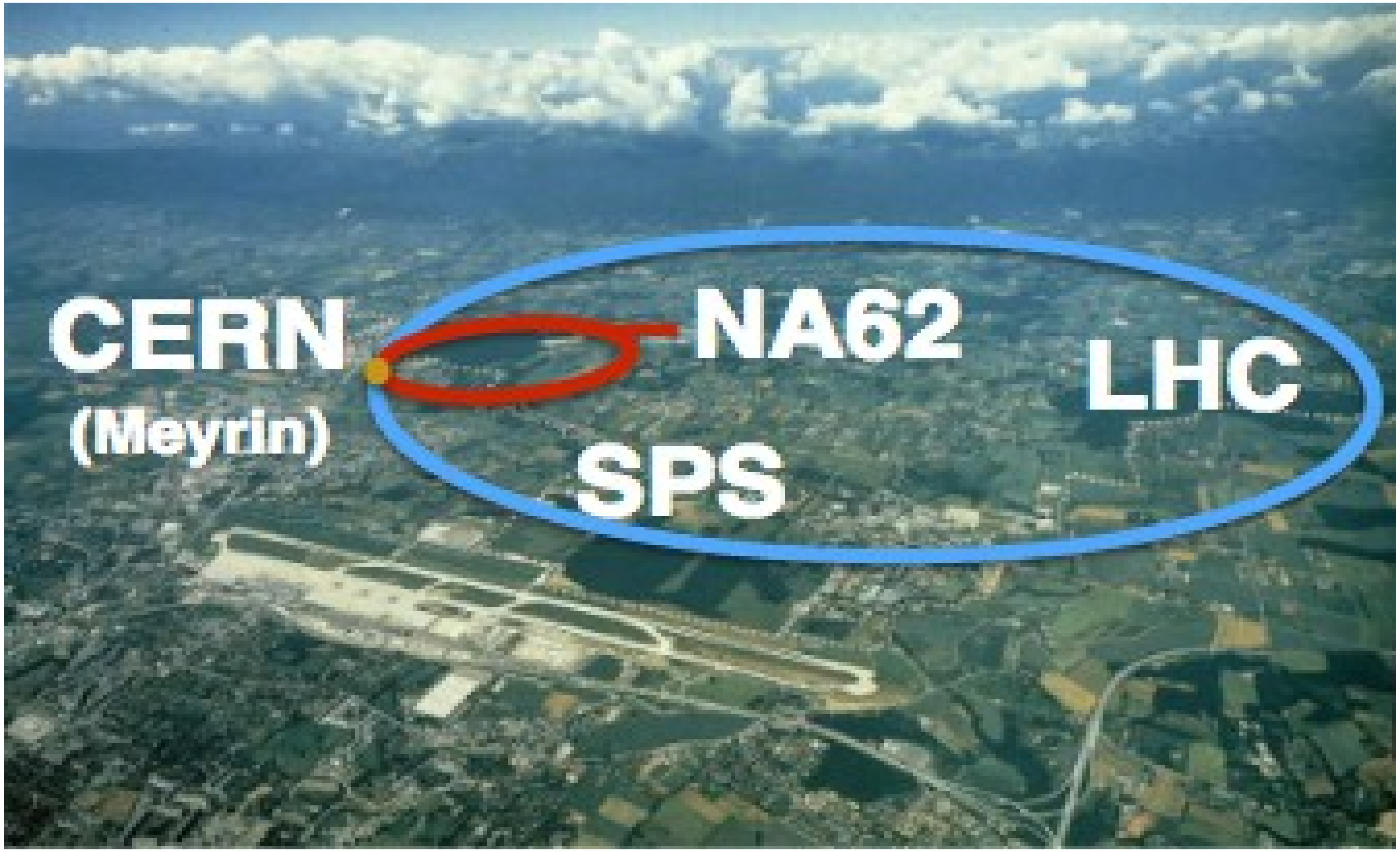
Introduzione all'esperimento NA62



Ermanno Imbergamo
Università Perugia & INFN

Perugia – 18 Maggio 2016

Sommario

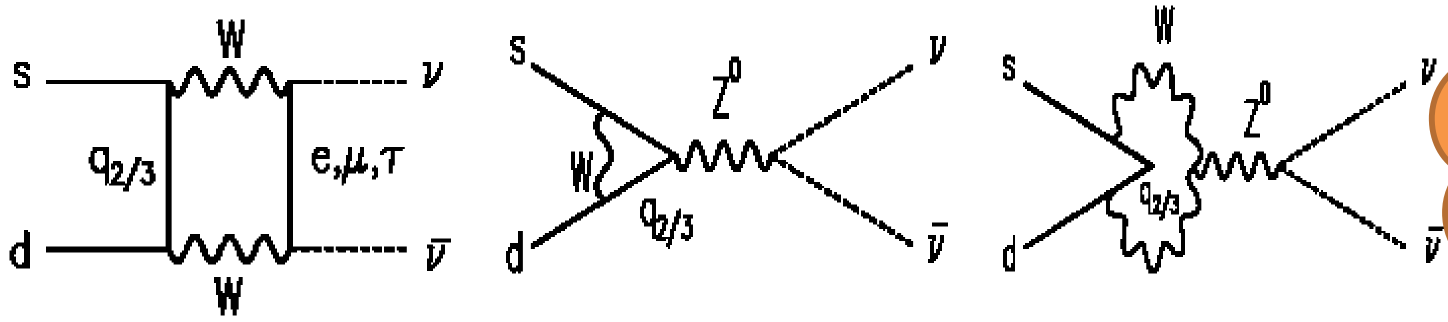
- Motivazioni teoriche
- Tecnica di misura
- Il rivelatore di NA62, i 4 (+1) criteri progettuali

  1. Alta intensità e tempi veloci
  2. Tracciatura a bassa massa
  3. Sistema ermetico di veto
  4. Identificazione particelle

- Un po' di foto del rivelatore

Decadimenti ultra-rari del K

$K \rightarrow \pi \nu \bar{\nu}$:"teoricamente puri e sperimentalmente quasi inesplorati"



NA62 goal: Misura del BR con precisione del 10% (100 evts)

Decay	Branching Ratio (x 10^{-11}) Theory (SM)				Experiment		
$K^+ \longrightarrow \pi^+ \nu\bar{\nu}$	7.81	$^{+0.8}_{-0.71}$	±0.29	[1]	17.3	$^{+11.5}_{-10.5}$	[2]
$K^0 \longrightarrow \pi^0 \nu\bar{\nu}$	2.43	$^{+0.4}_{-0.37}$	±0.06	[1]	<2600 (90%CL)		[3]

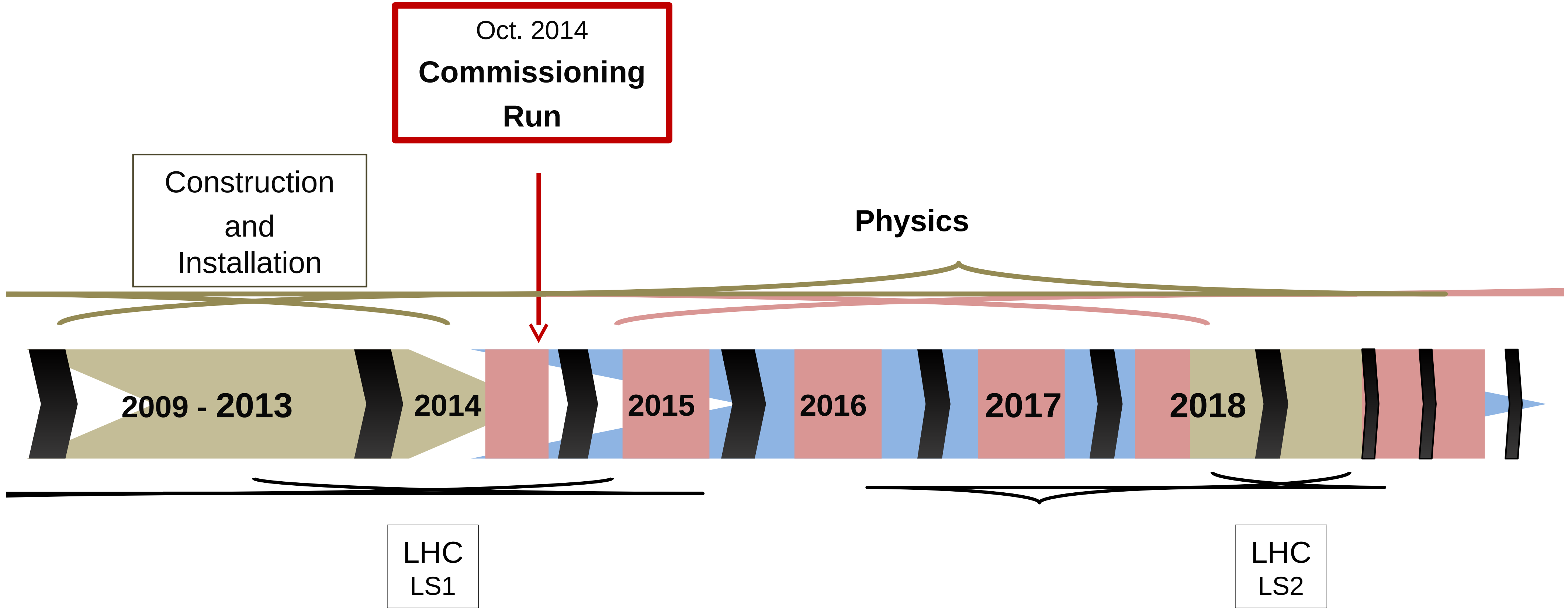
[1] **Joachim Brod, Martin Gorbahn, and Emmanuel Stamou** Phys. Rev. D83, 034030 (2011)

[2] **A. V. Artamonov *et al.* (E949 Collaboration)** B. Phys.Rev.Lett.101, 191802, 2008.

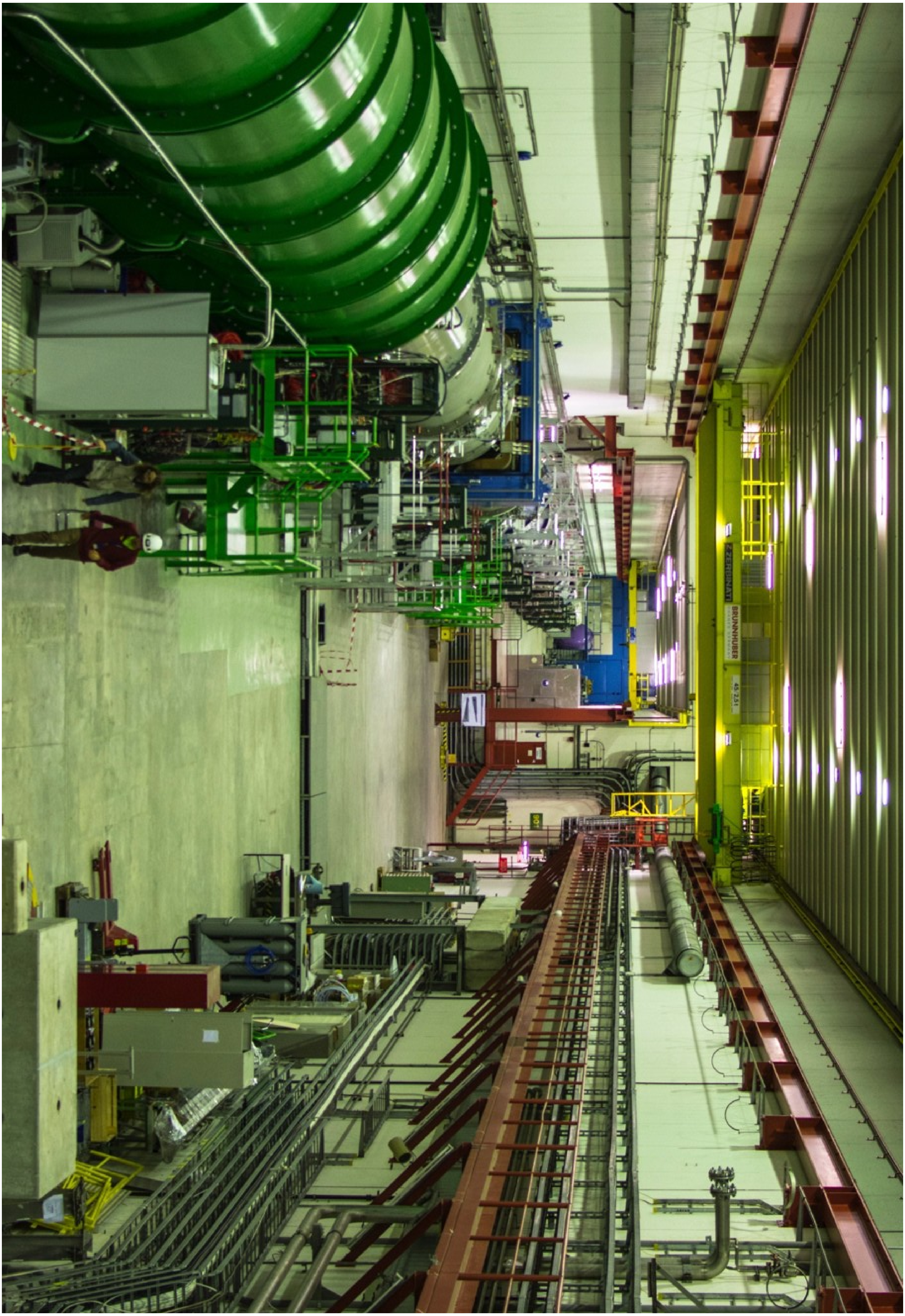
[3] **J. K. Ahn *et al.* (E391a Collaboration)** PR D81 (2010)072004

- Theoretical uncertanty mainly due to mass of Top quark
- This experimental effort allows to determine the CKM parameter |Vtd| to ≤ 10% accuracy.

NA62 Timeline

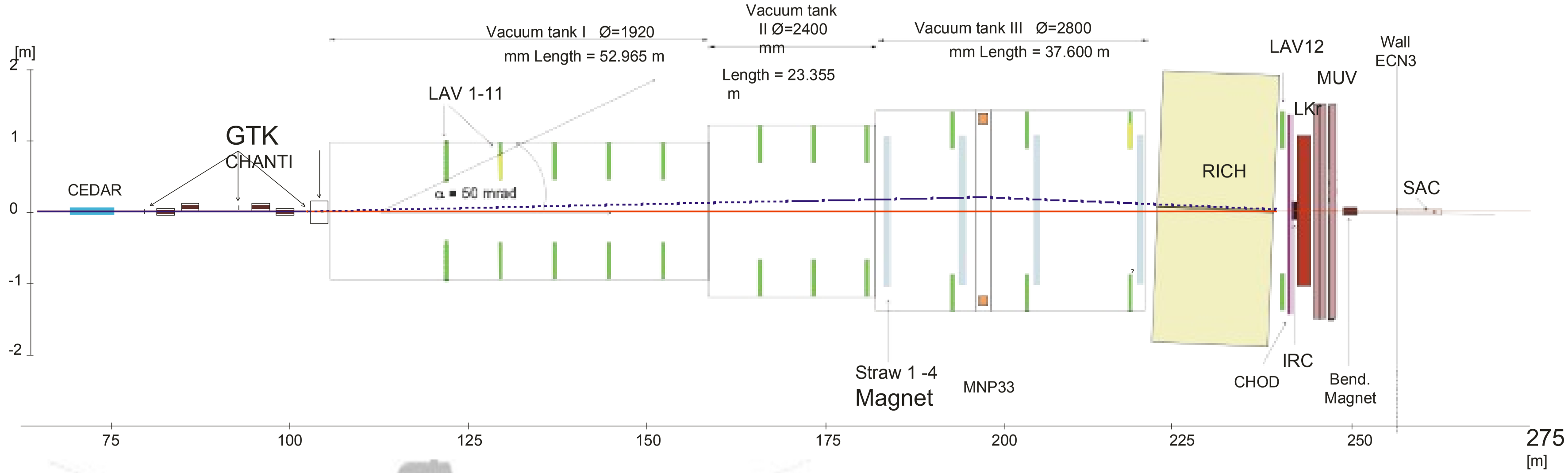


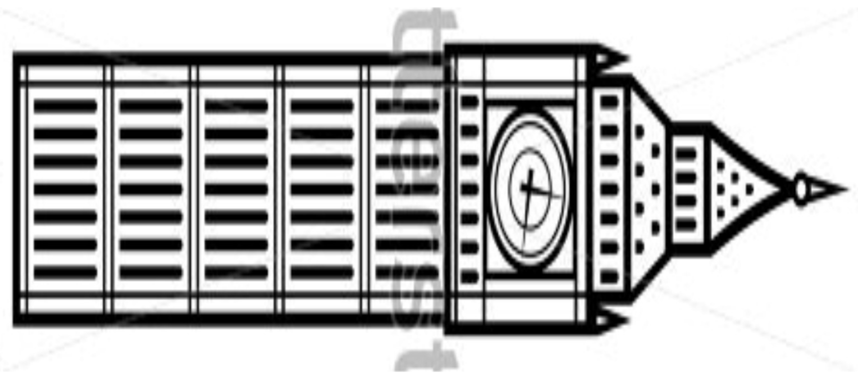
- 5 years of construction and installation
- Autumn 2014 Commissioning Run with full detector
- Plan 3.5 years of Physics data taking before LHC Long Shutdown 2 (LS2)
- Accumulate and analyze O(1013) good kaon decays before LS2


ZERBINATI
BRUNNHUBER

Il rivelatore NA62 (schematico)

