NA62/P-326: Status of the R&D

Augusto Ceccucci/CERN

for the Collaboration*

Proposal to Measure the Rare Decay $K^+ \to \pi^+ \nu \bar{\nu}$ at the CERN SPS

CERN-SPSC-2005-013
SPSC-P-326

***Bern ITP, Birmingham, CERN, Dubna, Ferrara, Fairfax, Florence, Frascati, IHEP, INR, Louvain, Mainz, Merced, Naples, Perugia, Pisa, Rome I, Rome II, San Luis Potosi, SLAC, Sofia, Triumf, Turin**

Physics Motivation

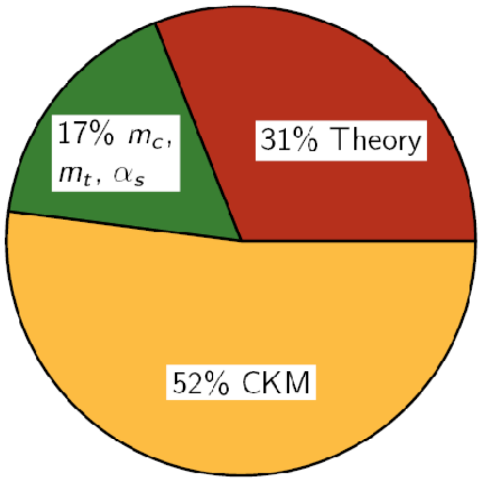
In Standard Model:

$$B(K^+ \rightarrow \pi^+ \nu \bar{\nu}(\gamma)) = k_+ (1+\Delta_{EM}) \times \frac{|V_{ts}^* V_{td} X_t(m_t^2) + \lambda^4 \mathrm{Re} V_{cs}^* V_{cd} (P_c(m_c^2) + \delta P_{c,u})|^2}{\lambda^5}$$

λ= Cabibbo Angle

- **NLO QCD [Buchalla, Buras '94], [Misiak, Urban '99], [Buchalla, Buras '99]**
- **Charm**
  - **NNLO QCD [Buras, Gorbahn, Haisch, Nierste '06]**
  - **EW Corrections to P_c [Brod, Gorbahn '08]**
- **Long Distance**
  - **|ΔE|< 1% [Mescia, Smith '07]**
  - **$\delta P_{c,u}$ +6% [Isidori, Mescia, Smith '05]**

•The SM Prediction error is dominated by the uncertainty on the CKM elements
•The theory error can still be reduced



[J. Brod @ CKM'08]

SM Prediction vs. Experiment

As reported by J. Brod, CKM '08

$$B^{TH}(K^+ \to \pi^+ \nu\bar{\nu}(\gamma)) = (0.85 \pm 0.07) \times 10^{-10}$$

For m_c=(1286 ± 13) MeV [Kühn et al. '07]

$$B^{EXP}(K^+ \to \pi^+ \nu\bar{\nu}(\gamma)) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$$

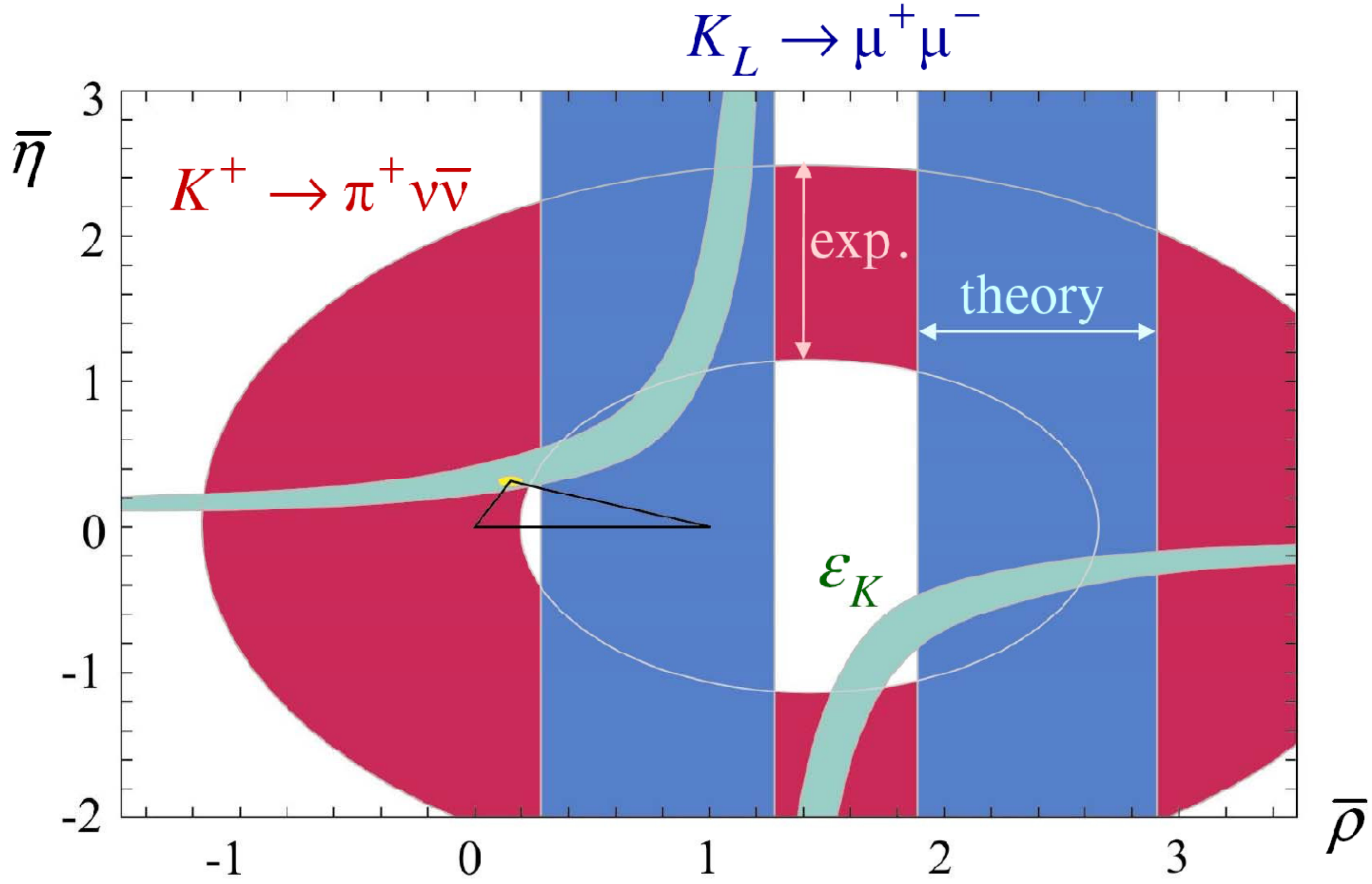
[E787, E949 '08]

And, for comparison:

$$B^{TH}(K^0_L \to \pi^0 \nu\bar{\nu}) = (2.76 \pm 0.40) \times 10^{-11}$$

$$B^{EXP}(K^0_L \to \pi^0 \nu\bar{\nu}) \le 6.8 \times 10^{-8} \quad 90\%\ \mathrm{CL}$$ [E391a '08]

