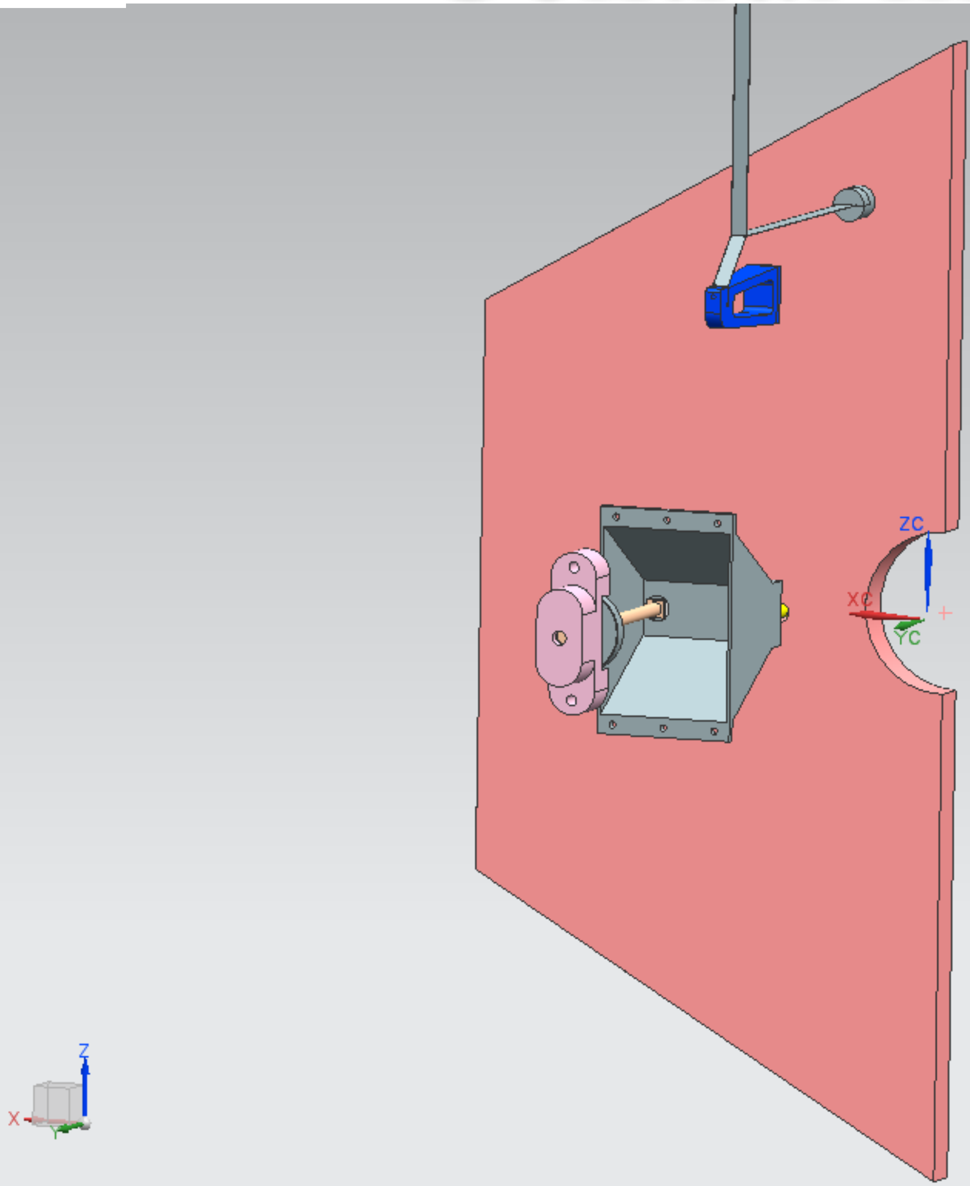




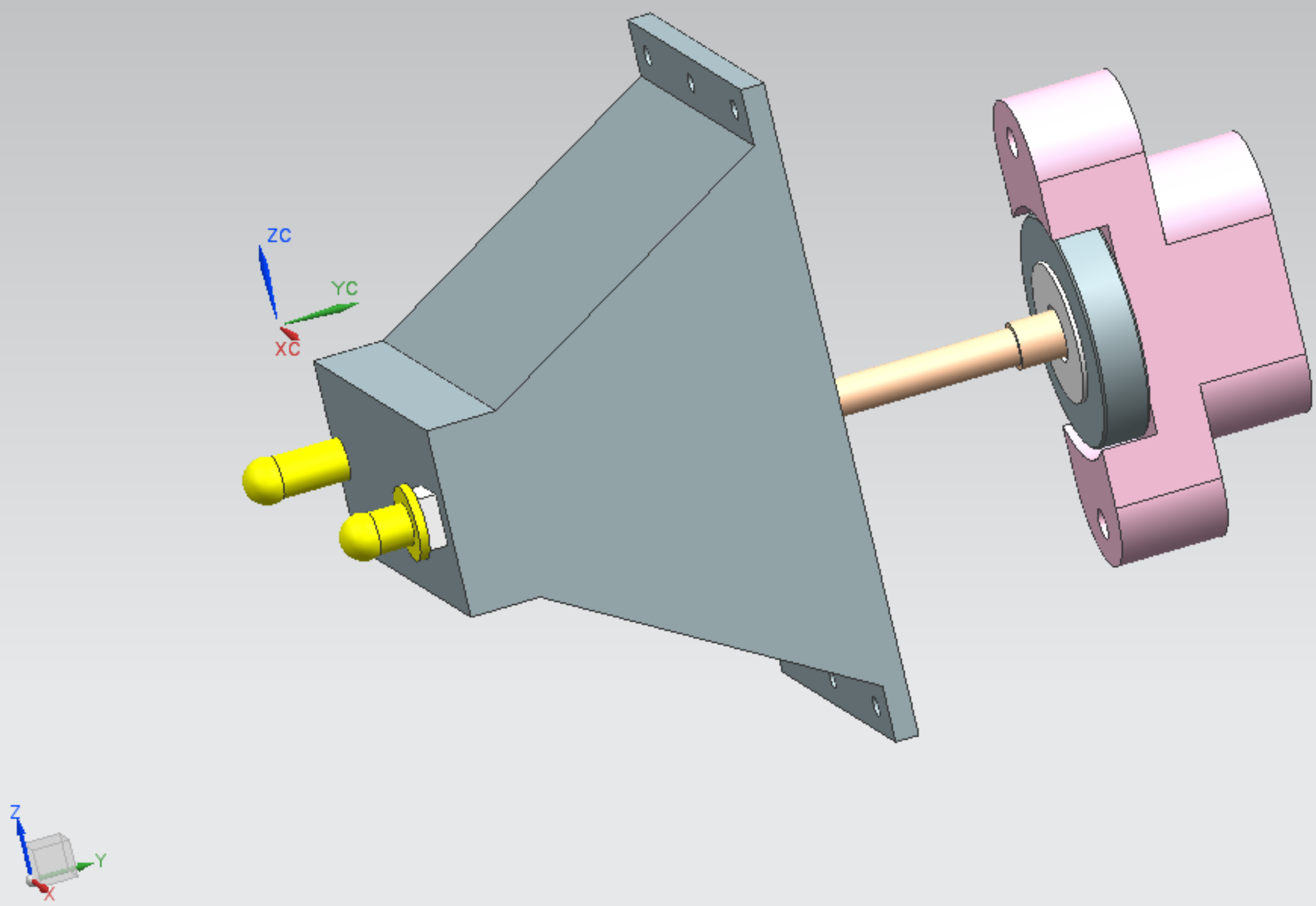
Central mirrors



Central mirrors \II



Central mirrors \III



Central mirrors \IV