Elizabeth Tower Scale



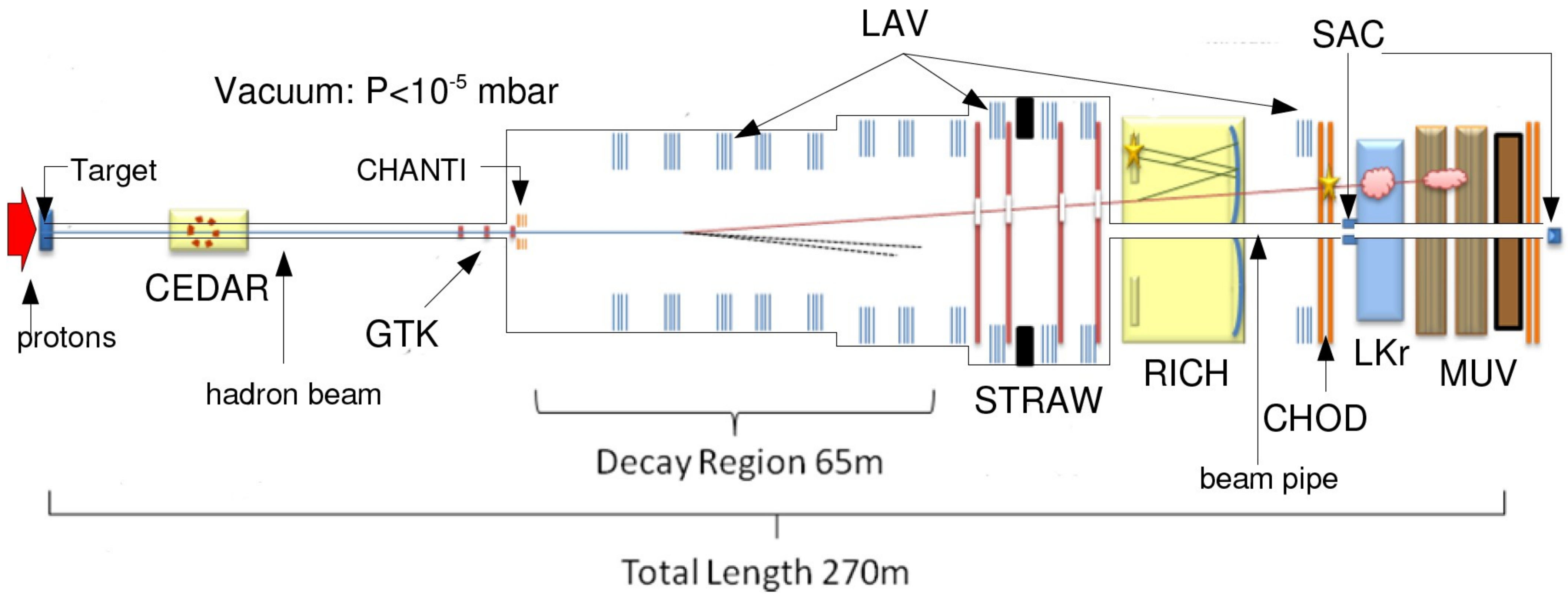


c ~ 4 m

~ 150

NA62 length = 2.8 ET's

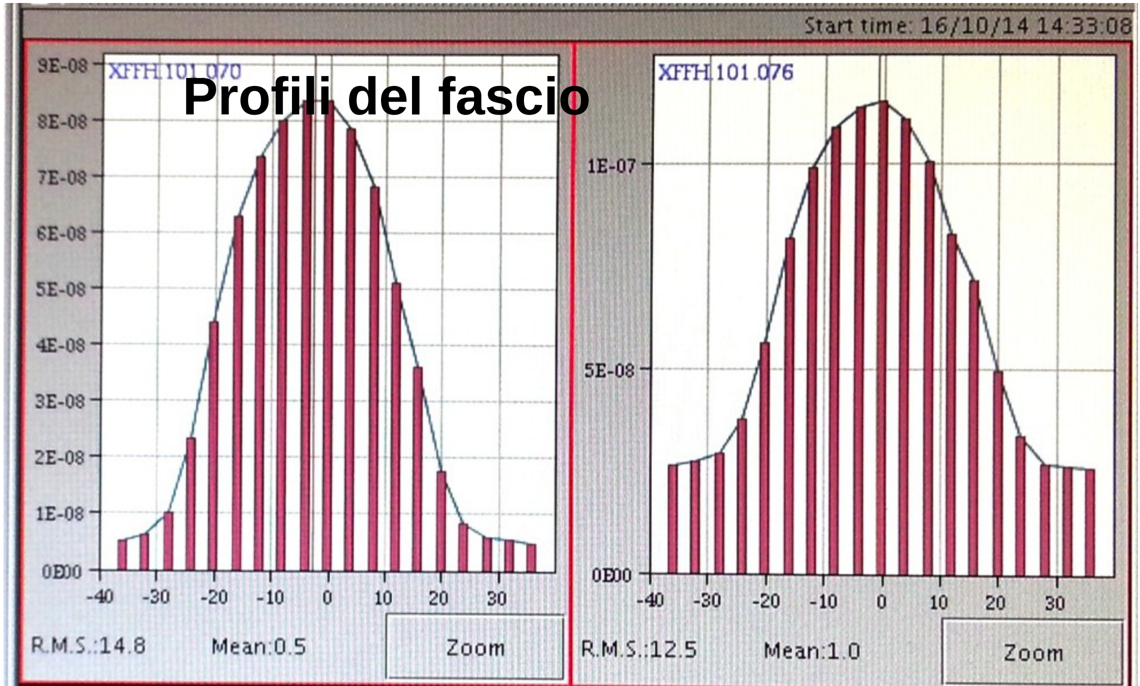
Schema del rivelatore



- Decadimenti di Kaoni in volo da un fascio “non separato” a 75 GeV/c, prodotto da un fascio di protoni a 400 GeV/c estratto dall’SPS contro un bersaglio fisso di berillio (fascio a ~800 MHz, ~6% kaons)
- Le particelle non decadute viaggiano nel tubo a vuoto centrale

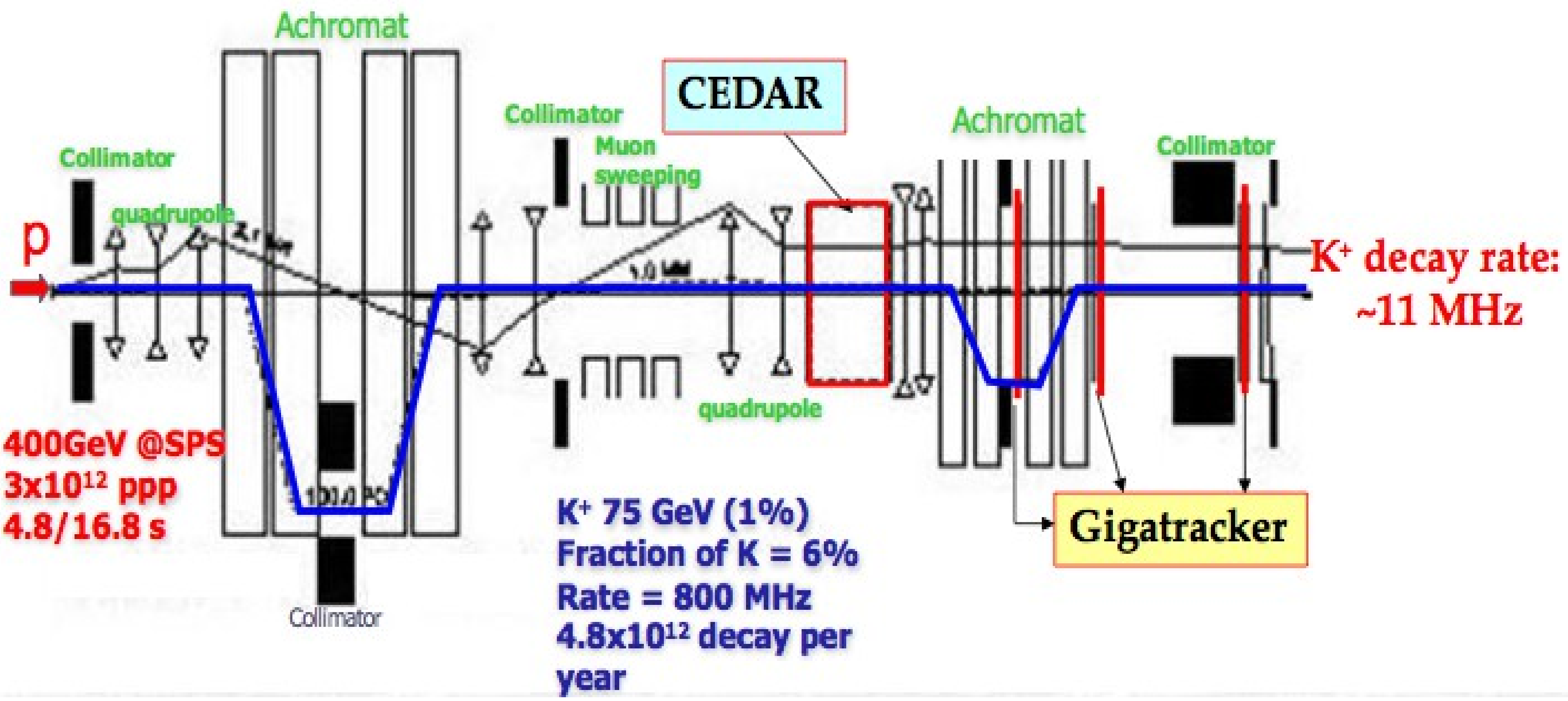
Il fascio di K

Beam Parameter	
400 GeV/c Protons on Target / s	3.1×10^{12}
75 GeV/c Hadrons / s (6% Kaons)	750×10^{6}
K+ decays / s	4.5×10^{6}
K+ decays / y	4.5×10^{12}
Ratio (K+ decays / Hadron Flux)	≈ 6‰



Profili del fascio

Il fascio di K^+



Tecnica di misura

Rispetto a un esperimento con decadimenti da K fermi:

- Vantaggi:
  - Più facile rivelare fotoni da decadimenti di fondo
  - Più facile avere fasci ad alta intensità
- Svantaggi:
  - Rivelatore e regione di decadimento di grandi dimensioni
  - Necessità di misurare l'impulso di ogni K
  - Fascio non separato di adroni

Decay	BR
$\mu^+\nu$ ($K_{\mu 2}$)	63.5%
$\pi^+\pi^0$ ($K_{\pi 2}$)	20.7%
$\pi^+\pi^+\pi^-$	5.6%
$\pi^0 e^+\nu$ (K_{e3})	5.1%
$\pi^0\mu^+\nu$ ($K_{\mu 3}$)	3.3%
$\pi^+\pi^0\pi^0$	1.8%
$\mu^+\nu\gamma$ ($K_{\mu 2\gamma}$)	0.62%
$\pi^+\pi^0\gamma$	2.7×10^{-4}
$\pi^+\pi^- e^+\nu$ (K_{e4})	4.1×10^{-5}
$\pi^0\pi^0 e^+\nu$ (K_{e4}^{00})	2.2×10^{-5}
$e^+\nu$ (K_{e2})	1.5×10^{-5}
$\pi^+\pi^-\mu^+\nu$ ($K_{\mu 4}$)	1.4×10^{-5}

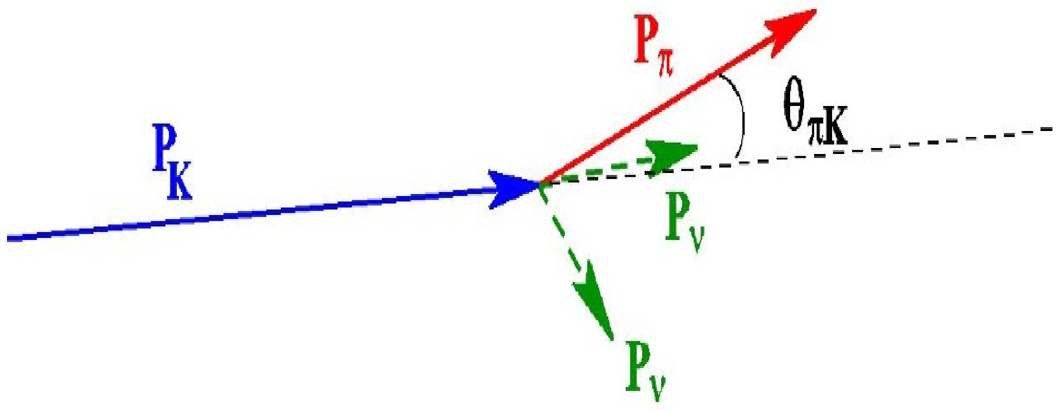
Punti chiave:

1. **Reiezione cinematica**
2. **Veto**
3. **Identificazione delle particelle (PID)**
4. **Alta intensità**

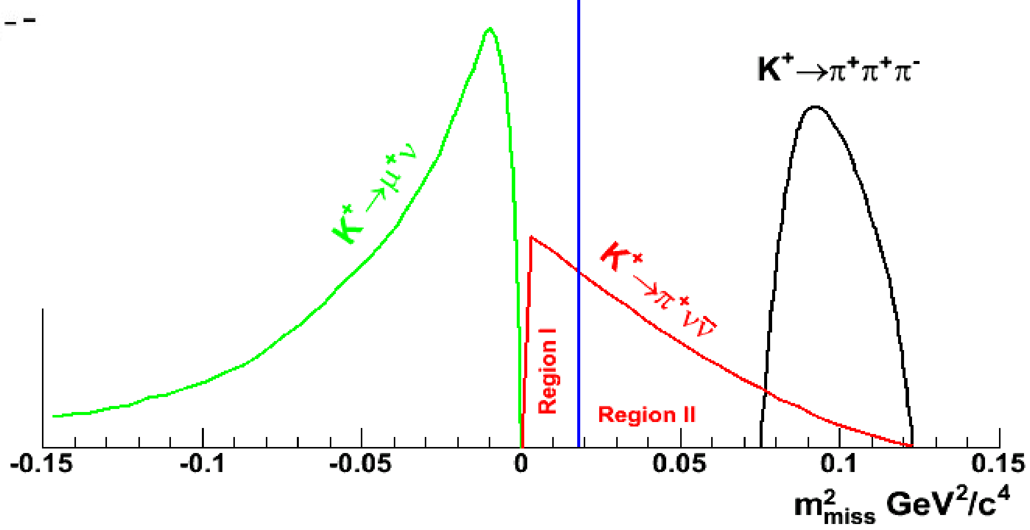
Segnale difficile da identificare e raro: $\mathbf{BR_{SM}=8x10^{-11}}$

Potenzialmente alta contaminazione da altri decadimenti di K

Reiezione cinematica



92% del fondo
cinematicamente
separabile dal segnale

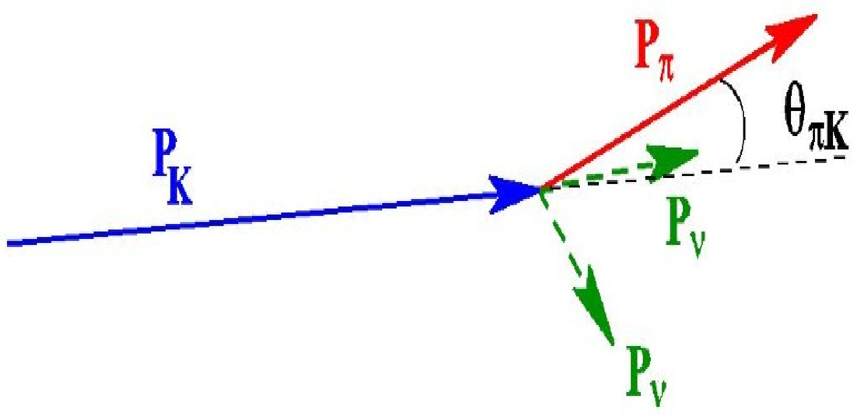


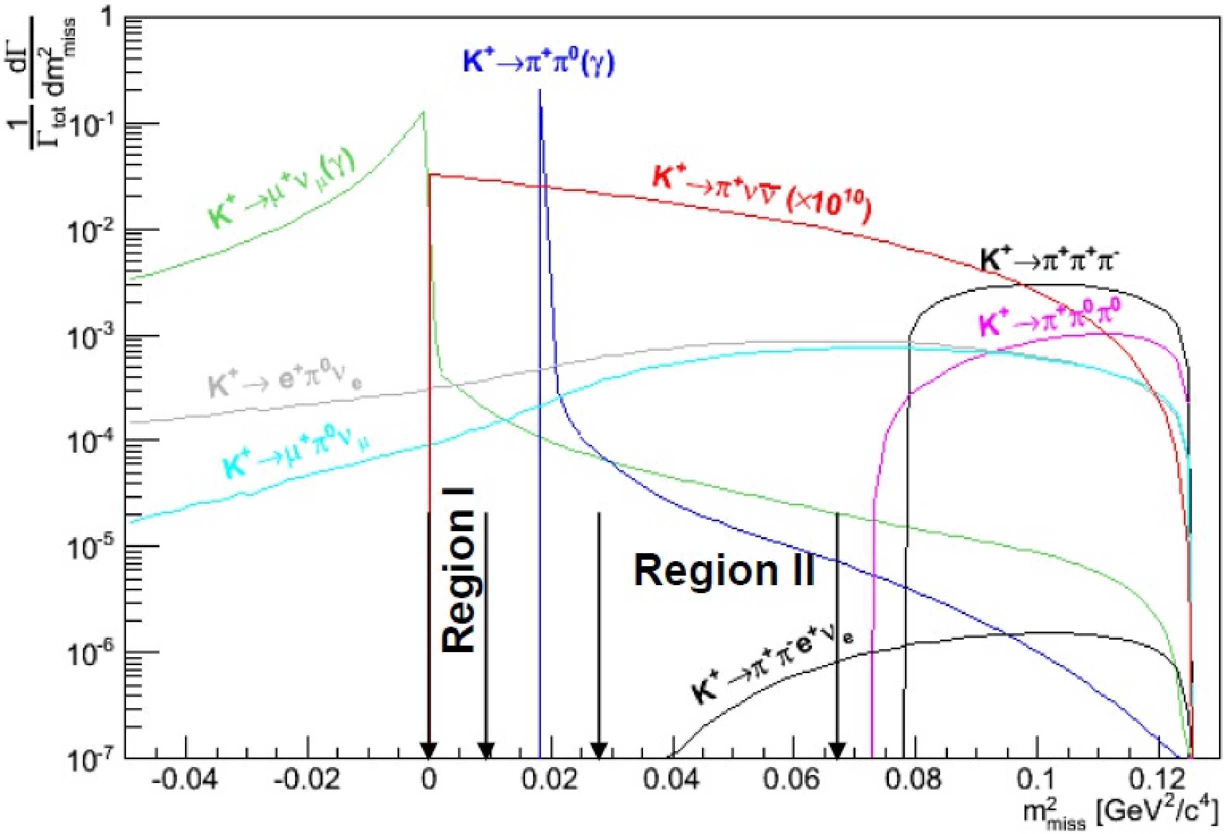
$$m^2_{miss} \approx m^2_K \left(1 - \frac{|P_\pi|}{|P_K|}\right) + m^2_\pi \left(1 - \frac{|P_K|}{|P_\pi|}\right) - |P_K||P_\pi|\theta^2_{\pi K}$$