Kaons and CKM triangle



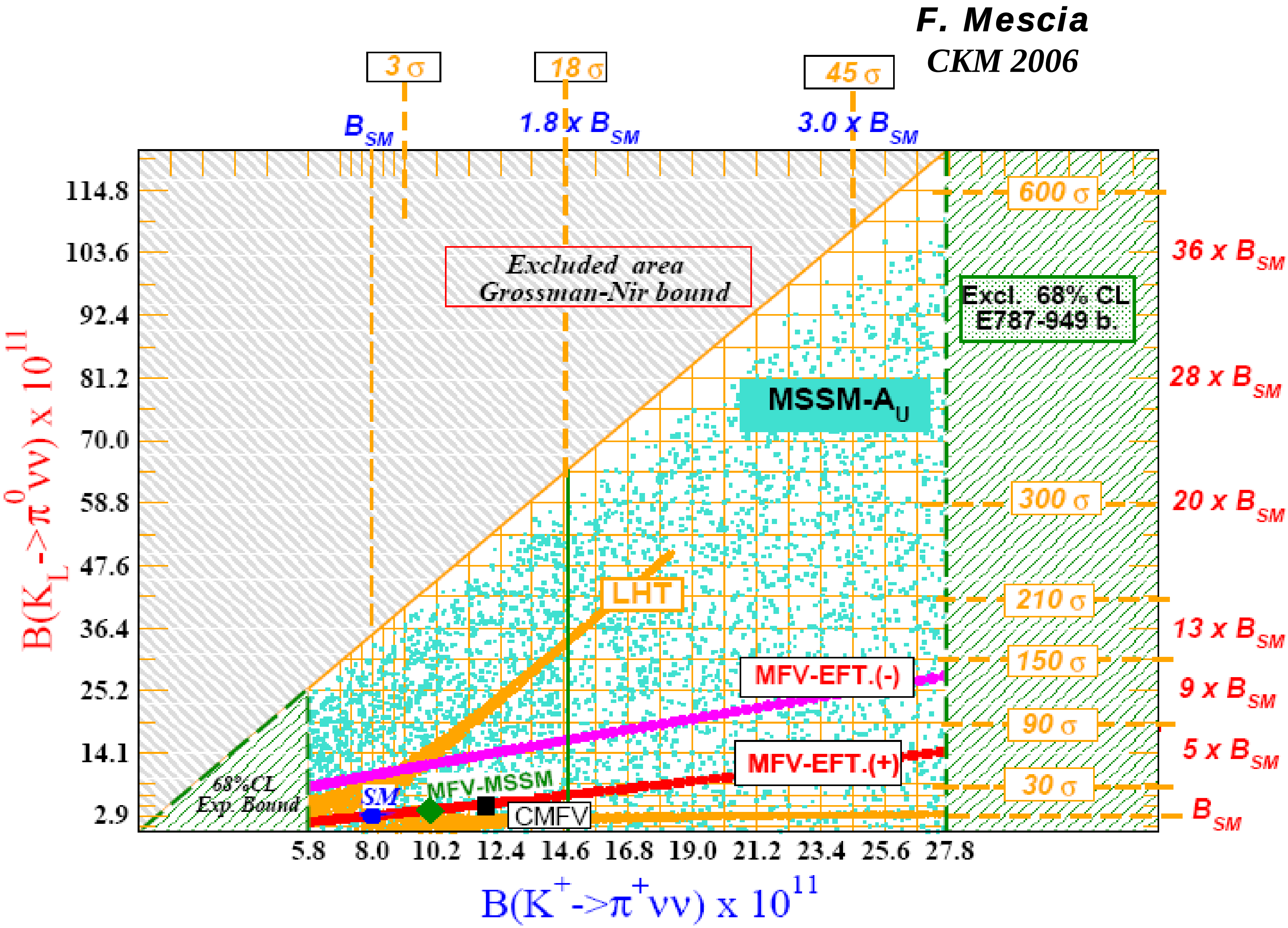
$K_L \to \pi^0\nu\bar{\nu}$:
$\bar{\eta} < 17$

$K_L \to \pi^0 e^+ e^-$:
$\bar{\eta} < 3.3$

$K_L \to \pi^0\mu^+\mu^-$:
$\bar{\eta} < 5.4$

Cristopher Smith @ CKM '08

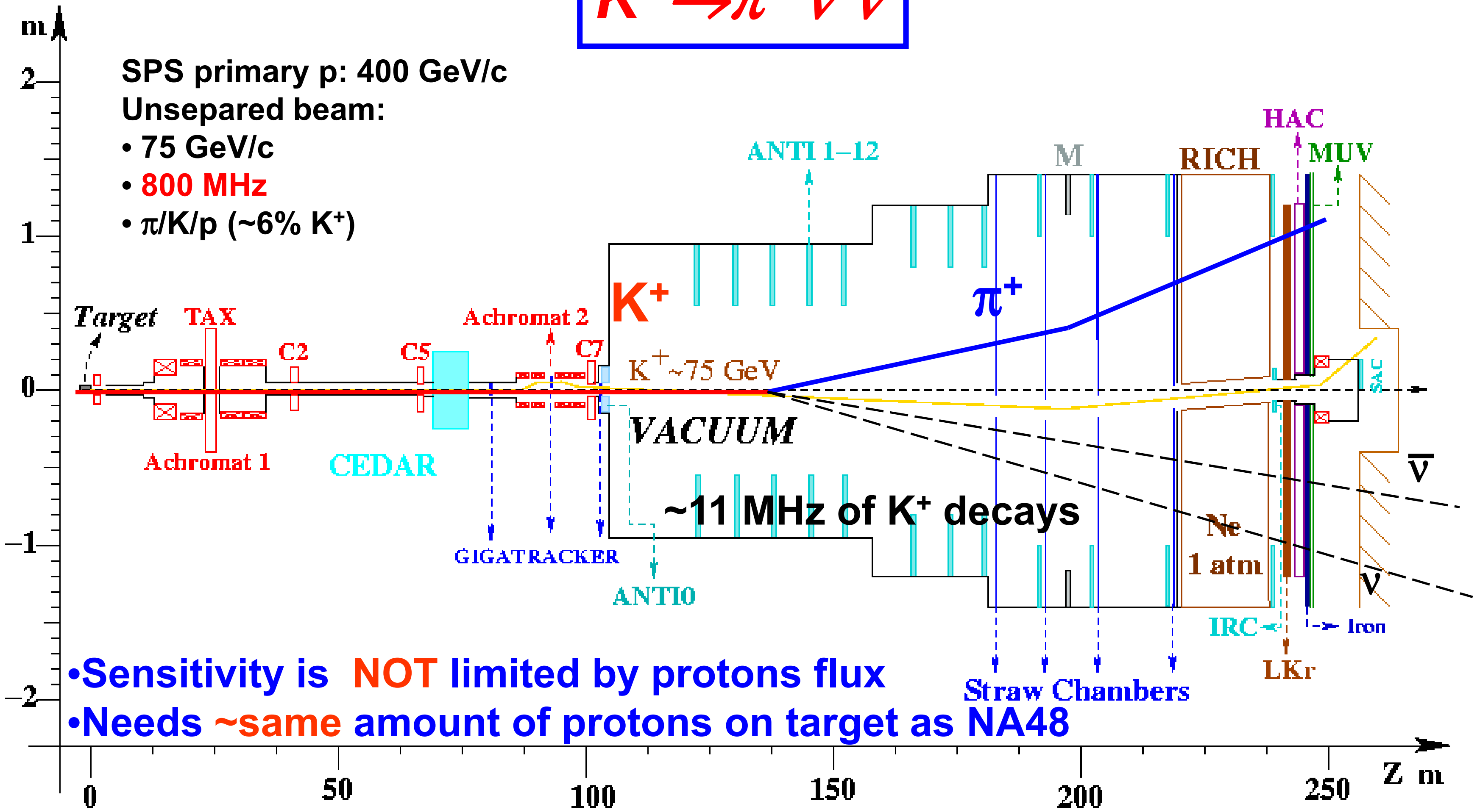
K → π νν & New Physics



Proposed Detector Layout

$K^+ \rightarrow \pi^+ \nu \bar{\nu}$

SPS primary p: 400 GeV/c
Unsepared beam:
- 75 GeV/c
- 800 MHz
- π/K/p (~6% K⁺)



- Sensitivity is NOT limited by protons flux
- Needs ~same amount of protons on target as NA48

Principles of NA62/P-326

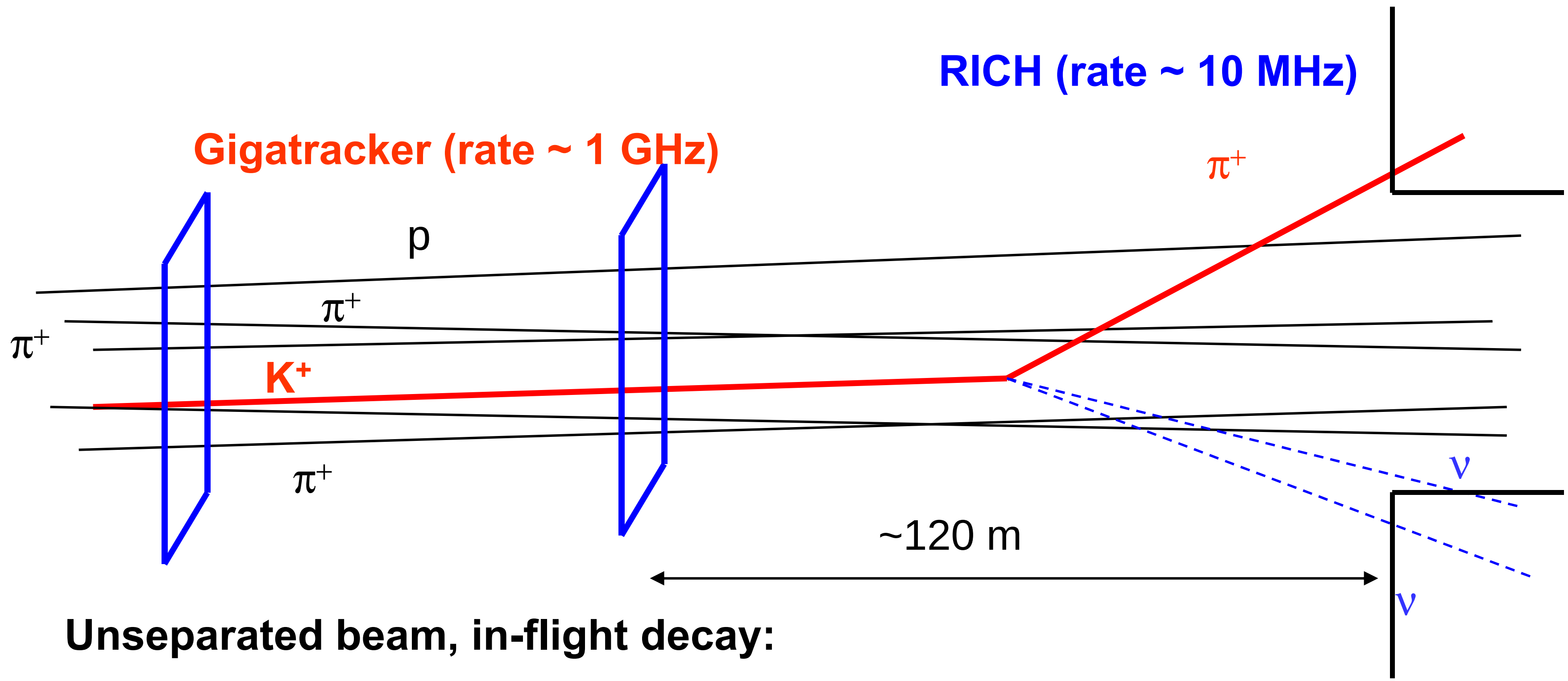
- **High momentum kaon beam to improve the rejection of the π^0 induced backgrounds**
- **Decay in-flight to avoid the scattering and the backgrounds introduced by the stopping target**