- richiesta conoscenza di P_K e P_π

– richiesta buona risoluzione

Reiezione cinematica



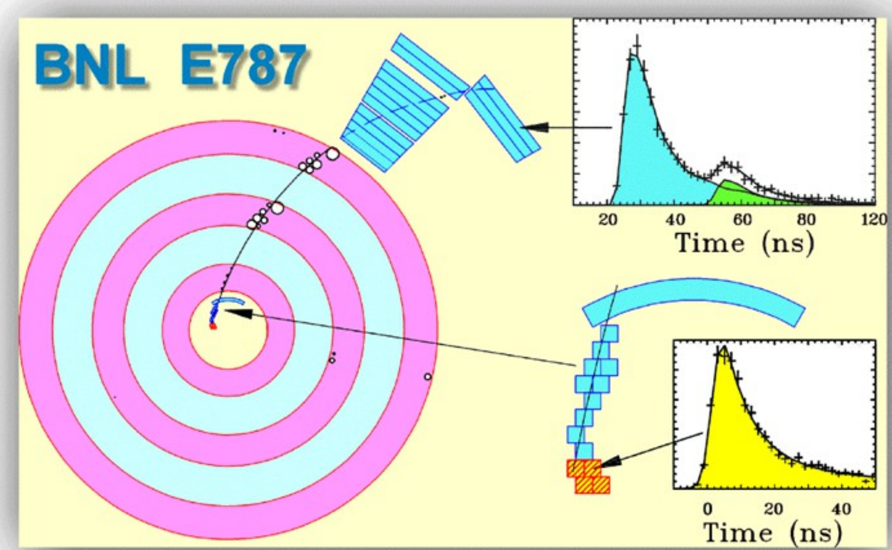


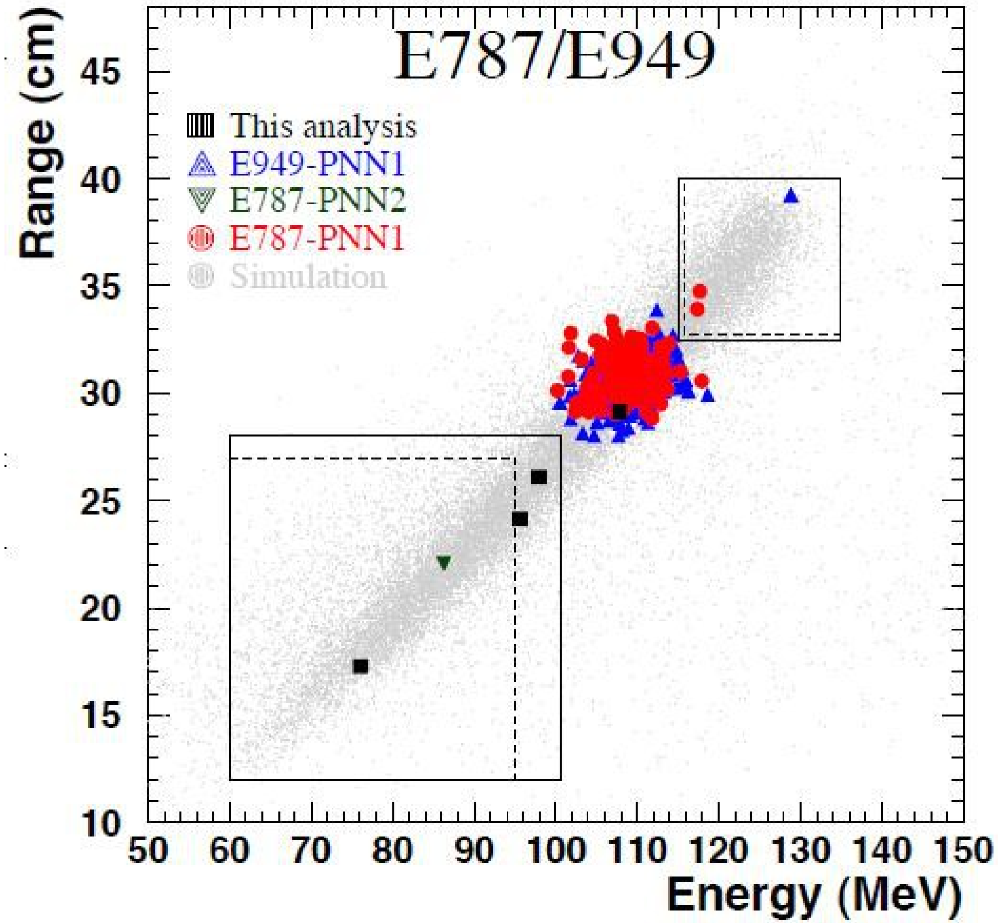
$$m^2_{miss} \approx m^2_K \left(1 - \frac{|P_\pi|}{|P_K|}\right) + m^2_\pi \left(1 - \frac{|P_K|}{|P_\pi|}\right) - |P_K||P_\pi|\theta^2_{\pi K}$$

Richiesti altri criteri di selezione:
- rivelatori di veto per fotoni e muoni
- distinguere fra π/μ/e (RICH)

Un approccio alternativo (già svolto)

Due esperimenti a BNL (Brookhaven National Laboratory-USA) dal 1997 al 2004, 7 candidati identificati in totale (di cui 4 compatibili con il fondo):





- K^+ fermati su un bersaglio circondato dal rivelatore
- Accettanza molto bassa, ~ 0.1%
- Inefficienze di veto (a causa delle basse energie)

I quattro (+1) criteri progettuali

- Alta intensità e tempi veloci
- Tracciatura a bassa massa
- Sistema ermetico di veto
- Identificazione particelle

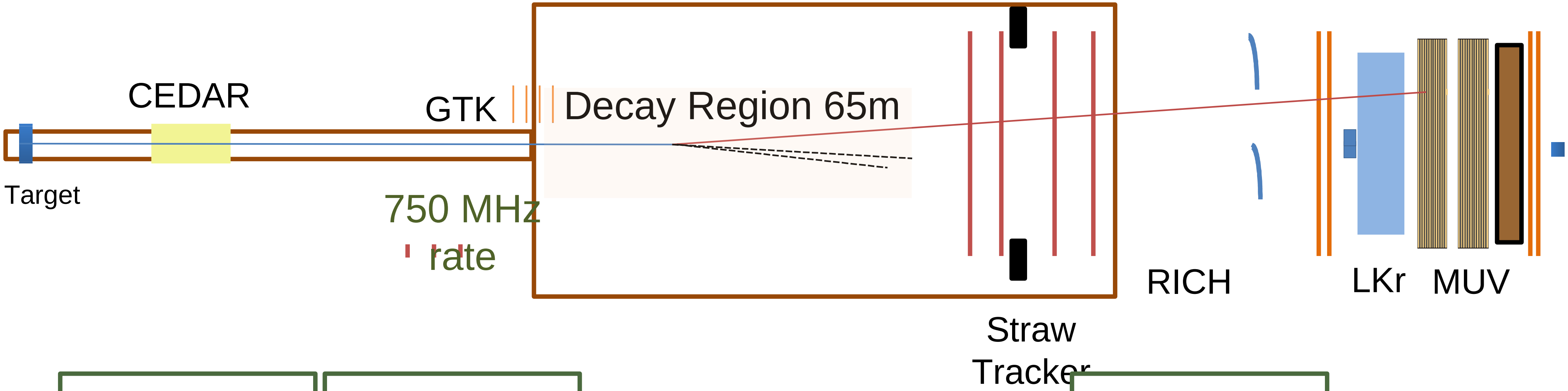
(+1) riuso dei rivelatori dell'esperimento NA48

I quattro (+1) criteri progettuali

(1) Alta intensità e tempi veloci

750 MHz primary
Hadron beam at 75GeV/c
6% are Kaons

7-12 MHz of Muon Rate
in the Detectors



σT < 100 ps

σT < 150 ps

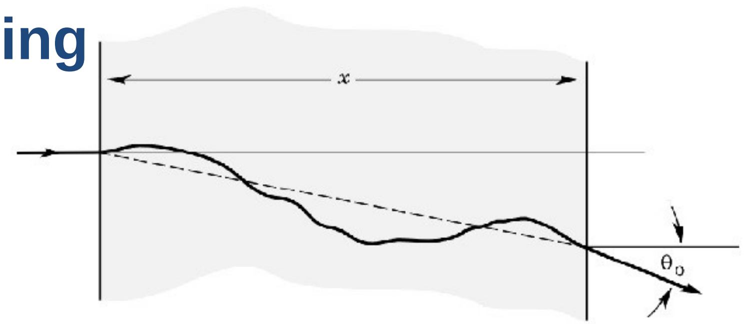
σT < 100 ps

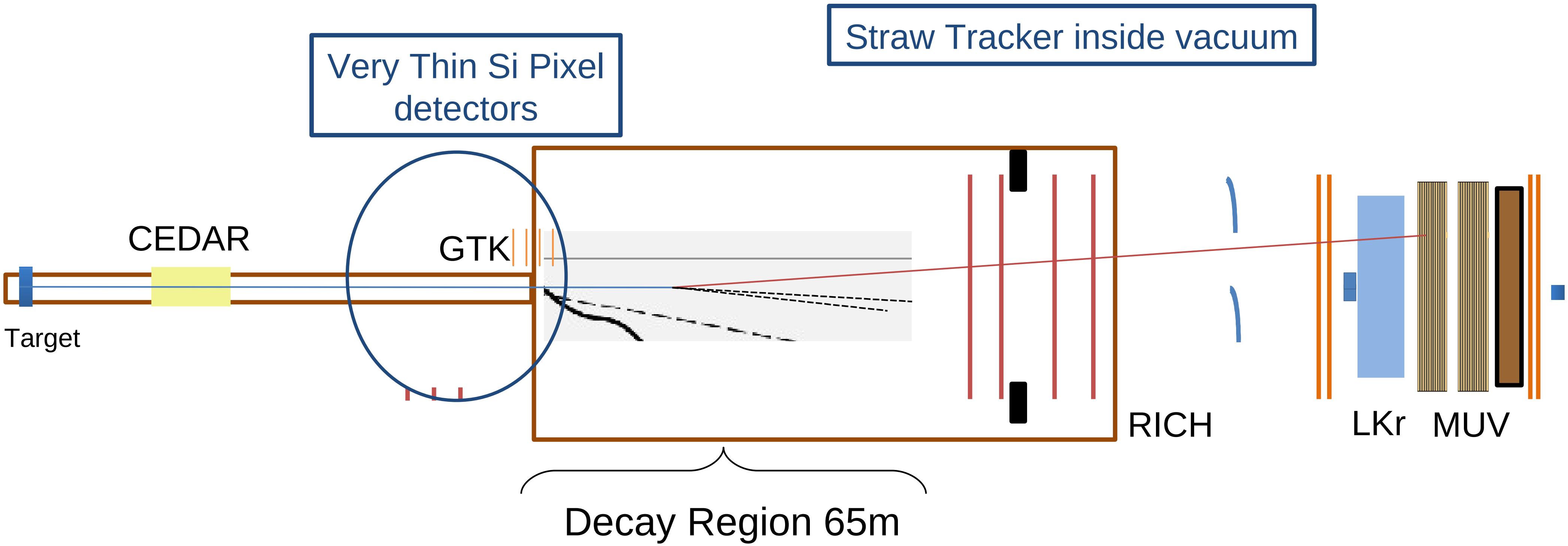
4.5 10^{12} K+ decays/ year in fiducial region

I quattro (+1) criteri progettuali

(2) tracciatura a bassa massa

Minimize multiple scattering

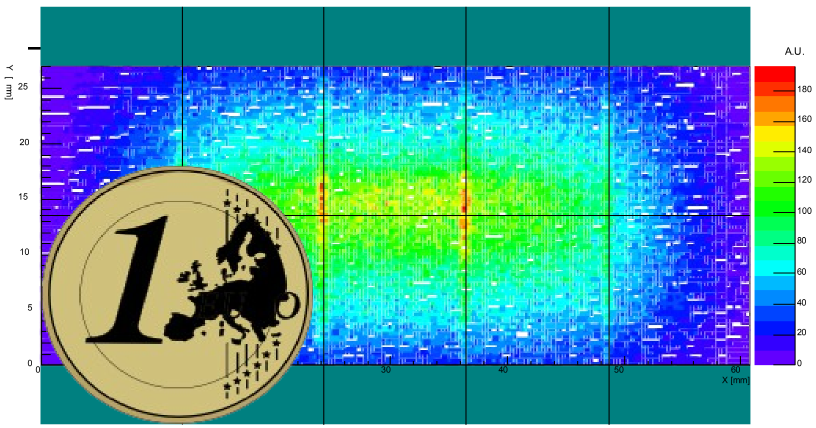




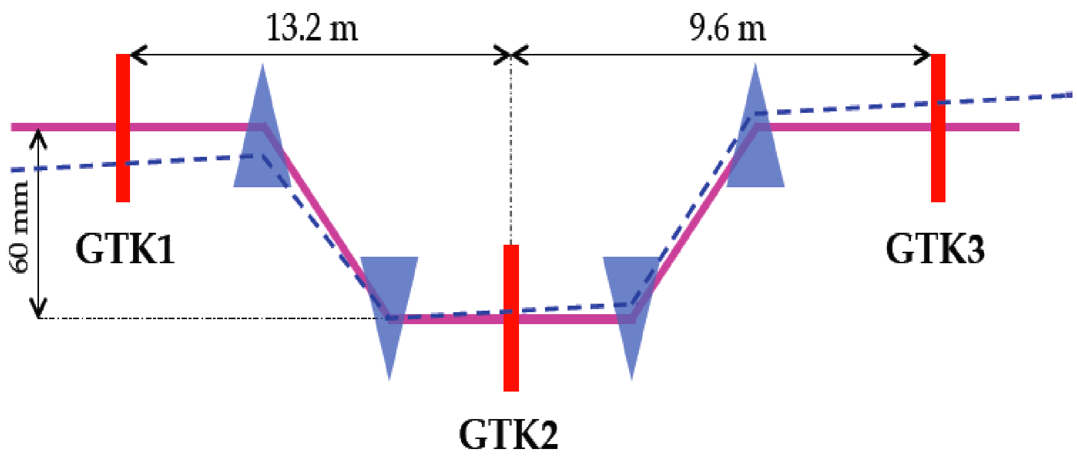
GigaTracKer (GTK)

3 stazioni di pixels al Silicio

- Pixel size:
  - 300 x 300 µm2 or 300 x 400 µm2
  - 18'000 pixels/ station
  - 54'000 pixels grand total
- Active area ≈ 60 (X) * 27 (Y) mm2



Montati dentro la beam pipe intorno a quattro magneti acromatici



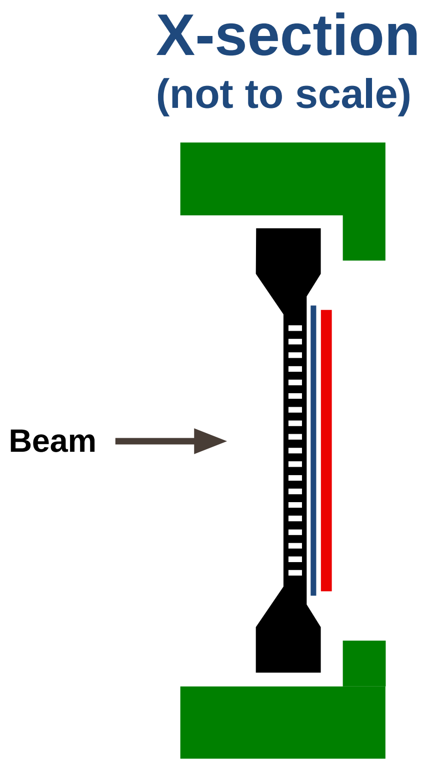
Beam Conditions:

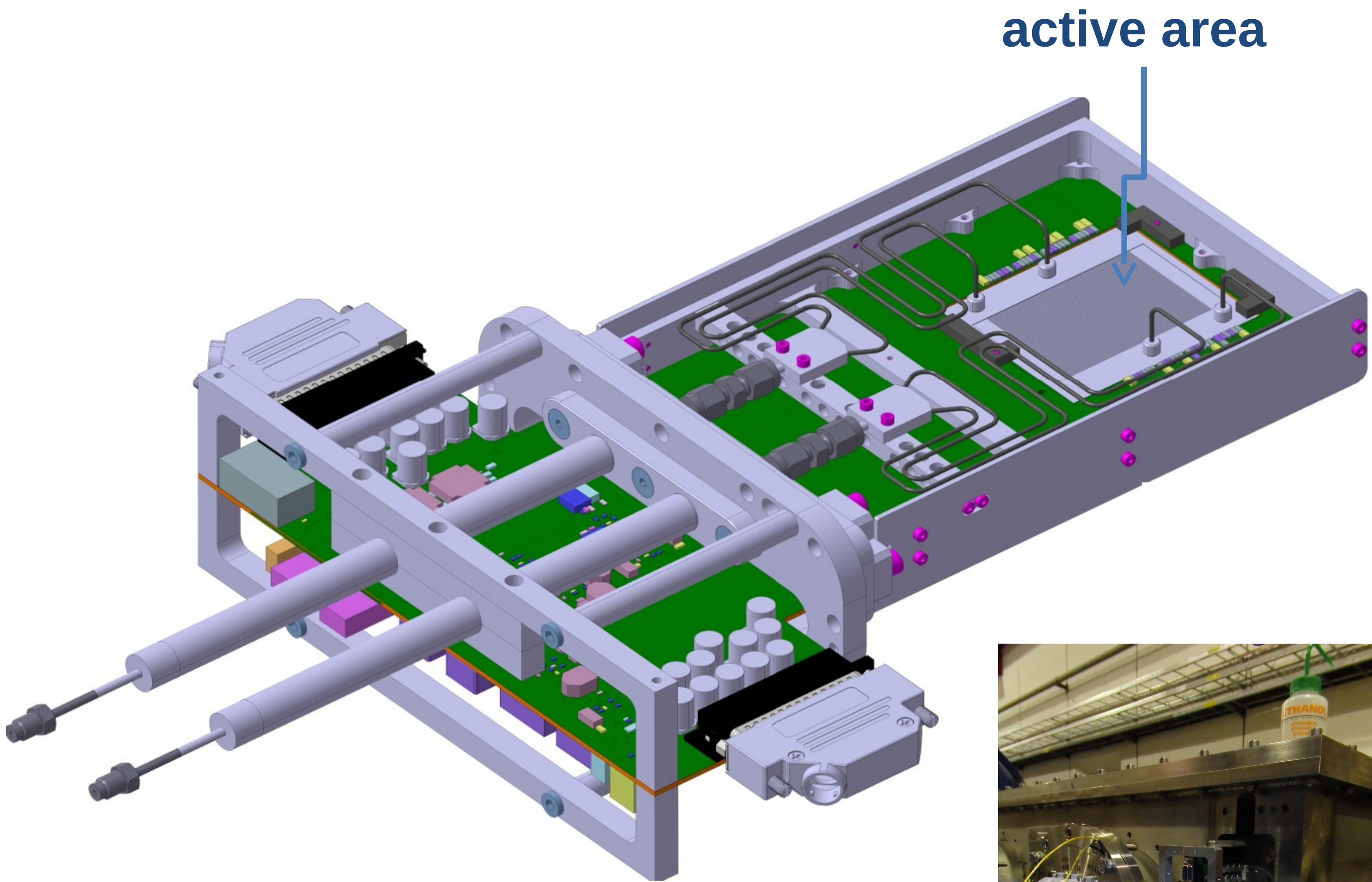
- **Overall Rate 750MHz**
- In beam centre 140kHz/pixel