The experimental technique exploits:

1. **Precise timing to associate the outgoing π^+ to the correct incoming parent particle (K^+)**
2. **Kinematical Rejection of two- and three-body backgrounds**
3. **Vetoes (γ and μ)**
4. **Particle Identification (K/π, π/μ)**

To achieve the required background suppression, these techniques will be combined together minimising the correlations

1. Precise Timing

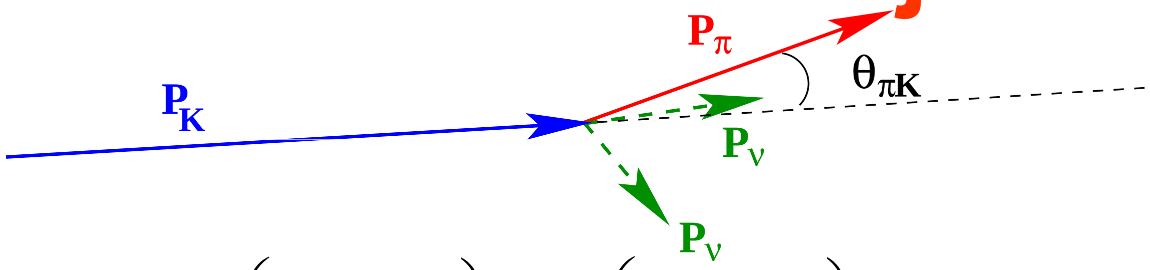


Unseparated beam, in-flight decay:

How do you associate the parent kaon to the daughter pion in a **~1 GHz beam** ?

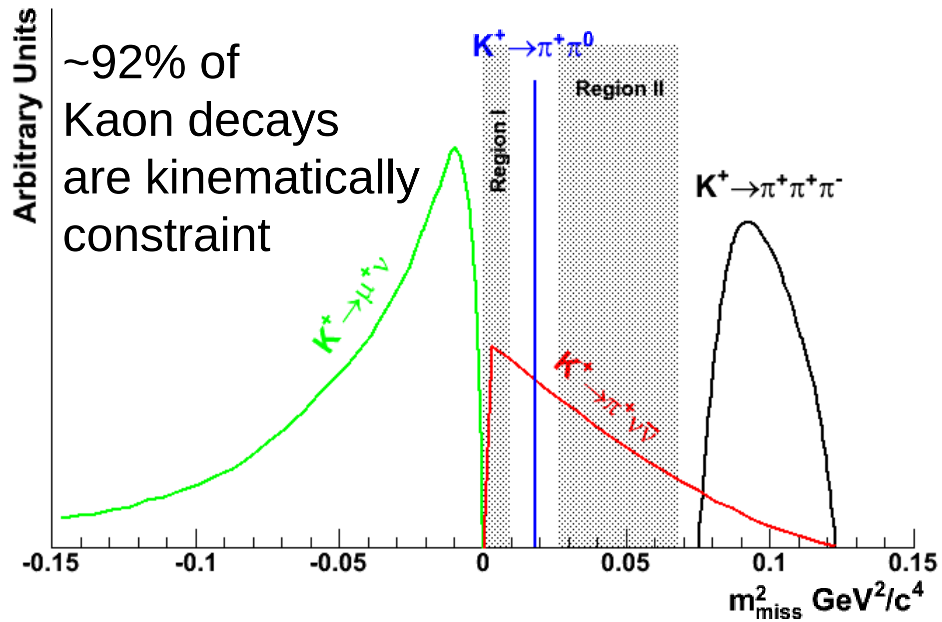
K^+ : Gigatracker (pixel detector) with very good time resolution **(~ 100 ps)**
π^+ : RICH (Neon, 1 atm) read out by Photomultipliers

2. Kinematic Rejection



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

Decay	BR
$K^+ \to \mu^+ \nu$ ($K_{\mu 2}$)	0.64
$K^+ \to \pi^+ \pi^0$ ($K_{\pi 2}$)	0.21
$K^+ \to \pi^+ \pi^+ \pi^-$ $K^+ \to \pi^+ \pi^0 \pi^0$	0.07

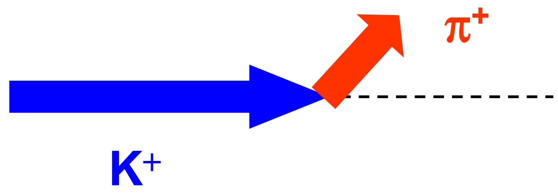


3. Vetoes

- **Photon vetoes to reject $K^+ \rightarrow \pi^+ \pi^0$**

  P(K^+) = 75 GeV/c
  Requiring P(π^+) < 35 GeV/c
  P(π^0) > 40 GeV/c ➡ It can hardly be missed in the calorimeters

Signature:
•Incoming high momentum K^+
•Outgoing low momentum π^+

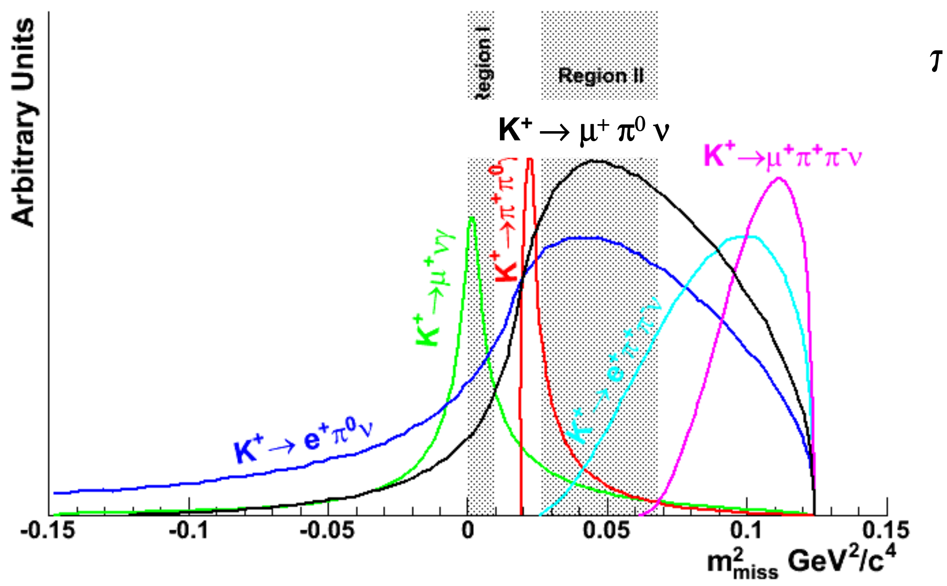


- **Muon Veto to reject $K^+ \rightarrow \mu^+ \nu$**

4. Particle Identification

- K^+ Positive identification (CEDAR)
- π/μ separation (RICH)
- π/e separation (E/P)

Decay	BR
$K^+ \to \pi^0 e^+ \nu$ (K_{e3})	0.051
$K^+ \to \pi^0 \mu^+ \nu$ ($K_{\mu 3}$)	0.034
$K^+ \to \mu^+ \nu \gamma$ ($K_{\mu 2\gamma}$)	6.2×10^{-3}
$K^+ \to \pi^+ \pi^- e^+ \nu$ (K_{e4})	4.1×10^{-5}
$K^+ \to \pi^+ \pi^- \mu^+ \nu$ ($K_{\mu 4}$)	1.4×10^{-5}