Measures precisely Kaon

- **Time (σt ≈ 200ps per station)**
- Direction (σ dx,dy ≈ 0.016mrad)
- Momentum (ΔP/P < 0.4%)

GigaTracKer (GTK)



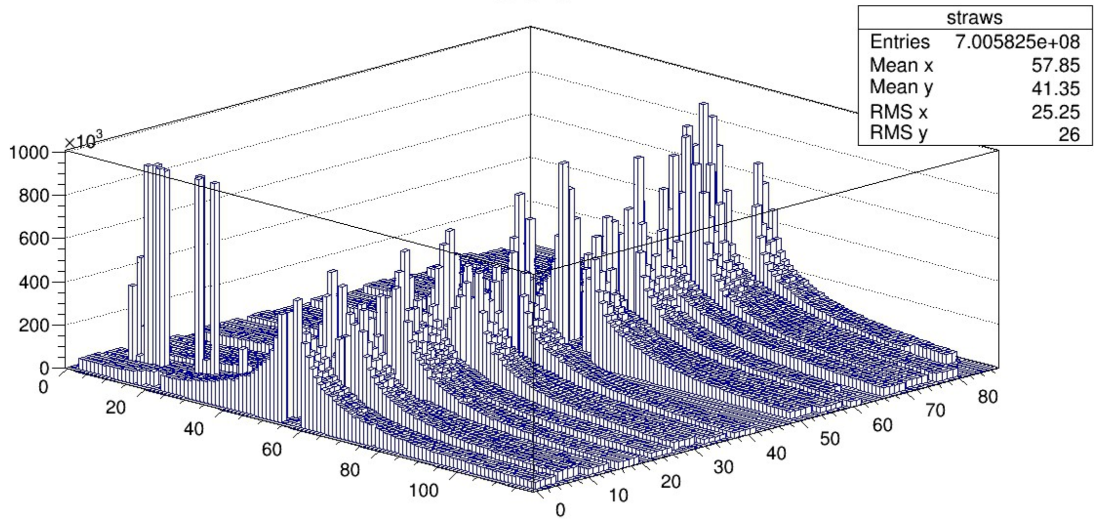


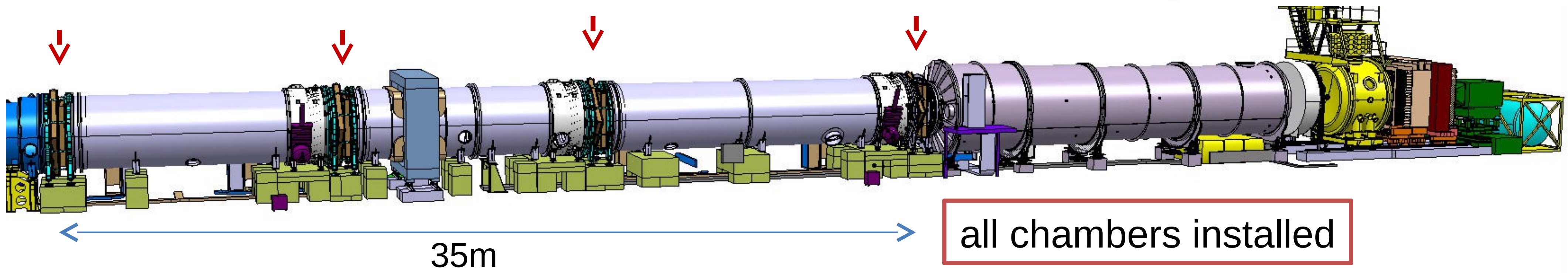
Thickness < 500 μm
< ≈130 Cooling + 100(readout) + 200(sensor)
< 0.5% of X0 (per Station)

Straw Spectrometer

- Ultra-thin Straws installed in Vacuum
- 4 Chambers each measures 4 coordinates (views)
- High accuracy (130mm

  per View)
- High efficiency

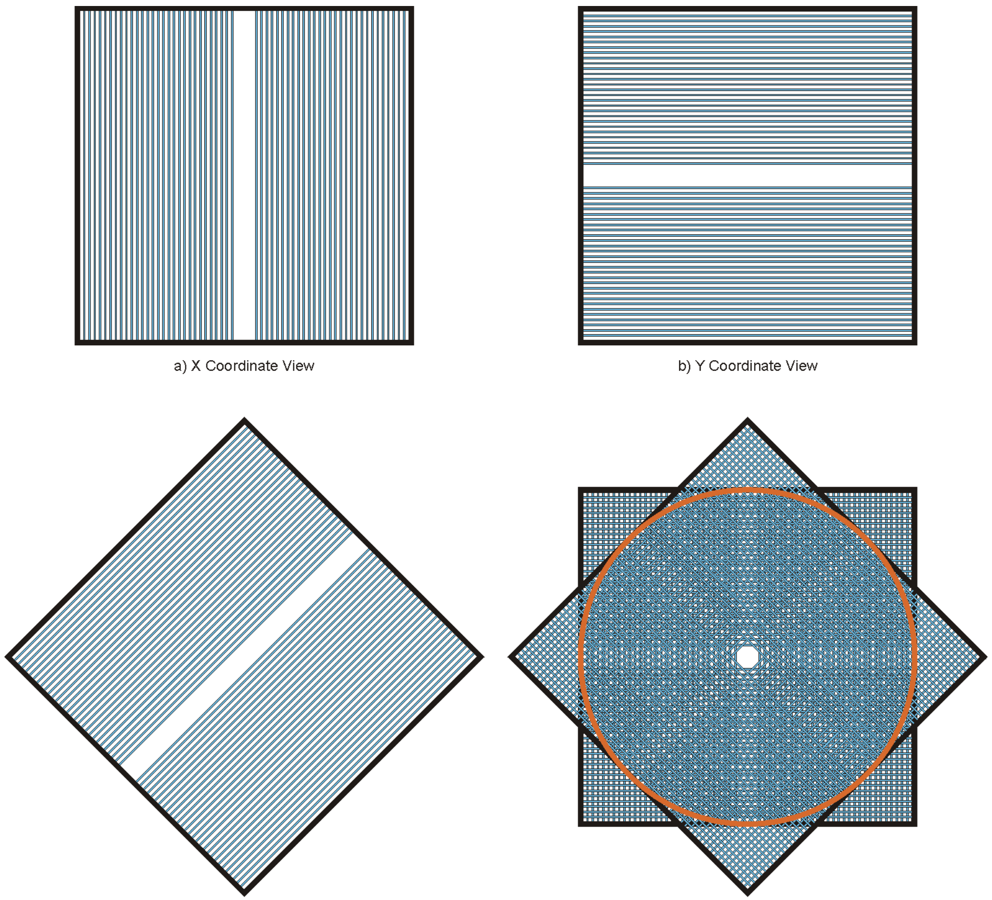




Straw Tracker

Straws installed inside vacuum tank (≈ 10-6 mbar

4 views in each Station

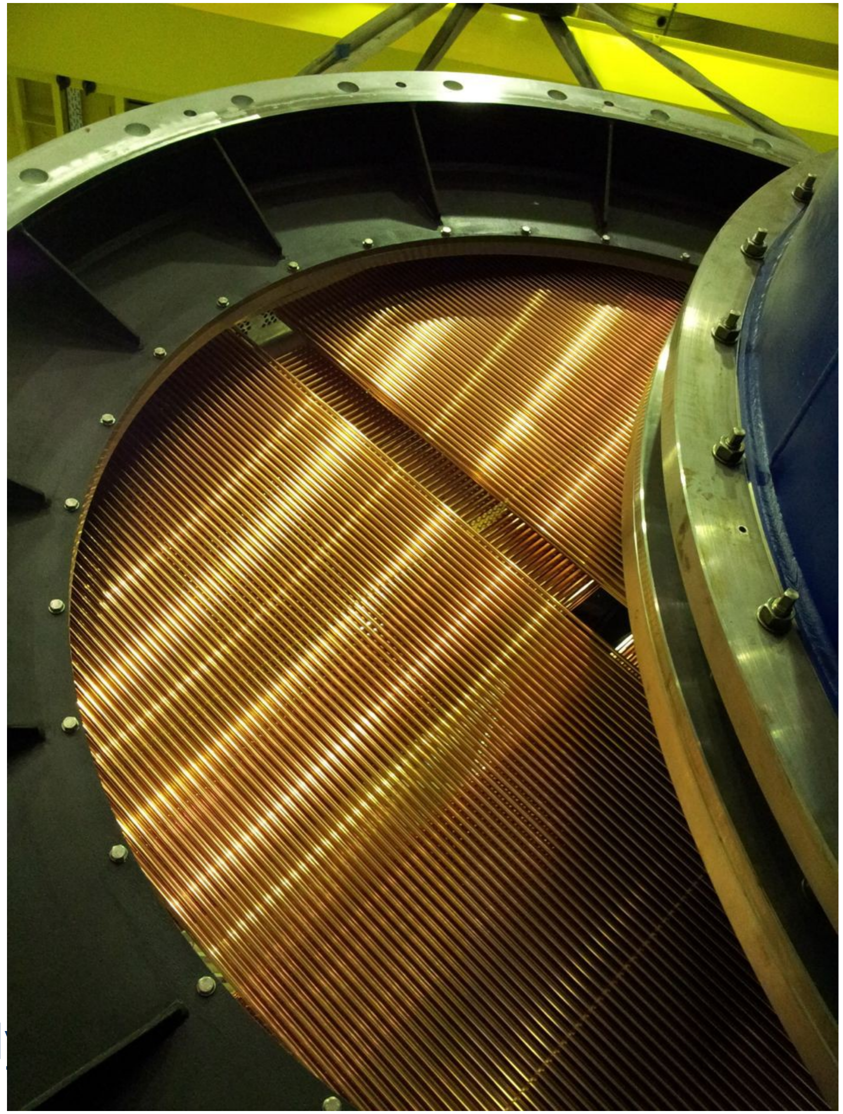


a) X Coordinate View

b) Y Coordinate View

c) U Coordinate View

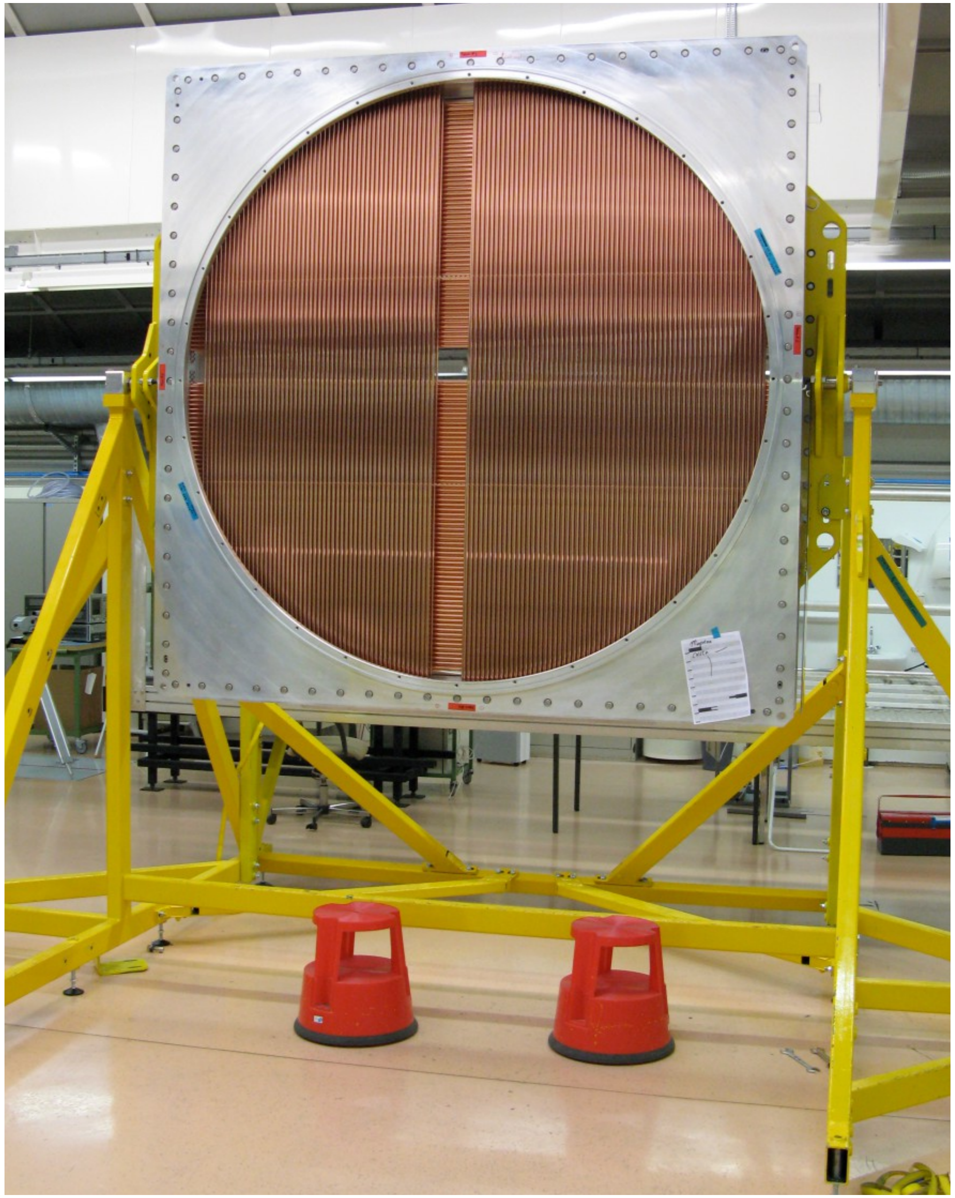
d) Overlay of four Views

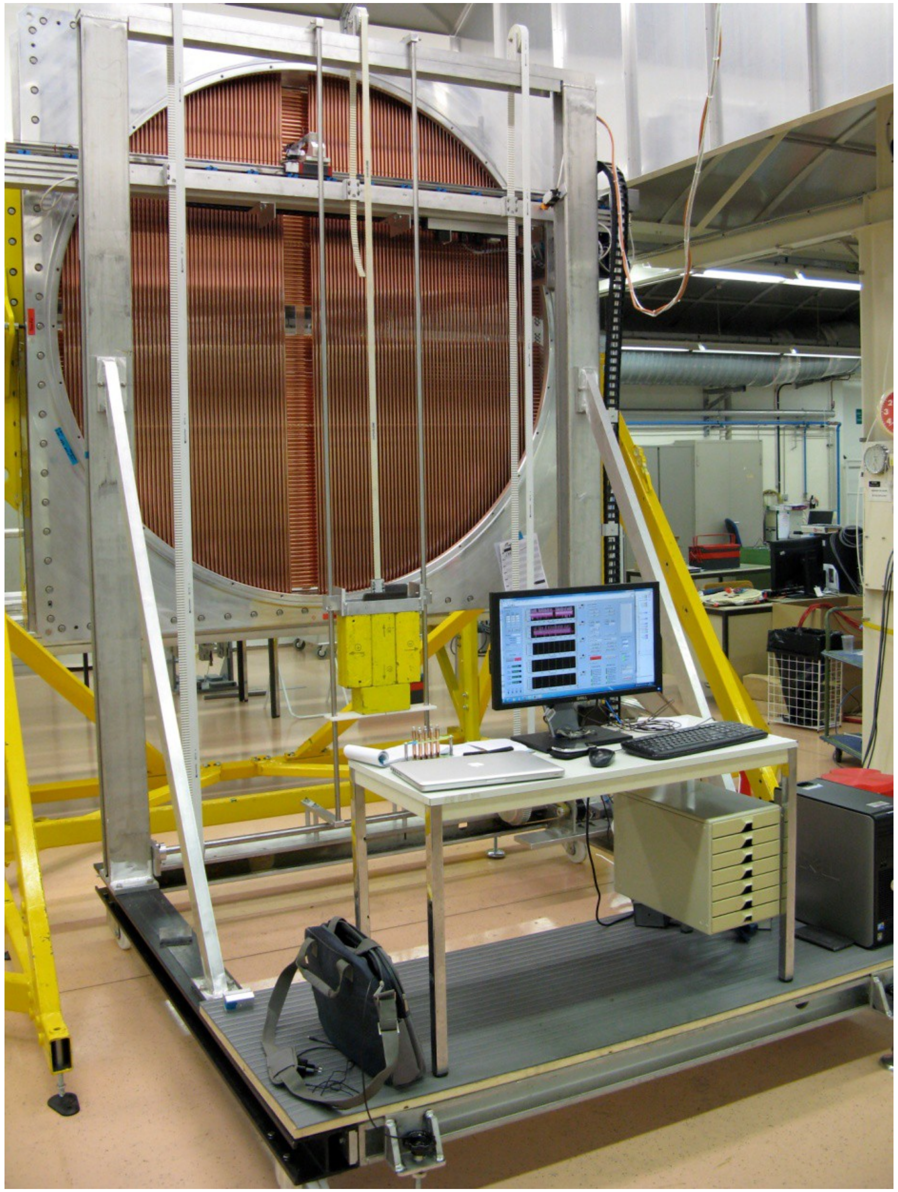


- Straws: 2.1m long and φi =9.8mm;
- Straw : 50 nm Cu + 20 nm Au on 36 μm of My
- Total 7168 Straws (4x4x4x112)

STRAW: module 1

896 straw tubes



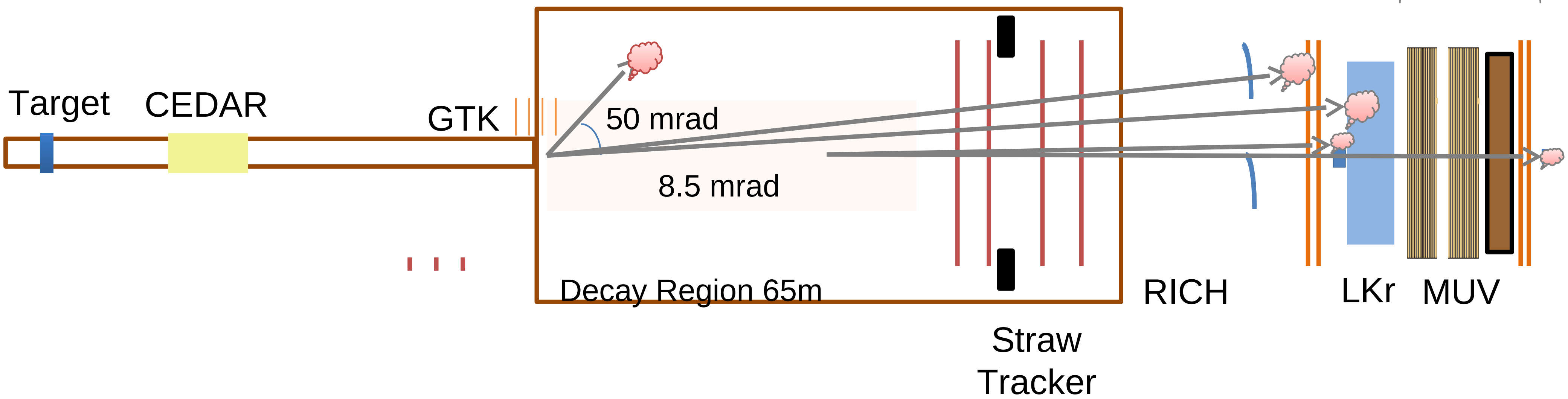


I quattro (+1) criteri progettuali

(3) Sistema ermetico di veto

Photon Veto's
- Large Angle Veto: 8.5 -50mrad
- LKR: 1 – 8.5 mrad
- Small Angle Veto ≤ 1mrad

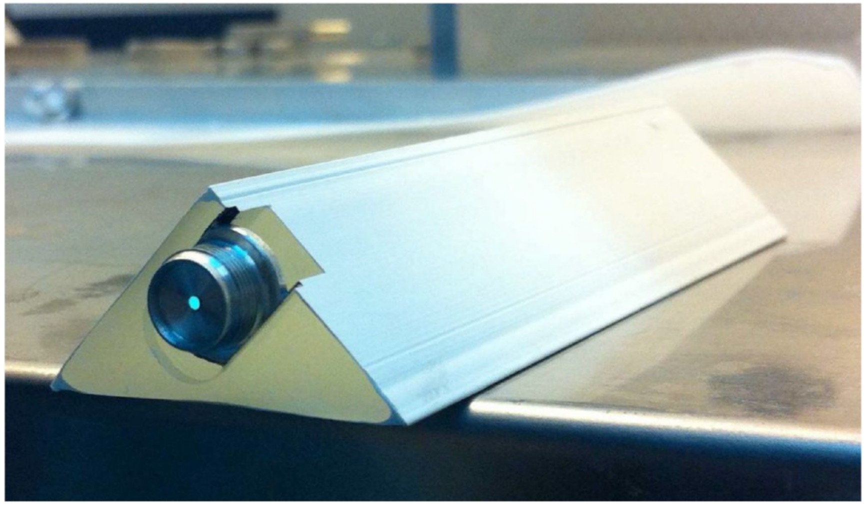
Fast Muon Veto's

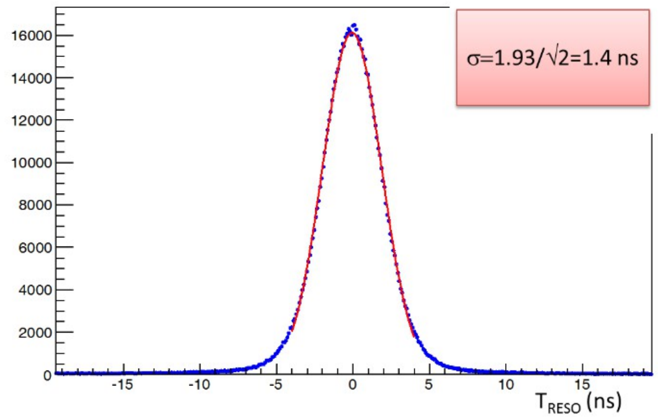


- Inefficiency for rejection of the π 0 must be at the level of 10-8
- Photon detection inefficiencies between 10-4 and 10-5

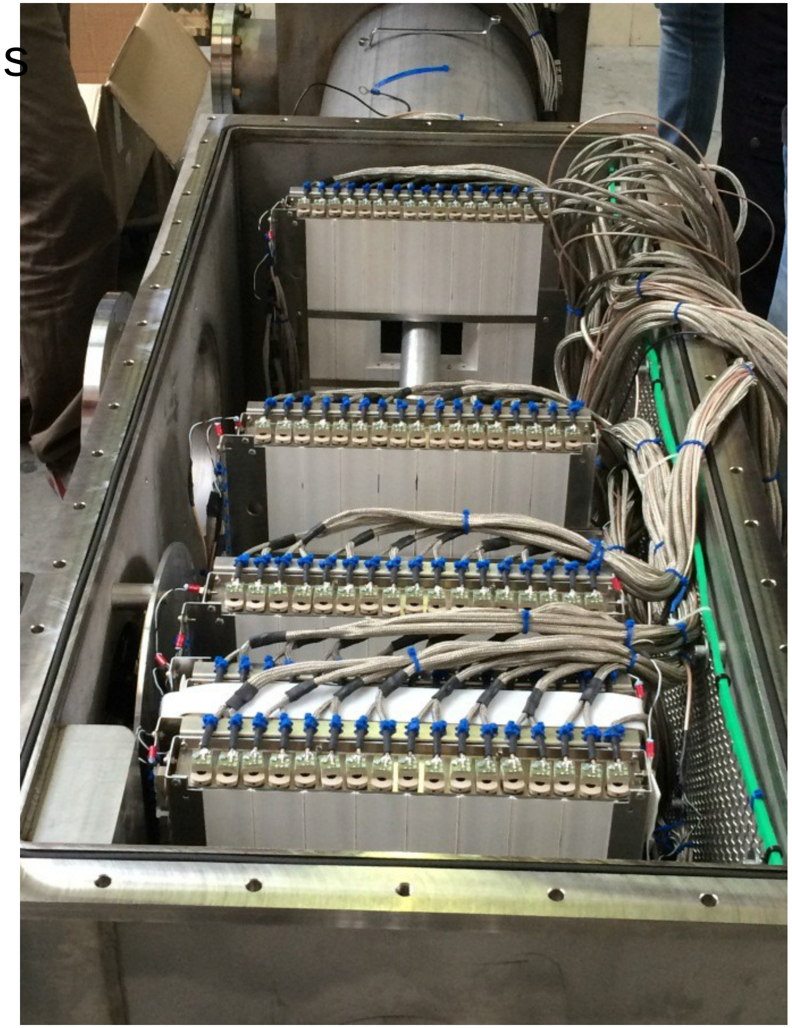
CHANTI

Tagging of background from inelastic interactions





Time resolution



The CHANTI detects the charged particles produced by inelastic interactions in GTK3

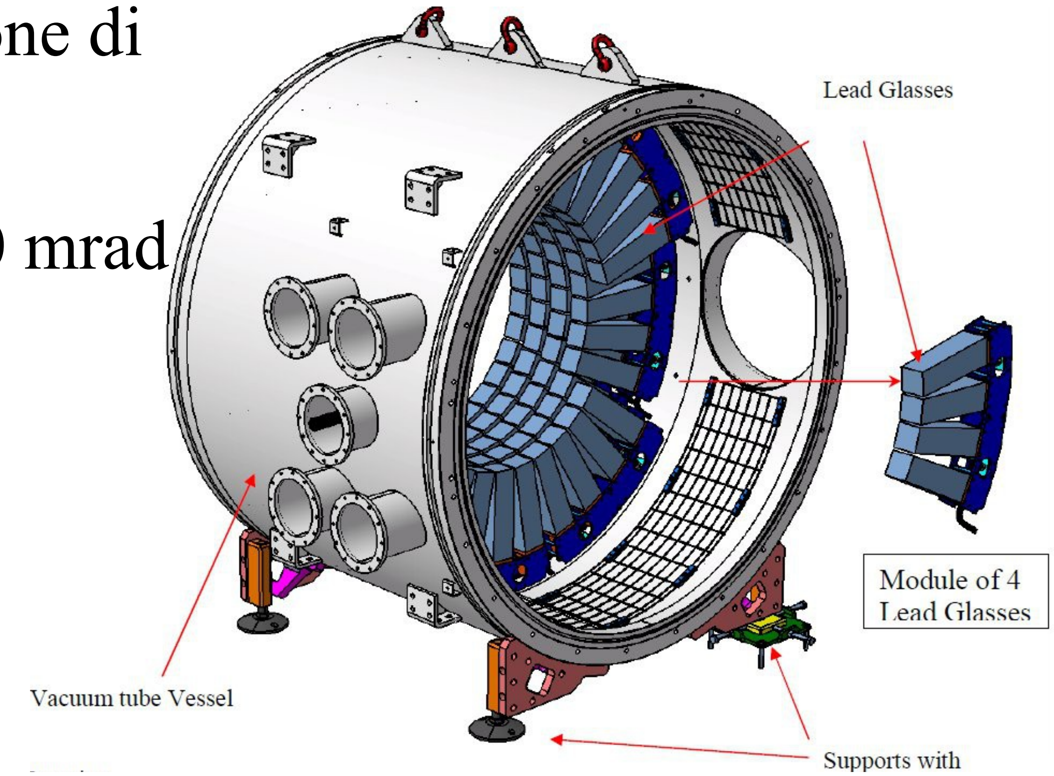
Veto a largo angolo (LAV)

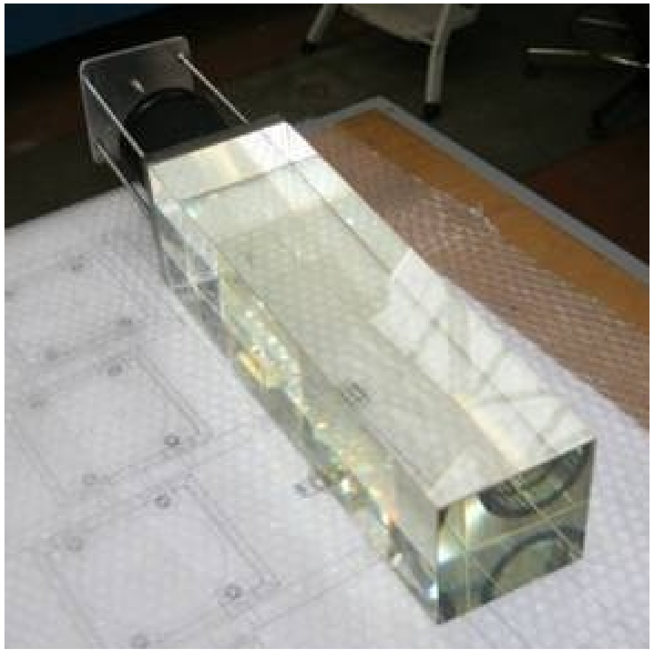
12 stazioni (ad anello) lungo la regione di decadimento (in vuoto)

Piena copertura angolare fra 8.5 e 50 mrad

I vetri-piombo del calorimetro dell'esperimento OPAL sono stati riutilizzati

Piu di 2500 cristalli (canali) in totale

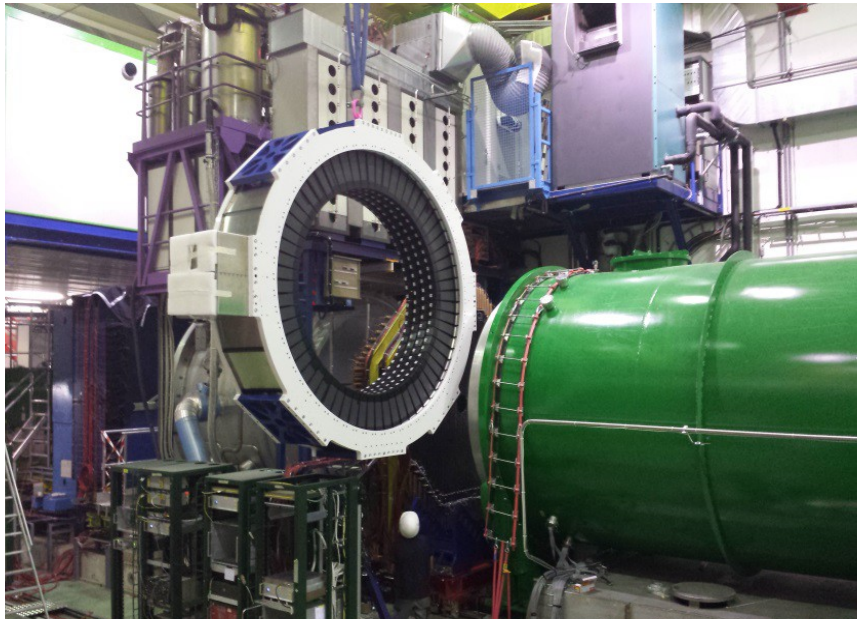


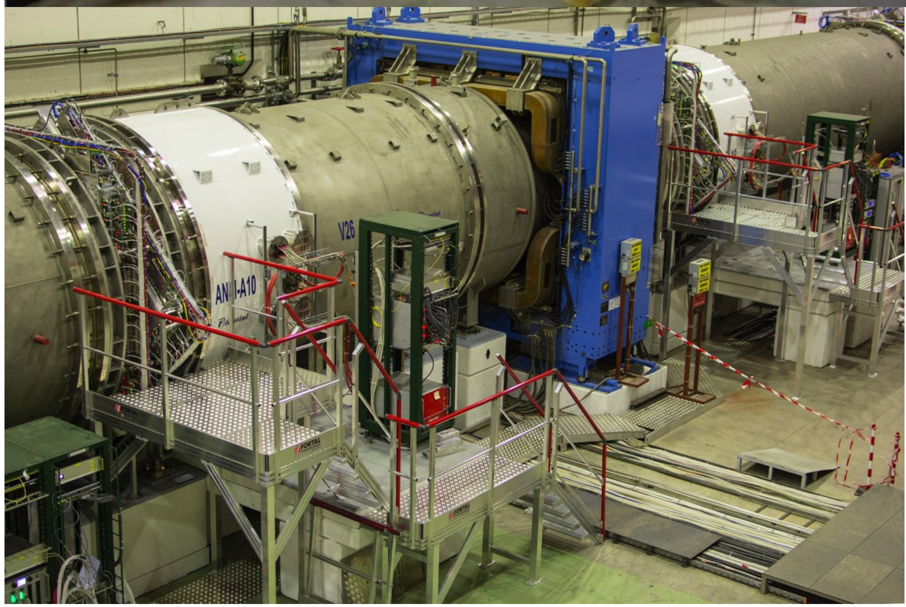


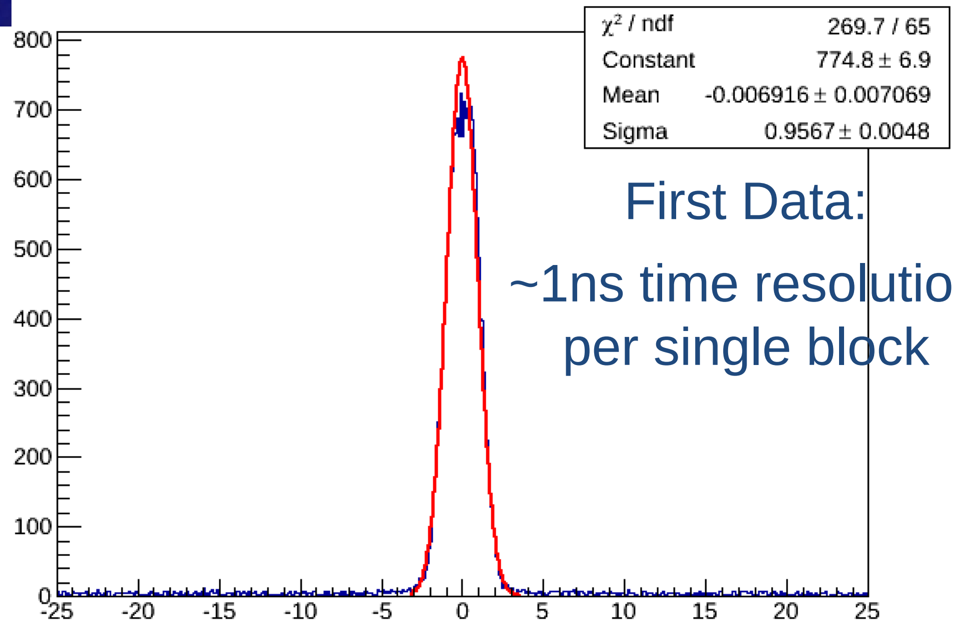
Blocchi controllati e testati a Frascati:

- inefficienza $< 10^{-4}$ per positroni a 476 MeV
- risoluzione temporale di 700 ps

Large Angle Veto (12 Modules)





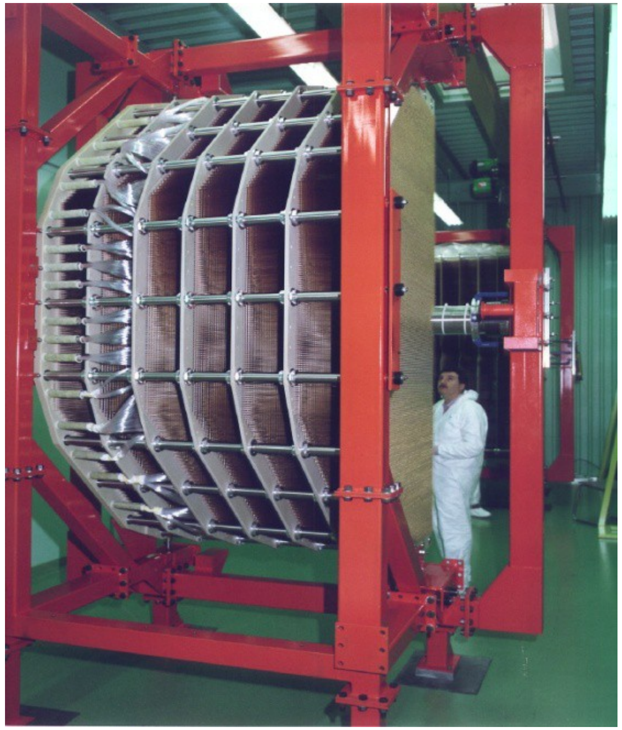


LAVs

- 8 LAV lungo la regione di decadimento fiduciale

Veto ad angoli intermedi (LKr)