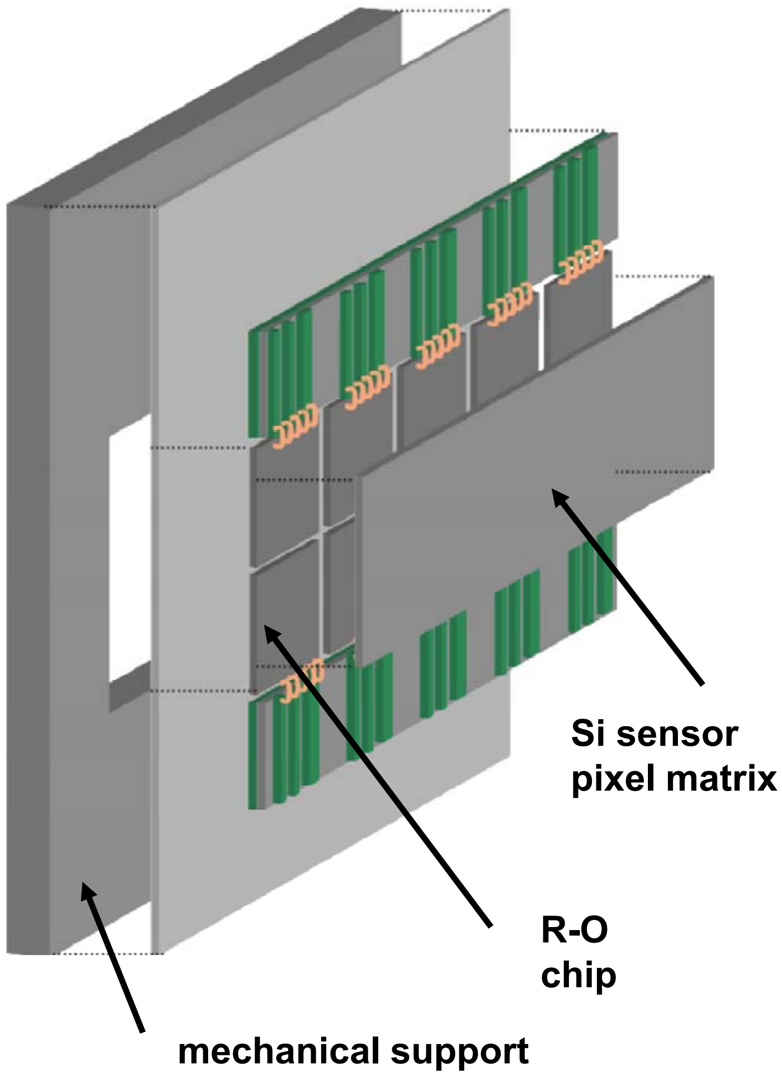
P-326/NA62 Sensitivity

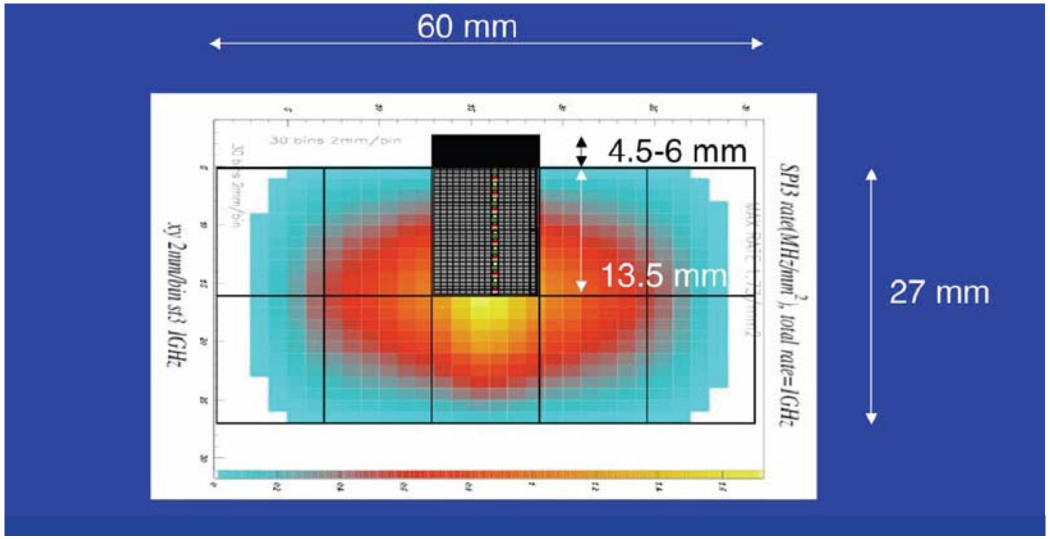
Decay Mode	Events
Signal: $K^+ \to \pi^+ \nu\bar{\nu}$ *[flux = 4.8×10^{12} decay/year]*	55 *evt/year*
$K^+ \to \pi^+ \pi^0$ [$\eta_{\pi 0} = 2\times10^{-8}$ (3.5×10^{-8})]	4.3% (7.5%)
$K^+ \to \mu^+ \nu$	2.2%
$K^+ \to e^+ \pi^+ \pi^- \nu$	≤3%
Other 3 – track decays	≤1.5%
$K^+ \to \pi^+ \pi^0 \gamma$	~2%
$K^+ \to \mu^+ \nu \gamma$	~0.7%
$K^+ \to e^+ (\mu^+) \pi^0 \nu$, others	negligible
Expected background	≤13.5% (≤17%)

Definition of "year" and running efficiencies based on NA48 experience

Gigatracker (GTK)

GTK Station





Requirements:

Track and time each beam particle
Time resolution: 200 ps / station
Material Budget: < 0.5 % X_0 / station
Pattern: 300 x 300 μm²

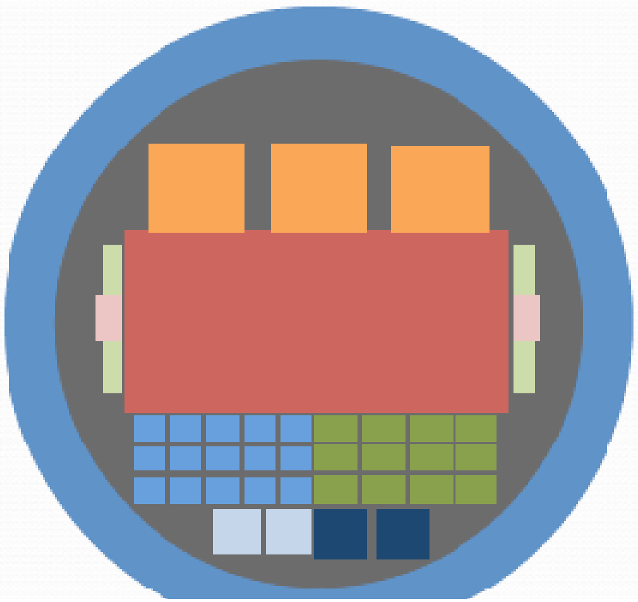
Two options for the Read-Out:

- **On-Pixel TDC**
- **End-of-Column TDC**

GTK sensors

- a batch of 20 wafers (→ 20 sensors) has been ordered to FBK-Trento,Italy
- wafer layout is ready
- bump details (dimensions and position) defined
- wafers to be processed before the end of 2008

Wafer layout



Legend for sensors:

- 1 full size 27.0 × 60.0 mm^2 [29.0 × 62.0 mm^2]
- 3 chip-size 12.0 × 13.5 mm^2 [14.0 × 15.5 mm^2]
- 12 TO-demo 2.1 × 4.5 mm^2 [4.1 × 6.5 mm^2]
- 15 CERN-demo 1.8 × 2.7 mm^2 [3.8 × 4.7 mm^2]
- 2 CMS diodes 7.0 × 7.0 mm^2
- 2 RADMON diodes 8.0 × 8.0 mm^2
- 4 no-bump-bonding test structures 0.9 × 6.0 mm^2 [2.9 × 8.0 mm^2]
- 2 VTT alignment structures 4.0 × 7.0 mm^2

GTK: Bump Bonding

- **Development of the processes with VTT (Finland)**

1. Bump-bonding of the final chip to the sensor: **standard technique**
2. Bump-bonding of the prototype: **how to bond a diced chip to a sensor ?**

This is a technical problem related to the lack of room on diced chips for galvanic contacts for electroplating and thus it is impossible to apply the standard bump-bonding technique.

Two solutions are however available:

1) Reverse rework: most promising and preferred solution

2) Au stud bumps practical only for ~100 pixels:

technique off-shelves (backup solution)

GTK: Cooling

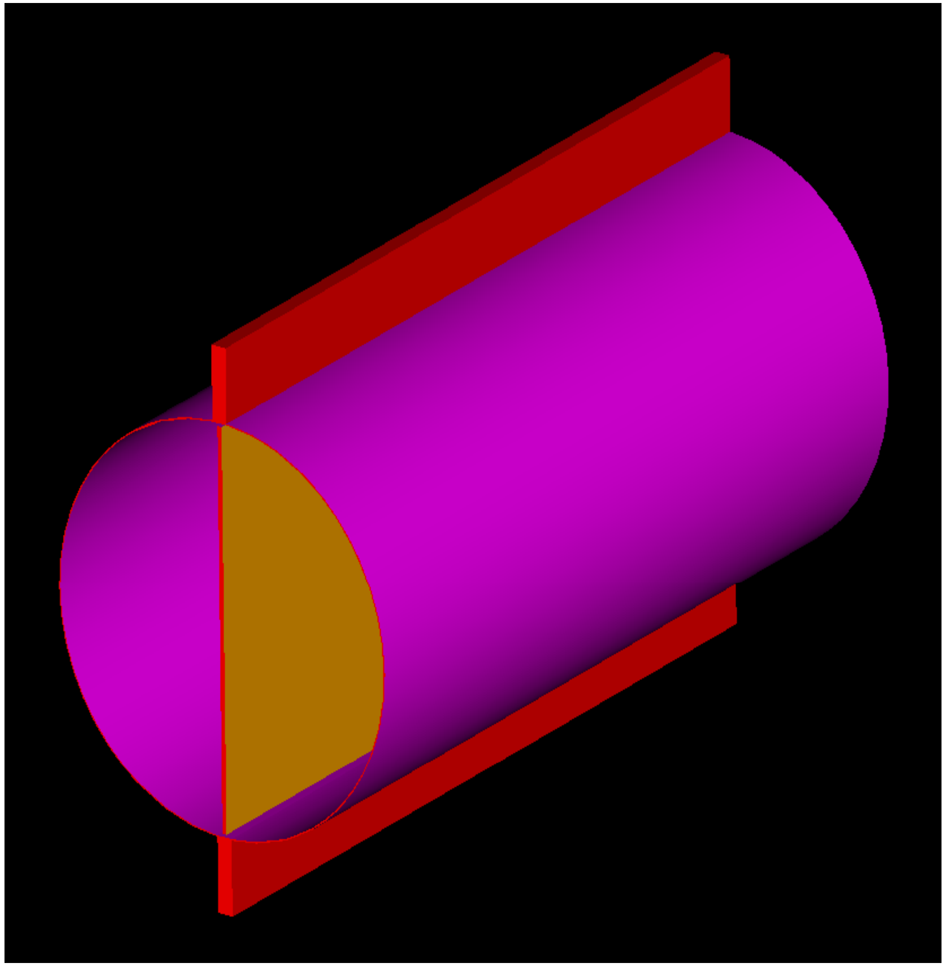
Power to be dissipated: 2W/cm^2 → 32 W

Target chip temperature < 5 ^{0}C

<u>Baseline solution</u>: two half-cylinders of carbon fibre enclosing the sensor+chip

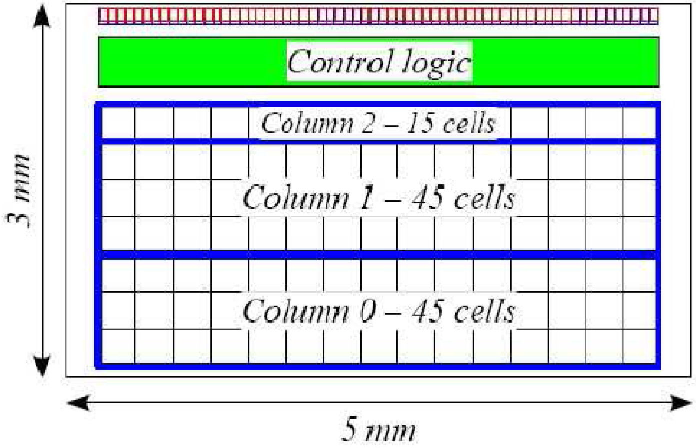
COOLING FLUID : NITROGEN		K	°C
Delivery temperature	**Ti**	**100**	**-173**
Wall temperature	**Tw**	**275,6**	**2,6**
dT	**T = (Tw – Ti)**	**175,6**	**175,6**
Tm	**Tm = (Tw+Ti)/2**	**187,8**	**-85,2**

NITROGEN PROPERTIES @ Tm and atmospheric pressure		
Specific weight (Kg/m^3)	**ρ**	**1,79**
Specific heat (J/KgK)	**Cp**	**1041**
Thermal conductivity (W/mK)	**λ**	**0,024**
Kinematic viscosity (m^2/s)	**v**	**1,34E-05**

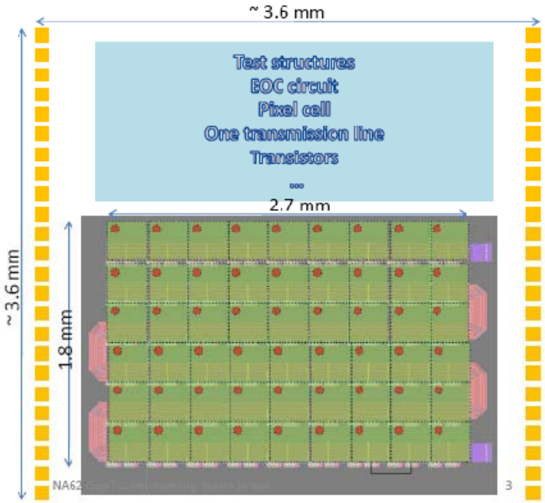


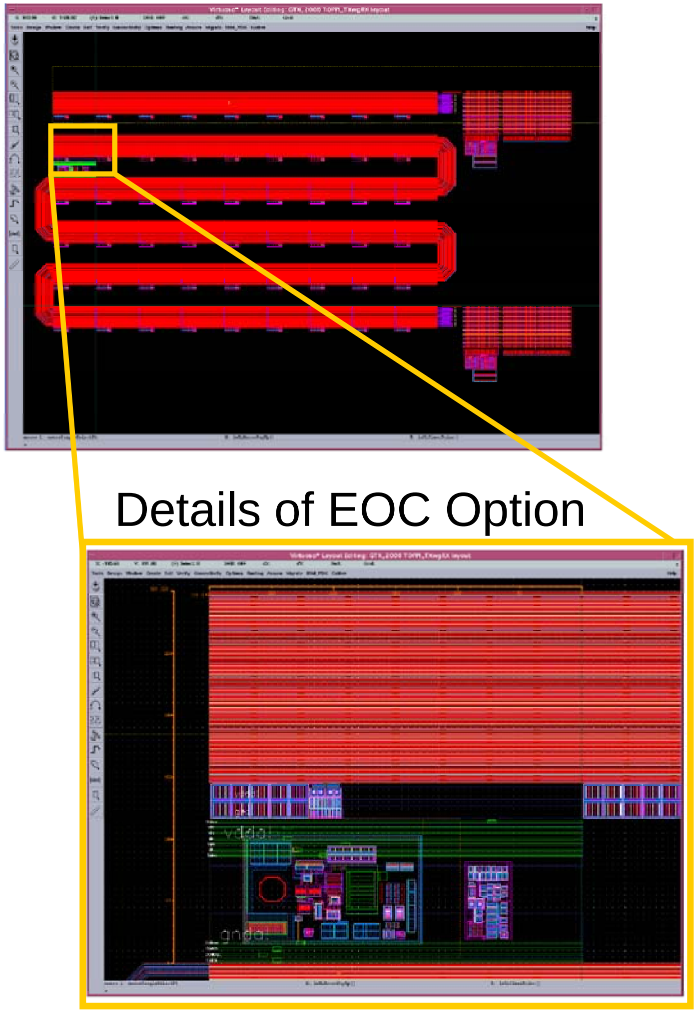
GTK: R/O Prototypes

On-Pixel TDC Option



End-of-Column Option





Details of EOC Option

GTK Prototypes: Engineering Review

Design review of the Gigatracker ASIC prototype (07-08 October 2008) Page 1 of 2

category | view: Indico style | focus on: | LOCAL: Europe/Zurich | login
- - all days - - | manage |

Design review of the Gigatracker ASIC prototype

from Tuesday 07 October 2008 (09:30)
to Wednesday 08 October 2008 (16:20)
Europe/Zurich
at CERN (14-5-022)
chaired by: pierre jarron

Tuesday 07 October 2008 | Wednesday 08 October 2008 |

Tuesday 07 October 2008 top

10:30	Introduction to physics requirement (20') (Slides)	Giulio Dellacasa (*Istituto Nazionale di Fisica Nucleare (INFN)*)
10:50	Introduction to NA62 GTK specification (25') (Slides, document)	Alex Kluge (*CERN*)
11:15	Sensor specification, mask layout, bump bonding (30') (Slides)	petra riedler
11:45	Overview of the on-pixel TDC Architecture (30') (Slides)	Angelo Rivetti (*INFN, Torino*)
12:15	Overview of the EOC-TDC architecture (30') (Slides)	Pierre Jarron (*CERN*)
12:45	Pixel cell design of the EOC option (45') (Slides)	Jan Kaplon (*CERN*)
13:30	lunch	
14:45	System Bus, transmission line, line driver line receiver (40') (Slides)	Pierre Jarron (*CERN*)
15:25	End of column TDC circuit of the EOC option (45') (Slides)	Teemu Sakari Tiuraniemi (*University of OULU, FINLAND*)
16:10	coffee break	
16:25	spectre simulation of the full 45 pixel EOC column (10') (Slides)	Maria Elena Martin Albarran (*Universite Catholique de Louvain-Unknown-Unknown*)
16:35	Specification of the EOC TDC demonstrator (40') (Paper; Slides)	Pierre Jarron (*CERN*)
17:15	discussion EOC-TDC demonstrator (45')	Alex Kluge (*CERN*)