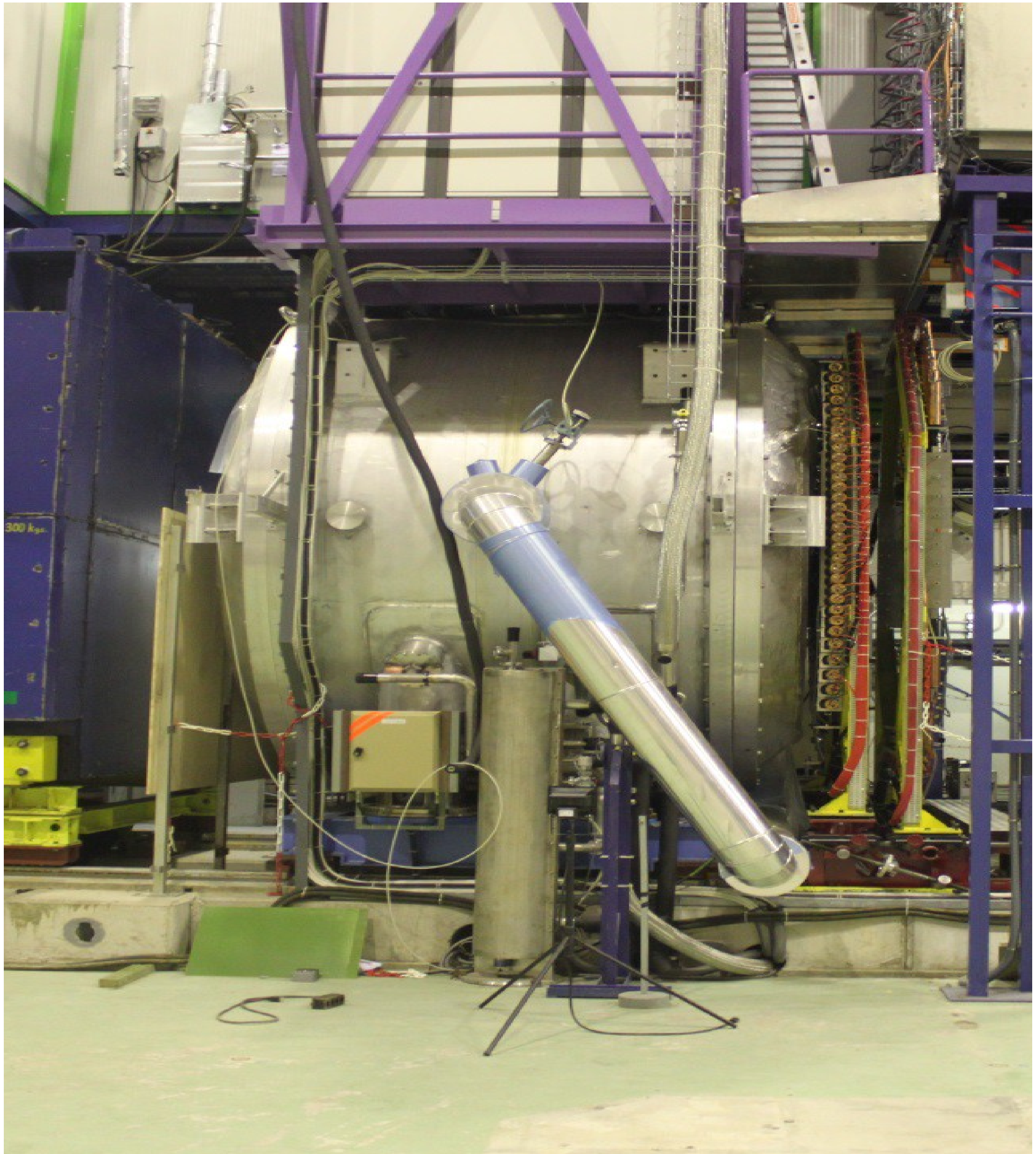
- Fra 1.5 e 8 mrad viene riutilizzatto il vecchio calorimetro elettromagnetico a kripton liquido di NA48
- Più di 13000 celle quasi omogenee (poco materiale passivo)
- 27 lunghezze di radiazione X_0
- Ottima risoluzione nella misura dell'energia
- Ottima risoluzione temporale (200 ps)
- Misura posizione (cm)

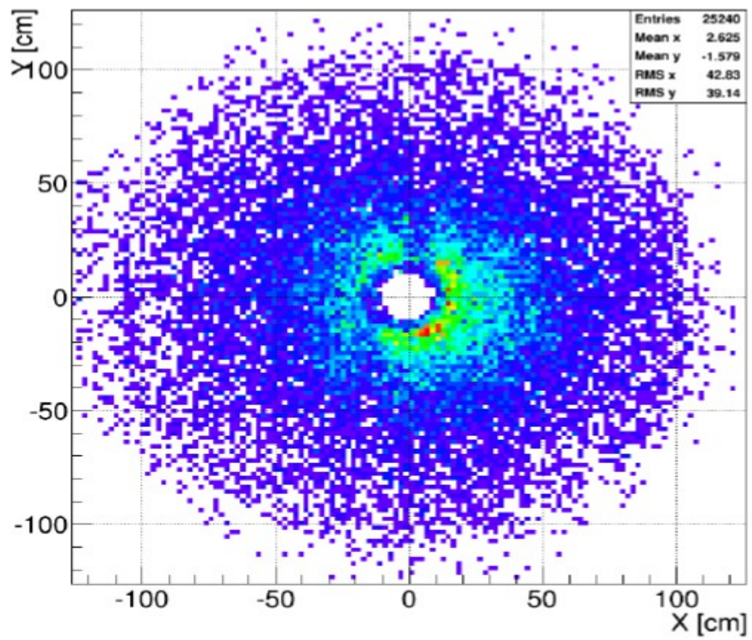


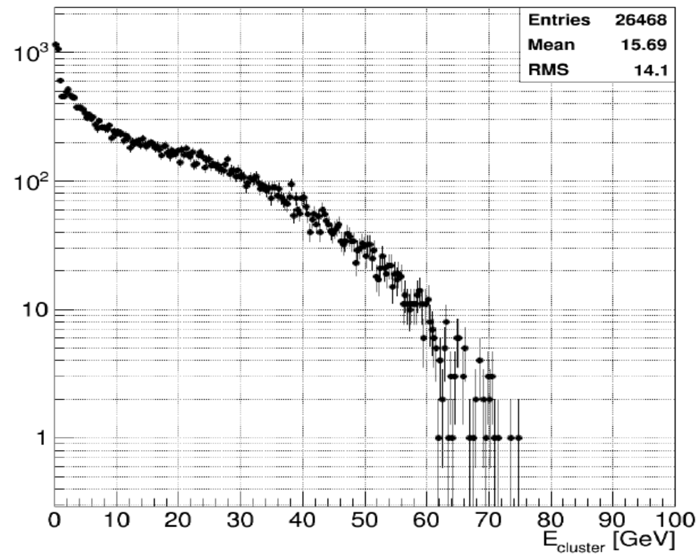
Le prestazioni come rivelatore in veto sono state misurate con un presa dati dedicata ed un fascio di K a 75 GeV

Energy(GeV)	Inefficiency
2.5-5.5	10^{-3}
5.5-7.5	10^{-4}
7.5-10	$5x10^{-5}$
>10	$8x10^{-6}$

Calorimetro a Krypton liquido (LKr)



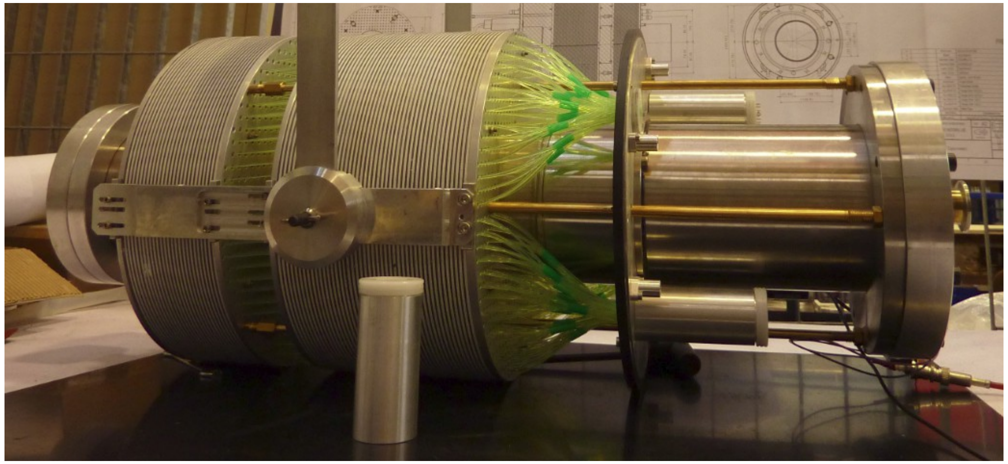




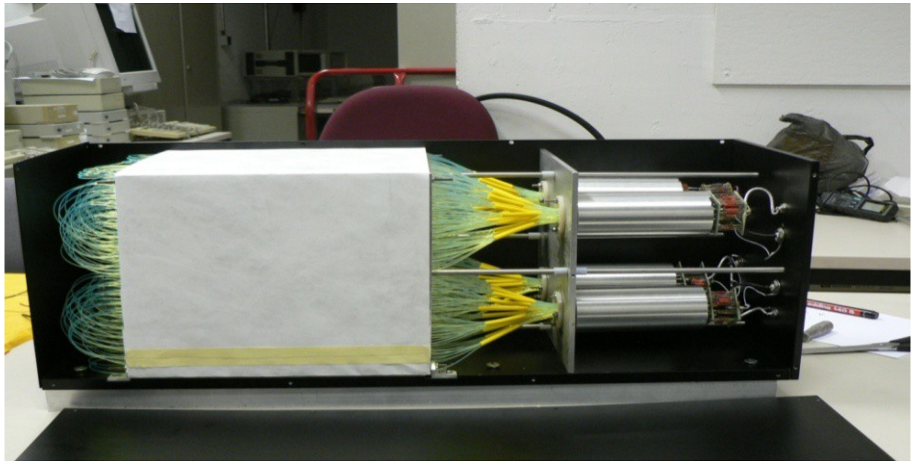
Veto a piccoli angoli (SAV)

Two Shashlik Calorimeters

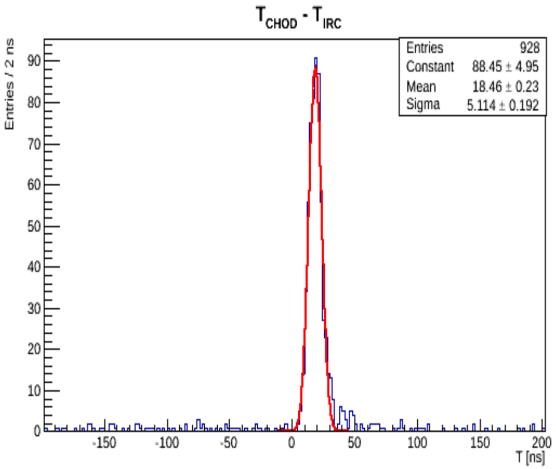
IRC

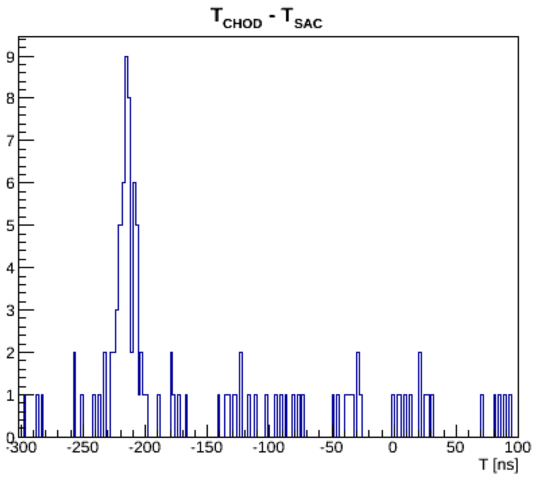


SAC

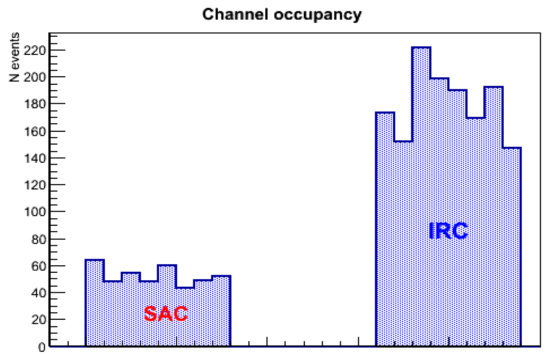


- IRC constructed at LNF
- SAC constructed at Univ. of Sofia
- 2014 run: RO: TDC/TEL62 based readout
- 2015 run: FADC readout





RAW data, no calibration or correction!



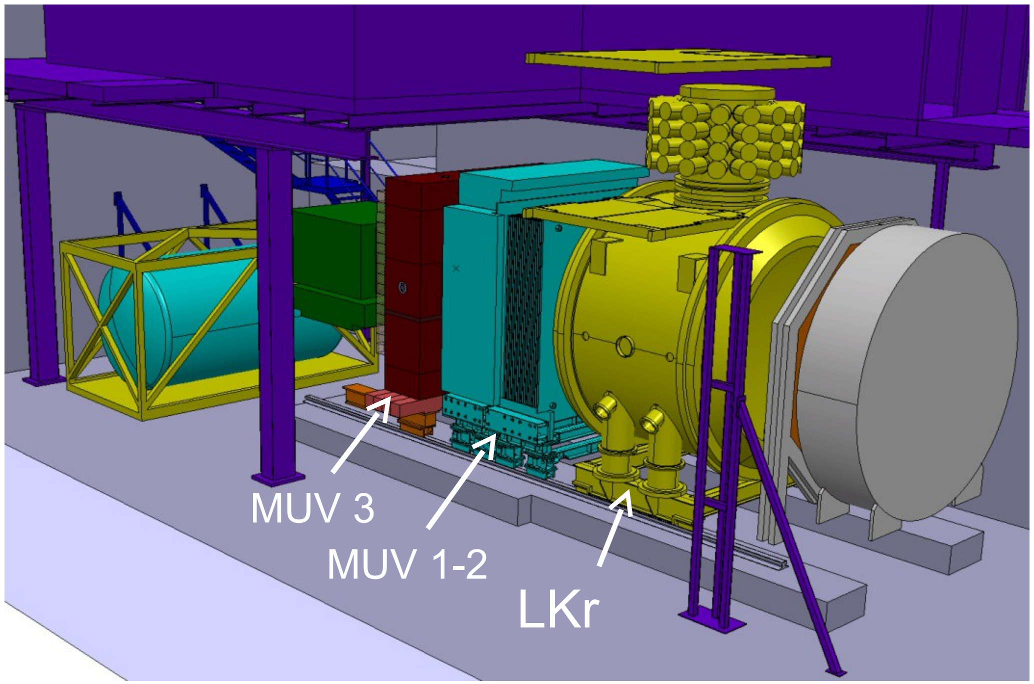
MUV1-2 e MUV3

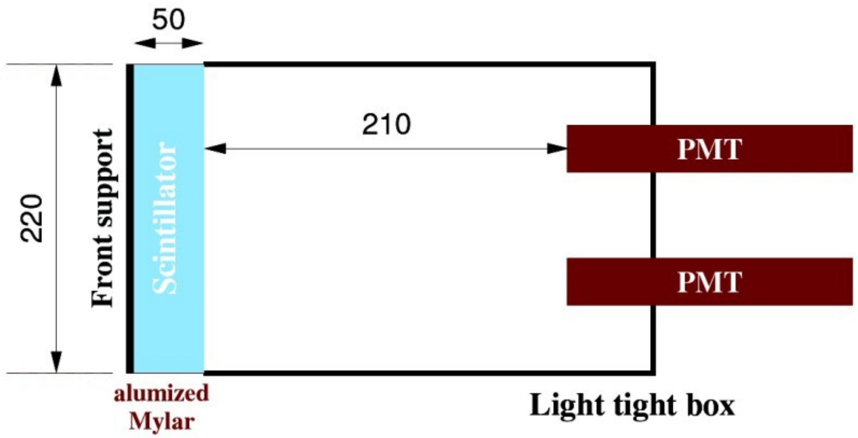
Dopo il calorimetro elettromagnetico ci sono dei blocchi di ferro ai quali sopravvivono solo i μ

MUV1-2: Sandwich ferro-scintillatore, identificano il μ e contribuiscono alla reiezione di decadimenti con μ nello stato finale (assieme al RICH)

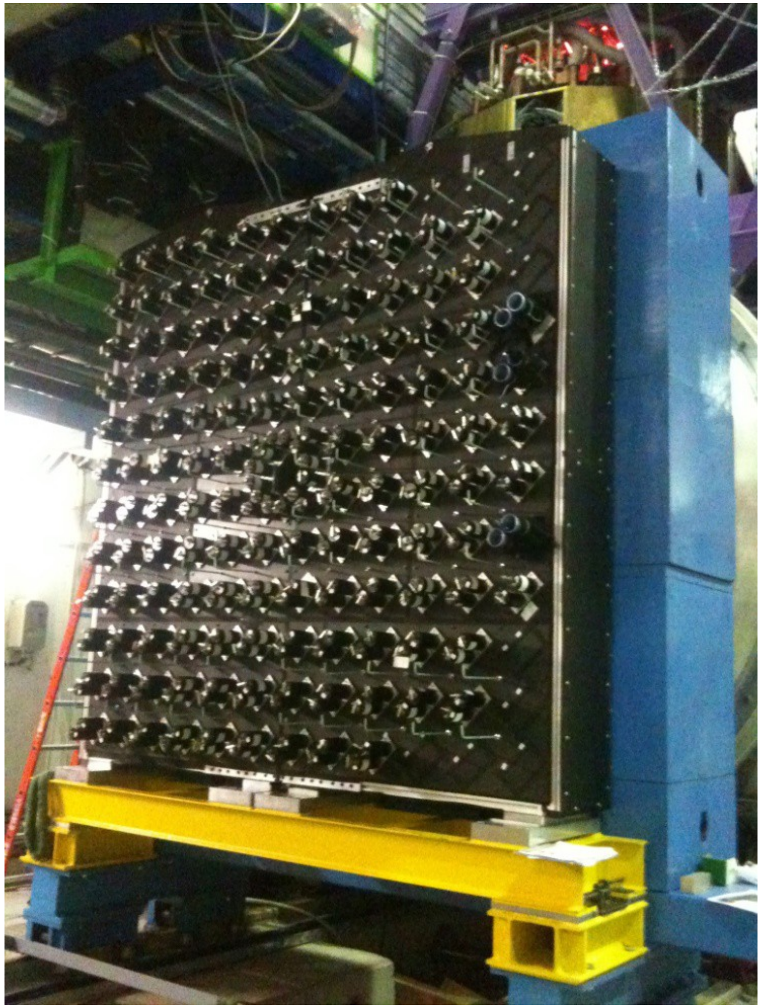
MUV3: Identificazione veloce dei μ a scopi di trigger, moduli di scintillatore con superficie 22x22 cm^2 letti da 2 PM