Wednesday 08 October 2008 top

09:00	On-pixel TDC analogue pixel cell design (45') (Slides)	Sorin Martoiu (*Istituto Nazionale di Fisica Nucleare (INFN)*)
09:45	on-Pixel digital circuits and bus (45') (Slides)	Gianni Mazza (*Univ. + INFN*)
10:30	coffee break	
11:00	End of Column circuit (45') (	Giulio Dellacasa (*Istituto Nazionale di Fisica*

http://indico.cern.ch/conferenceDisplay.py?confId=42003 03/11/2008

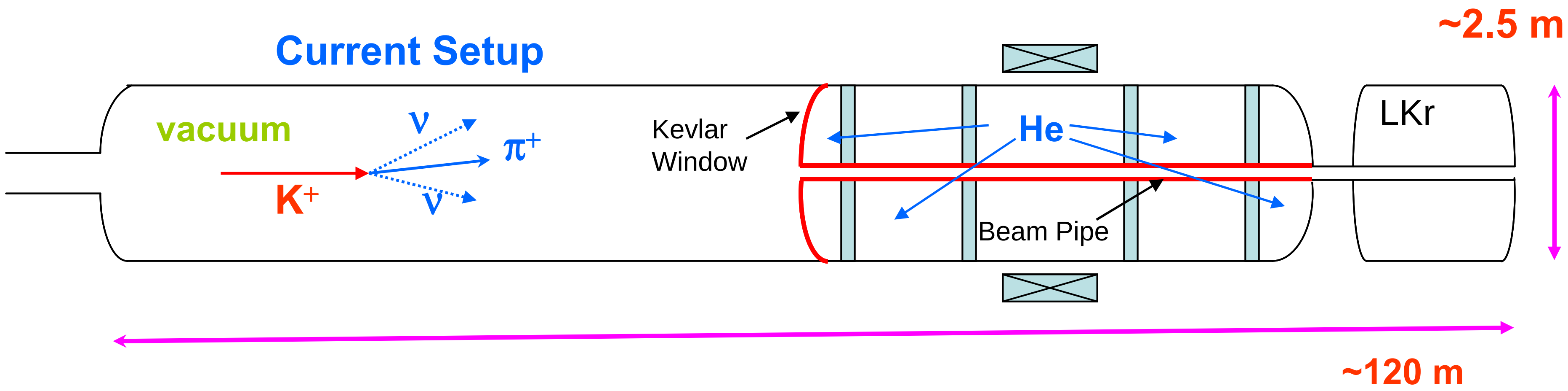
	Slides)	*Nucleare (INFN)*)
11:45	Demonstrator circuit of the on-pixel TDC option (45')	Angelo Rivetti (*INFN, Torino*) , Giulio Dellacasa (*Istituto Nazionale di Fisica Nucleare (INFN)*) , Sorin Martoiu (*Istituto Nazionale di Fisica Nucleare (INFN)*)
12:30	Testing of the GTK demonstrators (45') (Slides)	Angelo Cotta Ramusino (*Istituto Nazionale di Fisica Nucleare (INFN)*)
13:30	lunch	
14:30	Discussion with reviewers (1h30') (Slides)	Flavio Marchetto (*Universita degli Studi di Torino*) , Dominique Breton (*Laboratoire de l'Accelerateur Lineaire (LAL) (IN2P3) (LAL)*) , Michael Campbell (*CERN*) , Christian Mester, Kostas Kloukinas (*CERN*) , Ken Wyllie (*CERN*) , Paulo Moreira

The Review identified crucial points on both the On-Pixel TDC and End-Of-Column TDC options

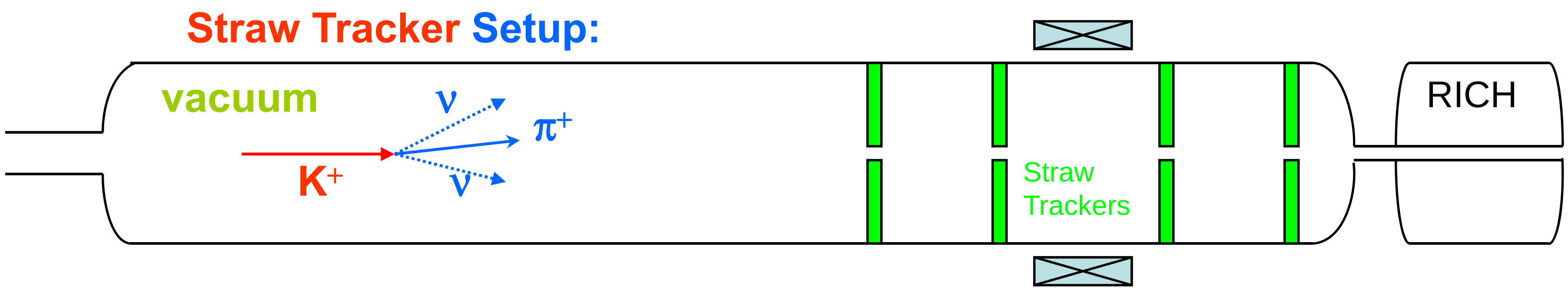
- **all the building blocks are ready**
- **no flaws have been spotted**
- **some further checks to be performed**
- **layout underway for both options**
- **submission moved to Jan. 20th 2009**
- **delivery expected by middle of March 2009**

Straw Tracker

Motivation



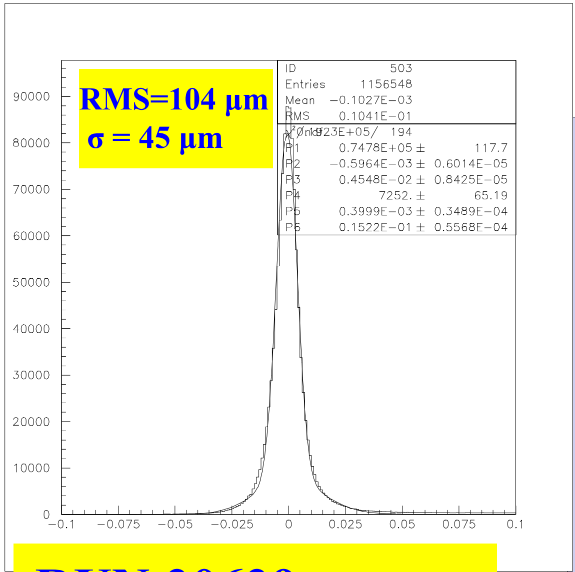
The Straw Trackers operated in vacuum will enable us to:
- **Remove the multiple scattering due to the Kevlar Window**
- **Remove the acceptance limitations due to the beam-pipe**
- **Remove the helium between the chambers**



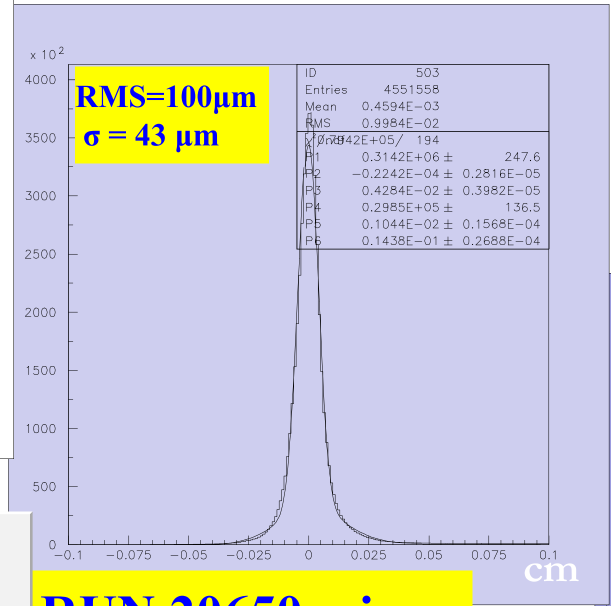
- **The Straw Tracker is essential to study ultra-rare-decays in flight**