Risoluzione temporale migliore di 1 ns già raggiunta in test su fascio

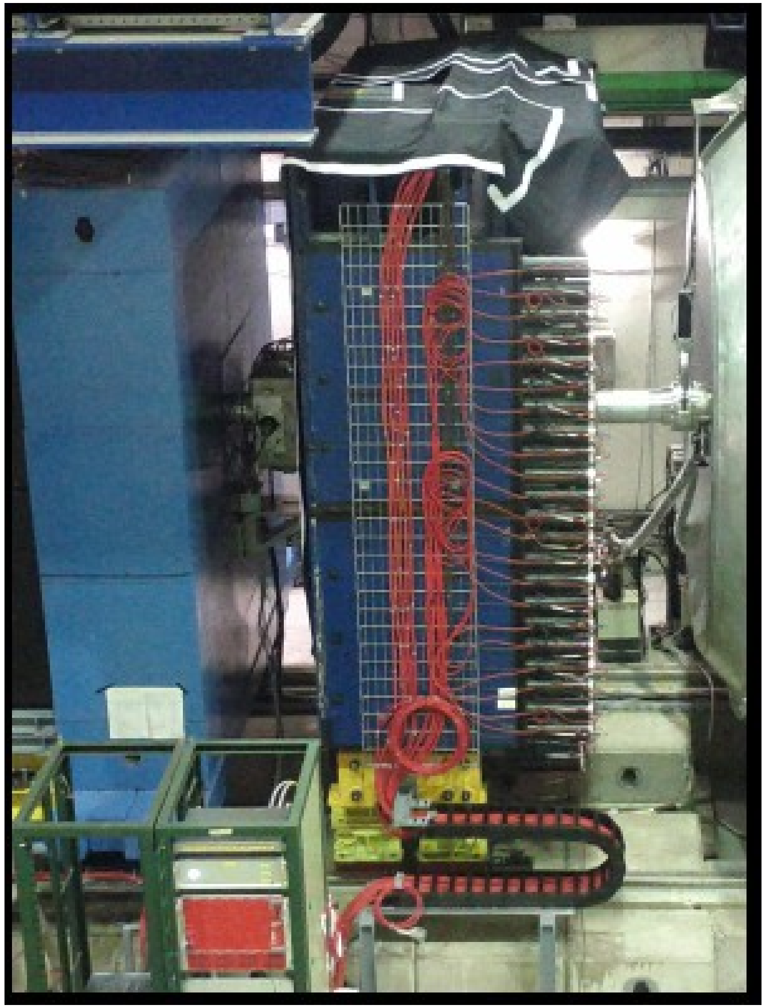




MUV1-2 e MUV3



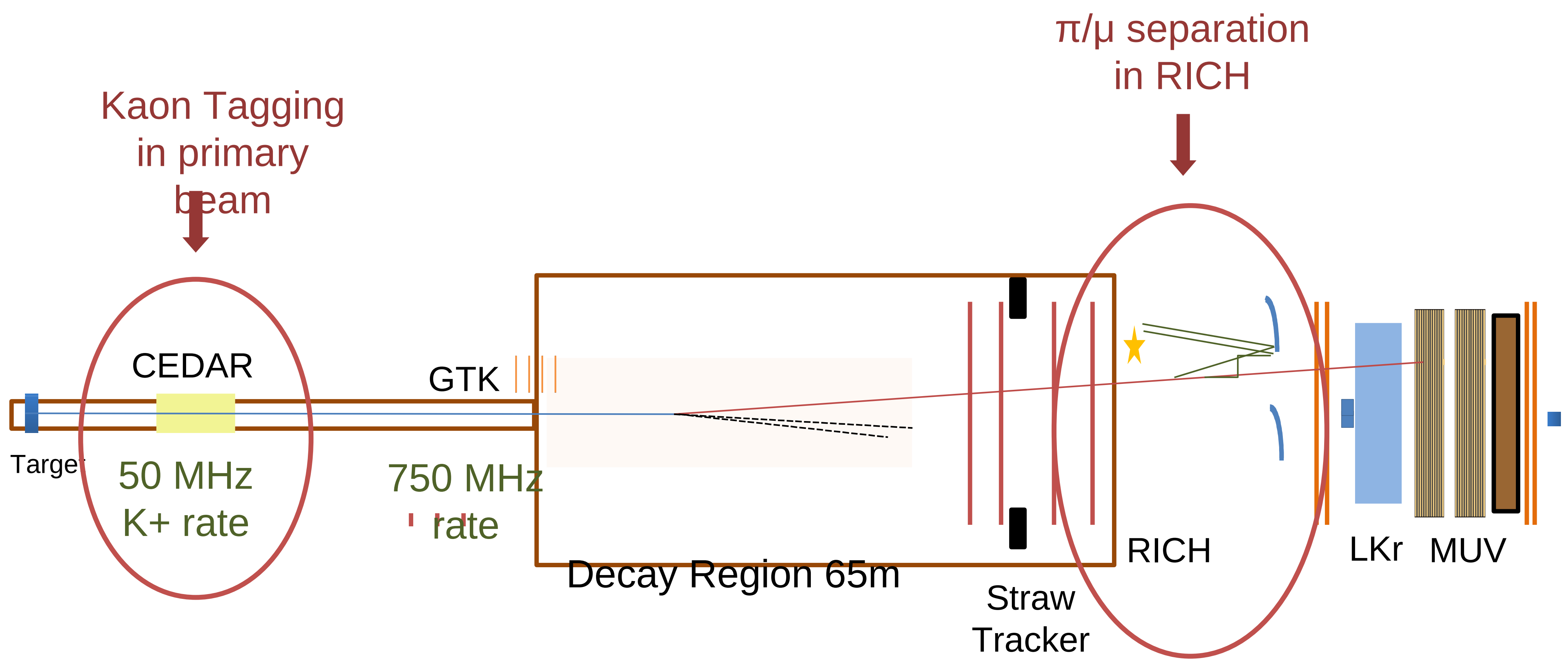
MUV3



MUV1-2

I quattro (+1) criteri progettuali

(4) Identificazione particelle



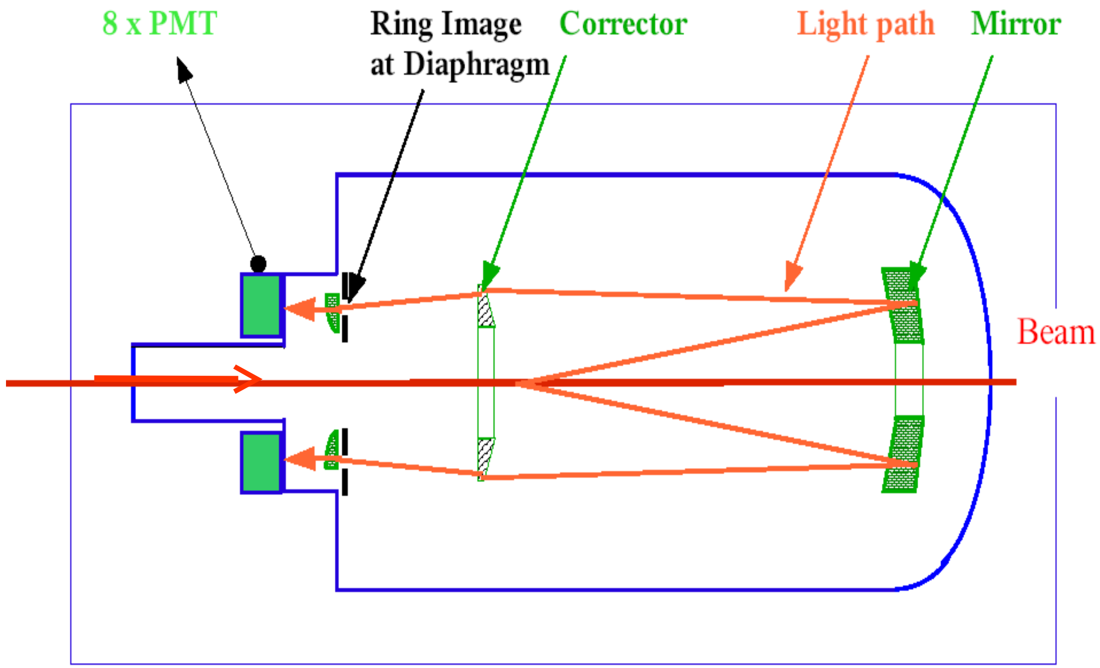
Identificazione K del fascio (CEDAR)

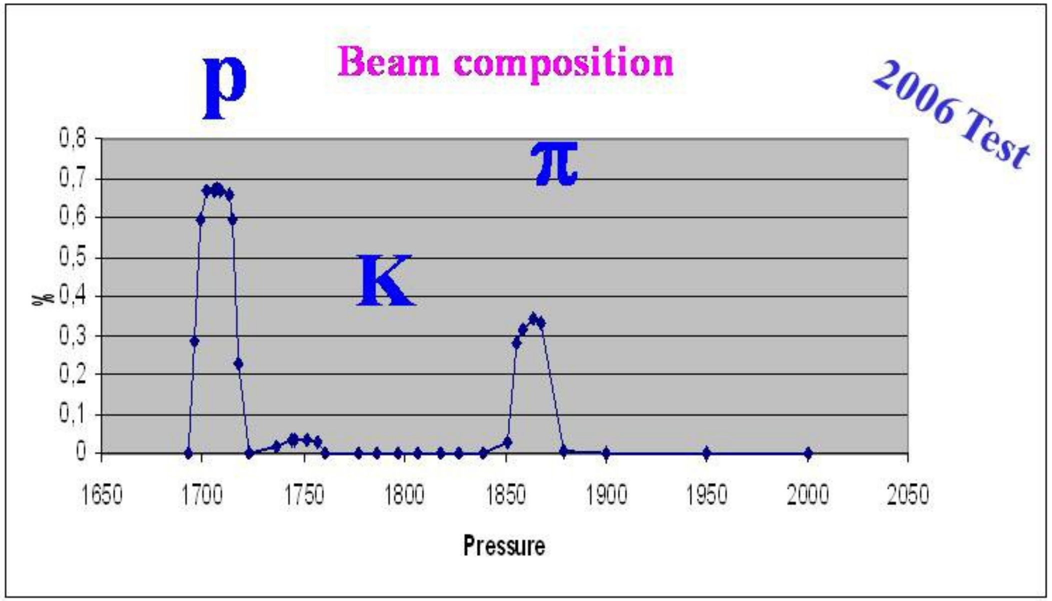
Scopo: Identificazione del Kaone nel fascio non separato per associarlo temporalmente ai prodotti di decadimento rivelati a valle.

Tecnica: Rivelatore Cherenkov differenziale (il radiatore e H_2 a 3,5 Atm)

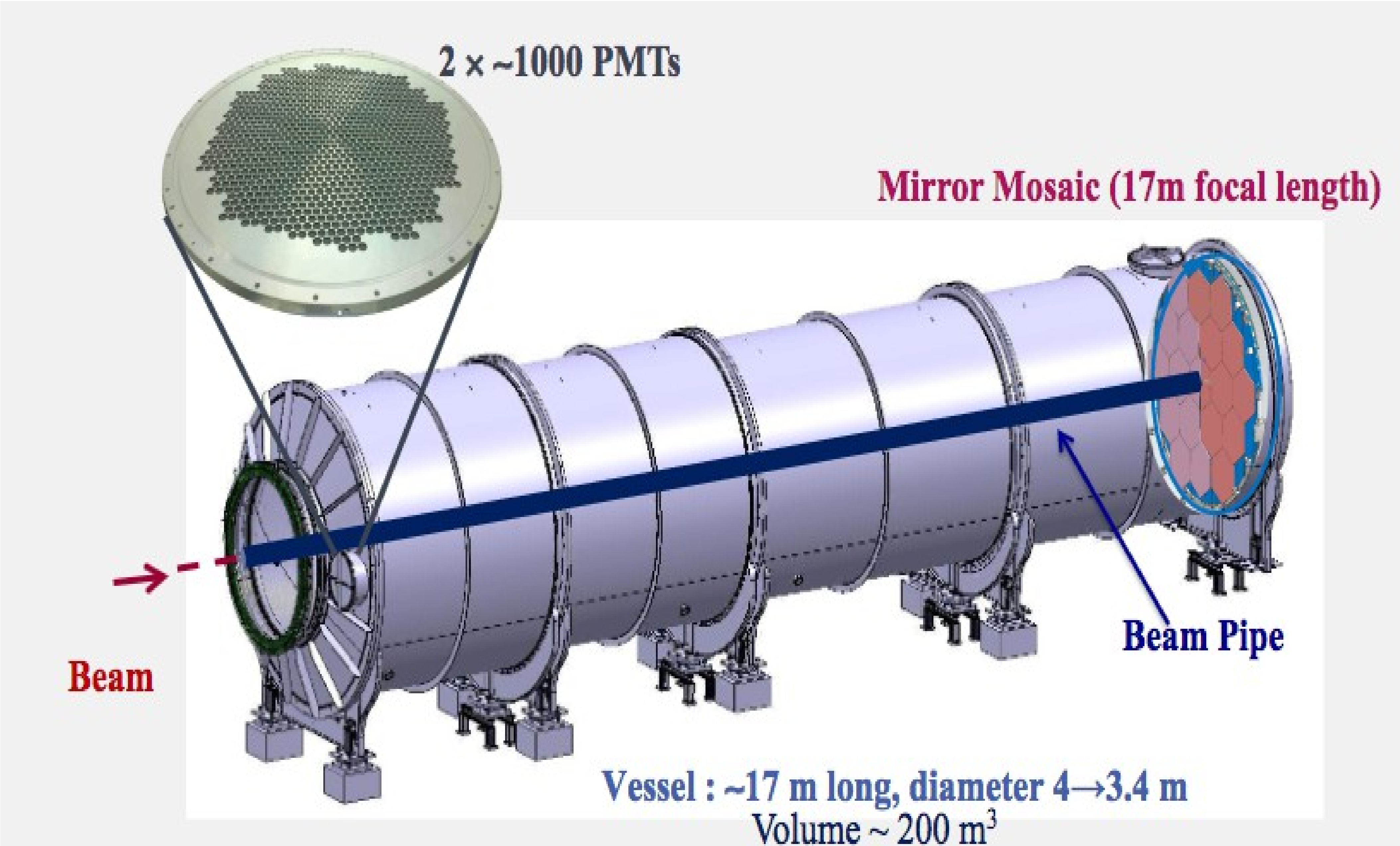
- riutilizzato un vecchio rivelatore costruito al CERN negli anni ’70