Straw Prototype: Beam Test 2007

Residuals

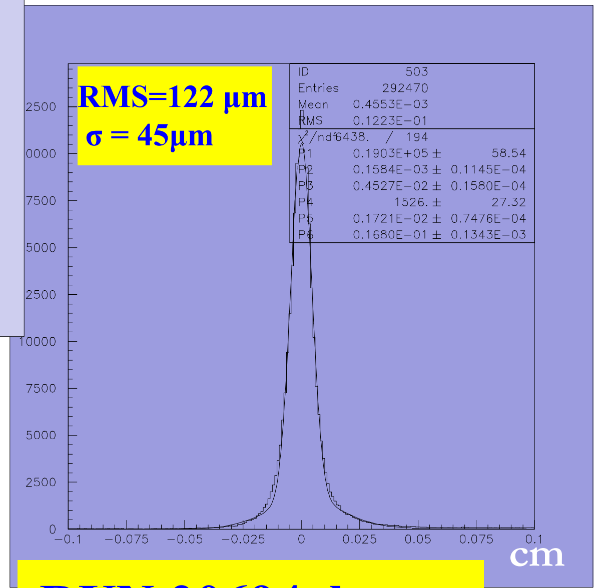


RUN 20629, muons

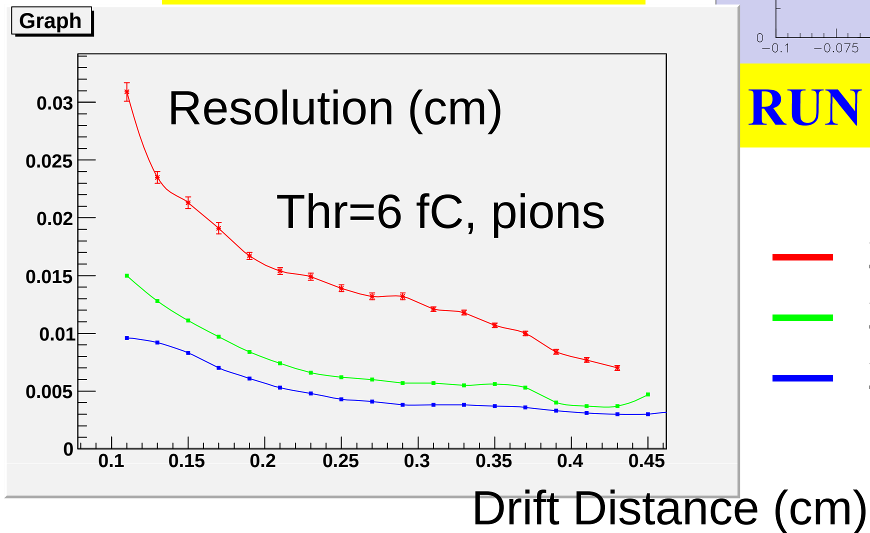


RUN 20650, pions

full length Straw Prototype: 2.1 m



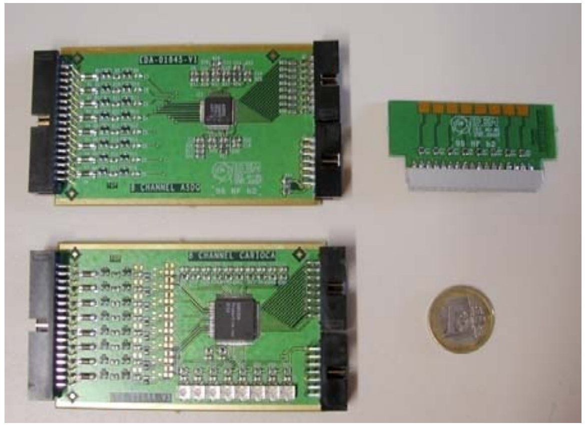
RUN 20694, kaons

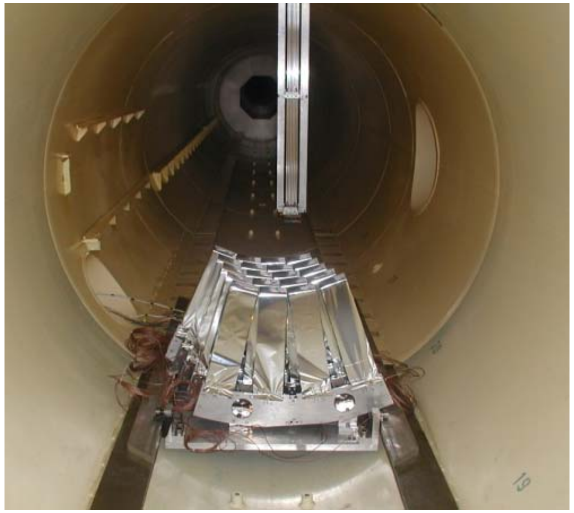


CO_2 (80%) CF_4 (10%) Isob. (10%)

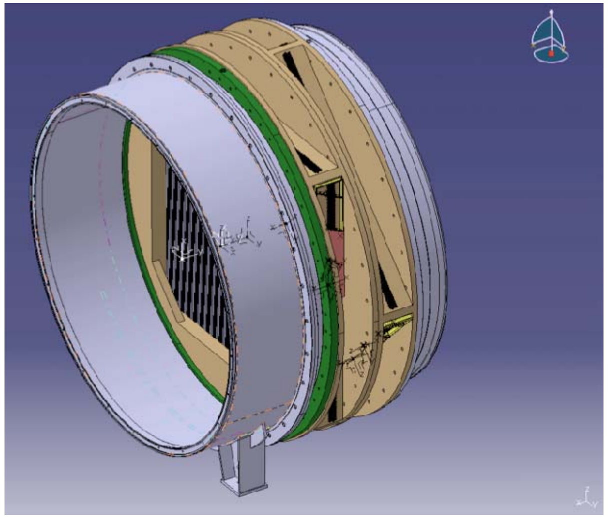
Straw Beam test 2008

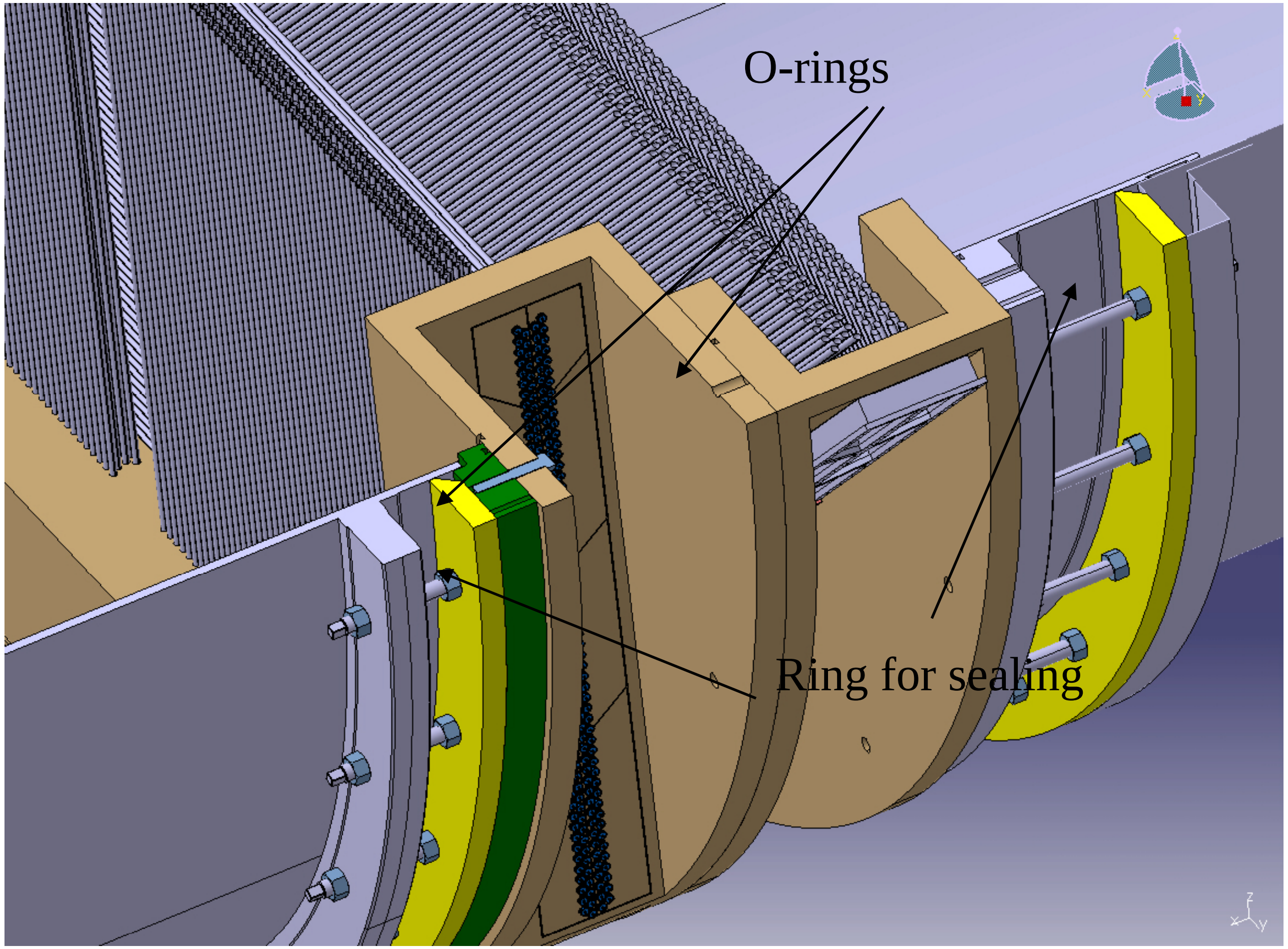
- The goal was to compare two candidates for the FE chips and operate the chamber with a new non-flammable gas mixture
- Same straw prototype as in 2007 was equipped with two types of FE: CARIOCA and ASDQ. Test boards were prepared in August at CERN, for these two chips
- The straw prototype was ready to take data as planned on October 2. Unfortunately the beam was stopped on October 6 owing to the LHC incident
- Nevertheless, we managed to take a few points with muons: 2.4 kV, 2.5 kV, 2.6 kV (two Thr settings) and 2.7 kV