$$\cos(\theta c) = c/nv$$
$$P = m\gamma v$$

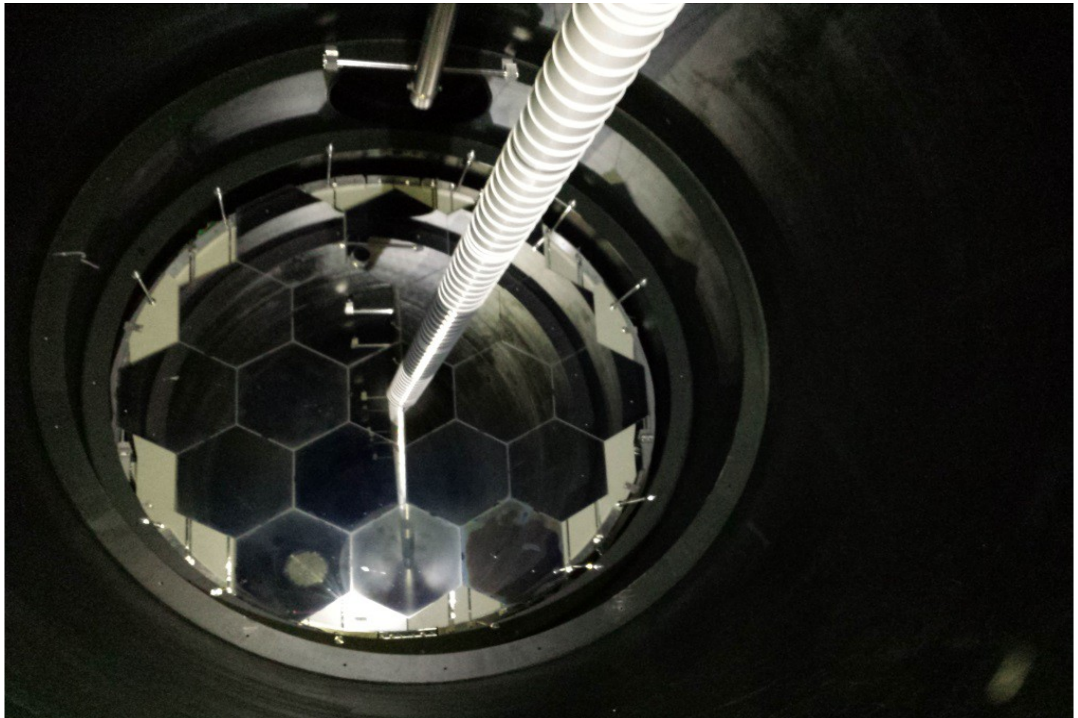




RICH Detector =>π/μ Separation

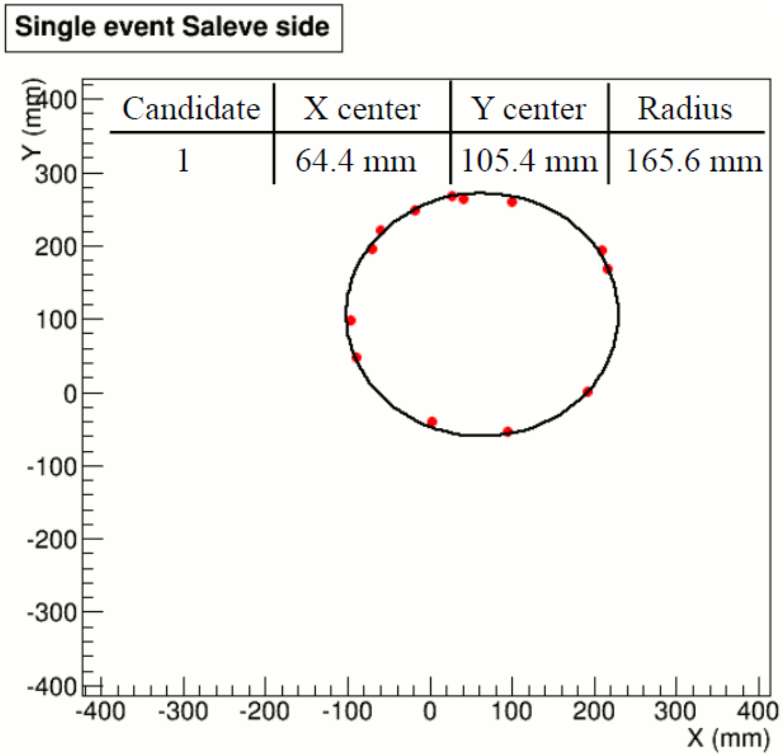


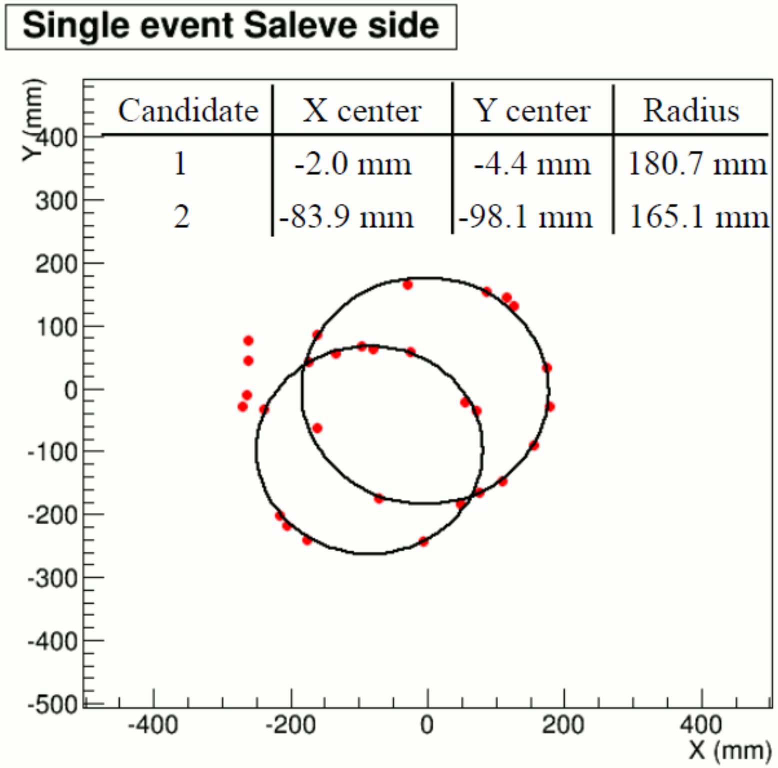
RICH Detector



RICH

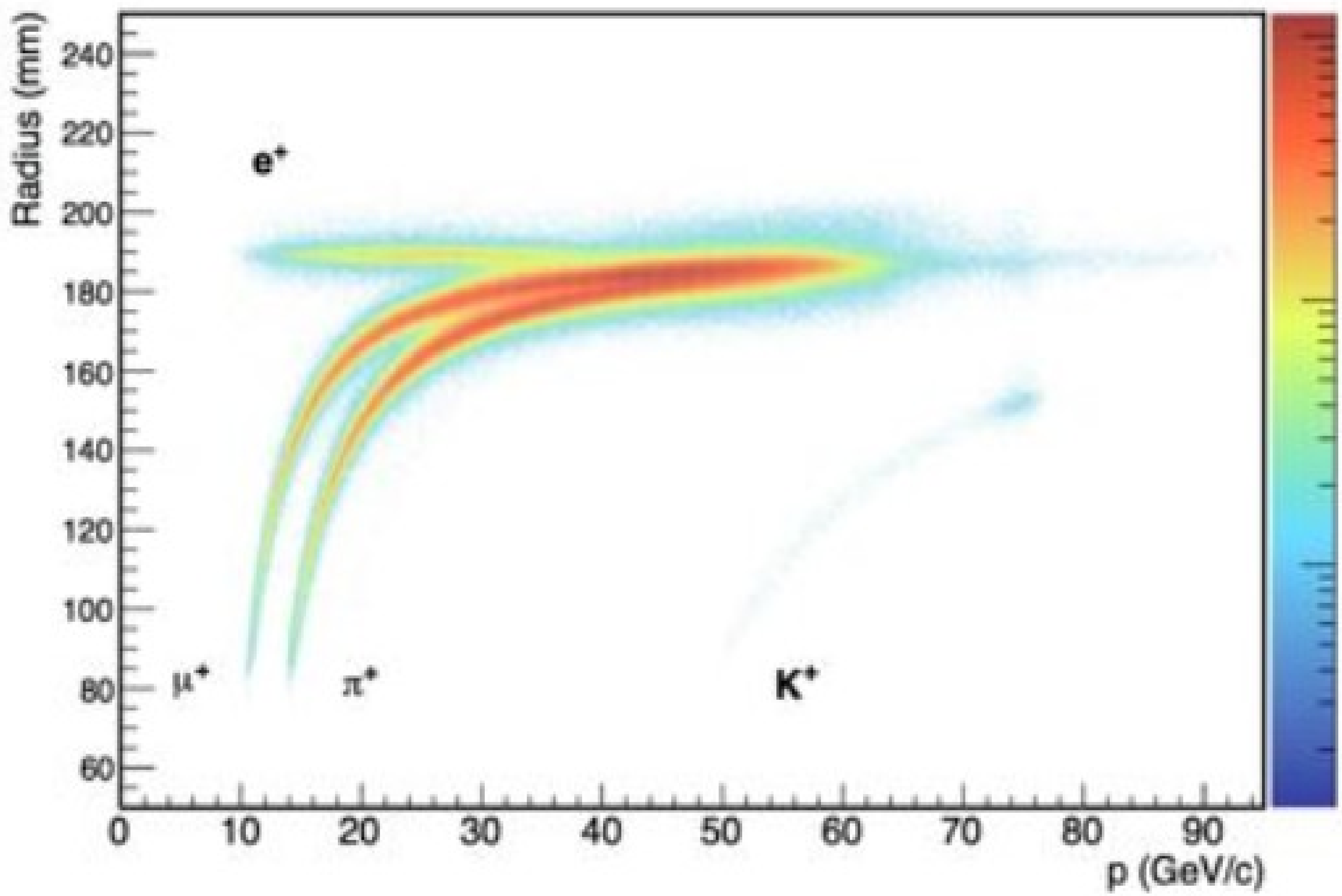
RICH RINGS





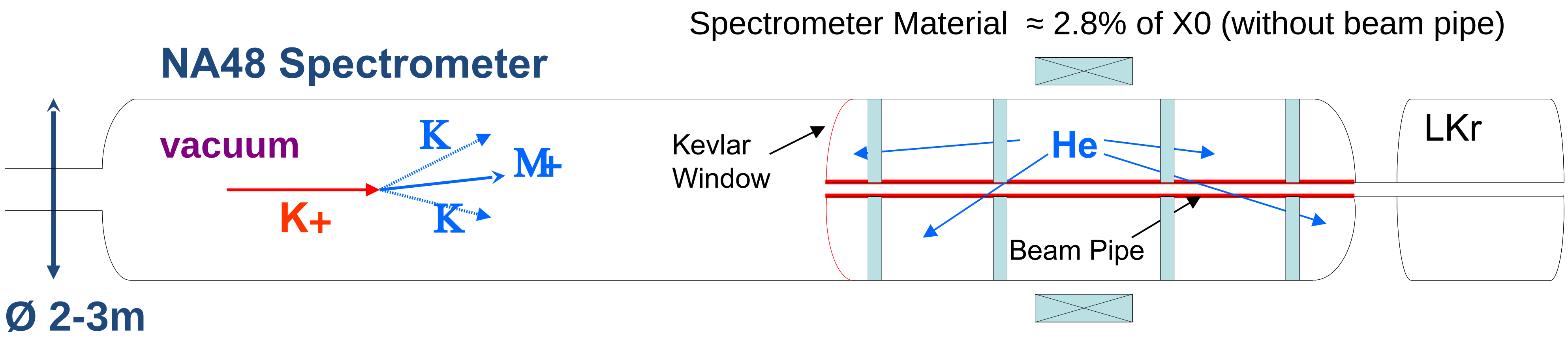
event time resolution = 100 ps

RICH particle identification

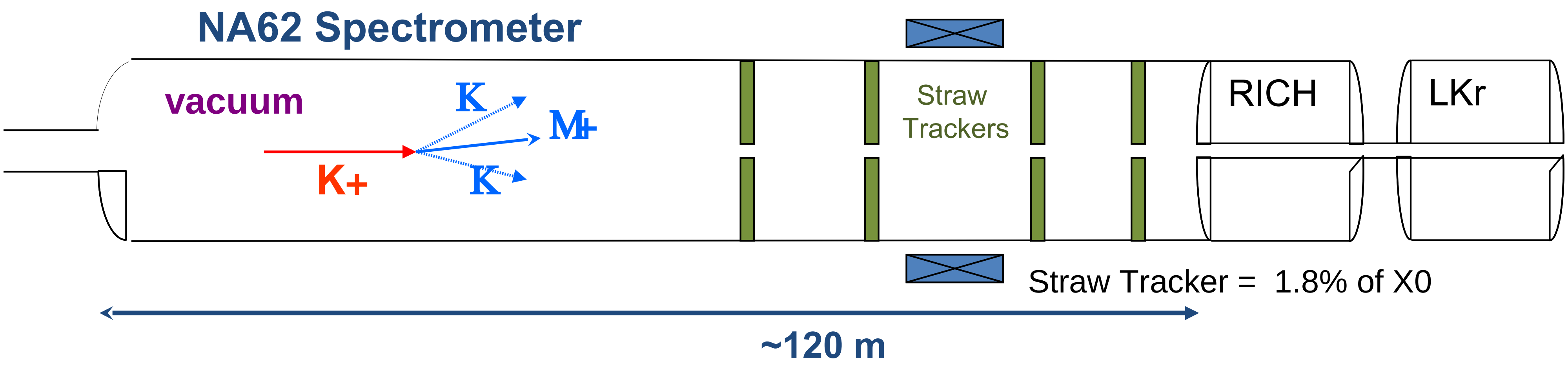


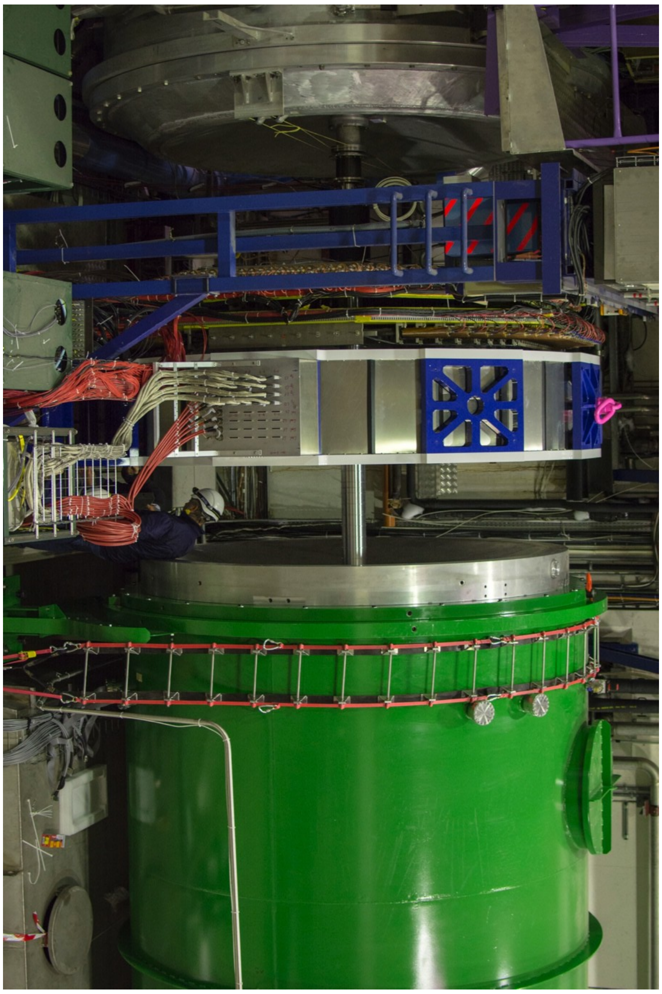
I quattro (+1) criteri progettuali

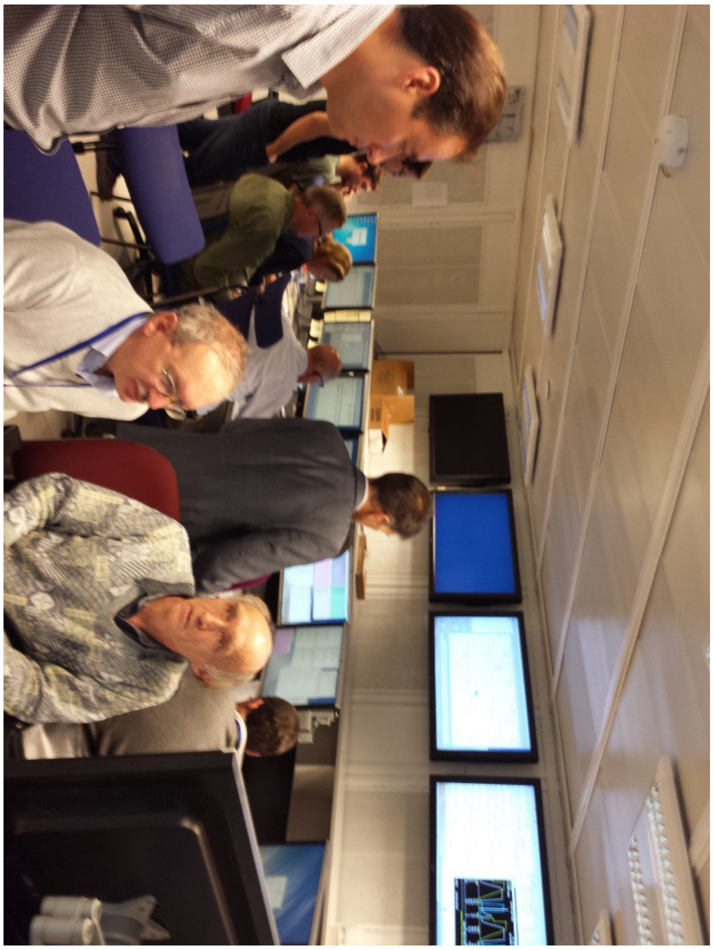
(+1) riuso rivelatori di NA48 (e non solo...)

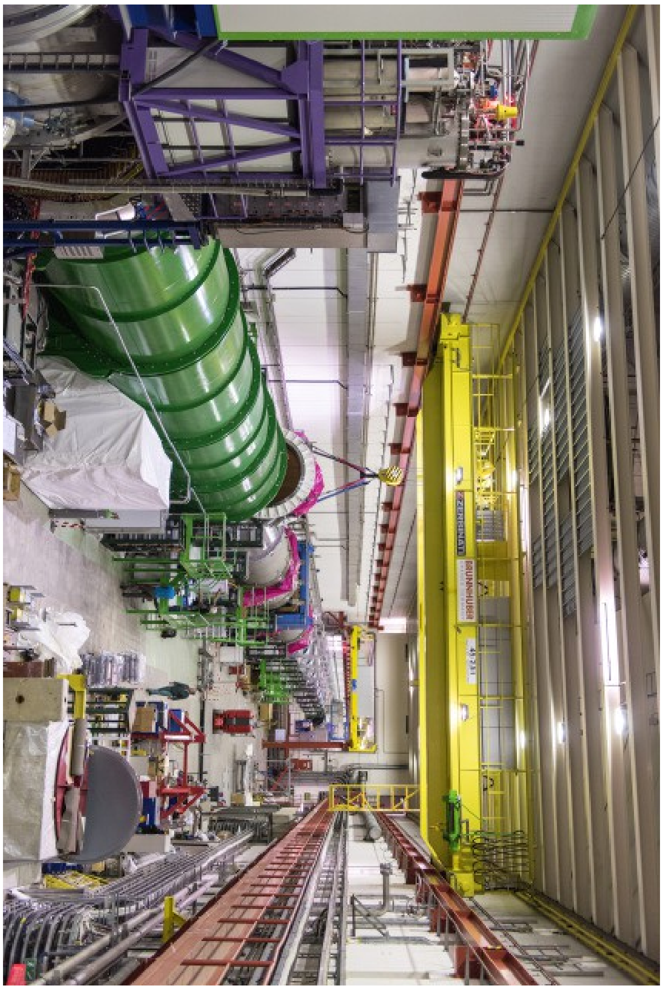


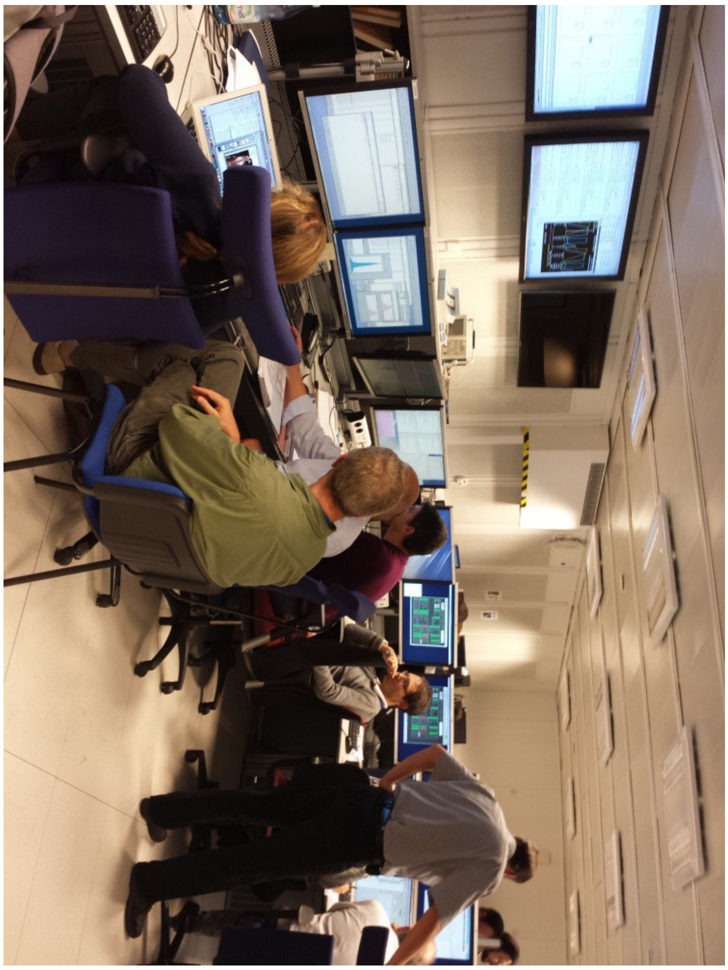
The Straw Trackers operated in vacuum will enable us to:
- Remove the multiple scattering due to the Kevlar Window
- Remove the acceptance limitations due to the beam-pipe
- Remove the helium between the chambers











NA62 Collaboration

Belgium, Bulgaria, Canada, Czech Republic, Germany, Italy, Mexico, Romania, Russia, Slovakia, CERN, United Kingdom and United States