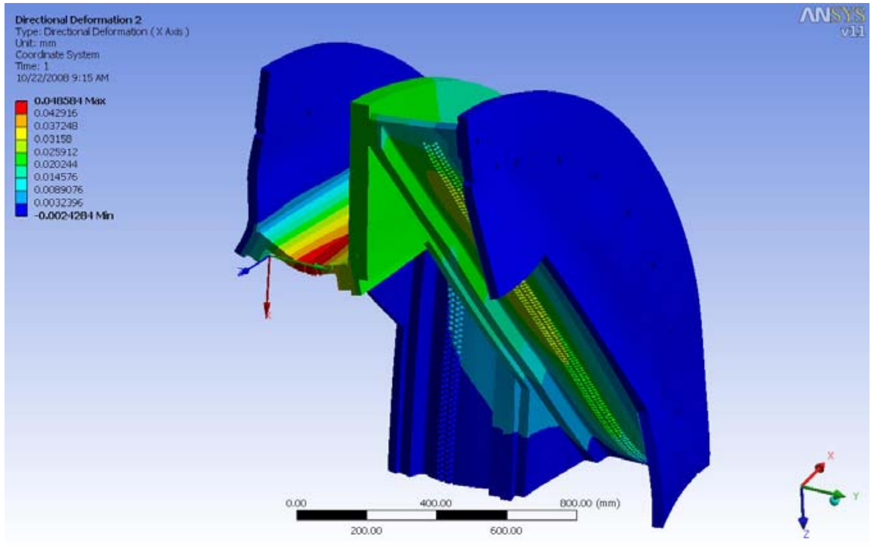


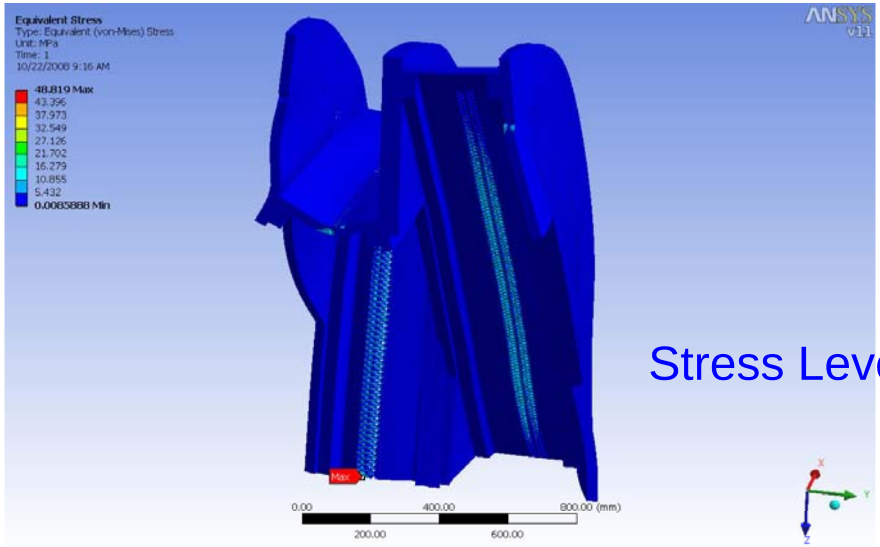
Full Straw Chamber design





FEM calculations of the chamber





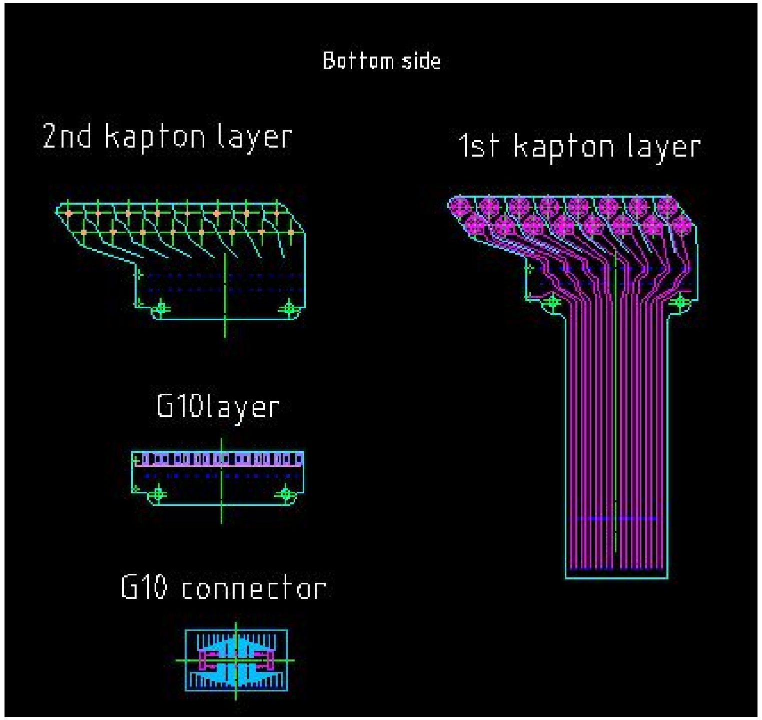
Stress Level

- The model contains all the loading details: Pressure difference, pretension, fixation points to the vacuum tube etc.
- We have a model to study global deformations and details e.g. stress concentration around the holes.
- We are working on a model to study the deformation of individual straws.
- 25 mm thickness looks ok
- Basis for tender

Prototypes of the gas manifold, straw connectivity and web

- Questions that will be addressed are:
- Type of glue
- Gluing procedure
- Tooling and access
- Leak tightness
- Electrical connection to the straws (web)

- The design of the web(16 channels) is finished and a prototype is launched in the. 4– 6 weeks for production



Straw Plans

- Complete the detailed study on the straw material and its mechanics
- Detailed FEM analysis of the structure and the straw
- Finalise the layout of the mechanical structure
- Plan and build a new sector prototype:
  - Verify mechanical support of the straws (and wire) . Measure final straw deformation and wire off-set
  - Final straw layout
  - New connectivity
  - Finalise electronics
- Build a full-scale engineering prototype
- Aging component validation

Large Angle Photon Vetoes (LAV)

Main 2008 Activities

- Activities during the past year focused on engineering the solution to use the OPAL barrel Lead glass for a "All-in-vacuum design"
- In particular it was shown that
  - The blocks and photomultipliers can work in vacuum
  - The outgassing is tolerable
  - The design for installation in ECN3 is viable
- A major setback due to the floods in a storage area is being recovered
- Prototypes were beam tested
- The order for a full size ring was made (functional prototype)
- The Read-out electronics was defined

The flood

- In April, because of heavy rain, dirty water flooded the storage area in BB5
  - Half of the lead glass blocks were touched on part of their surface
- The CERN insurance is providing support for cleaning, recovery and validation of those blocks
  - There are about 1800 blocks to be recovered
  - The cleaning rate is 30/week
  - The blocks are cleaned, cabled and tested in a dark box with a LED pulser

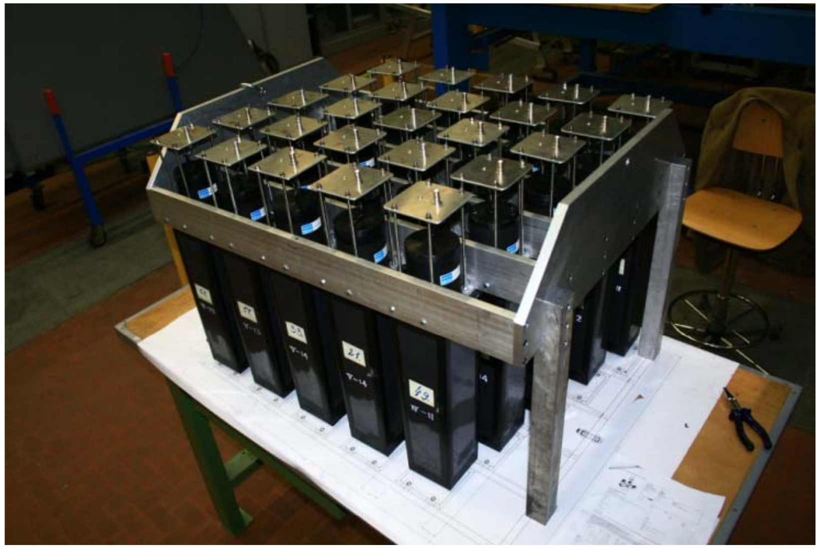
OPAL Lead Glass Recovery Procedure

- ½ of blocks touched by flood water
- Some blocks (~9%) were broken by the thermal shock
- Other blocks require polishing

Careful recovery procedure underway to make sure that all the needed (2496 blocks) will be available

Large Angle Photon Vetoes

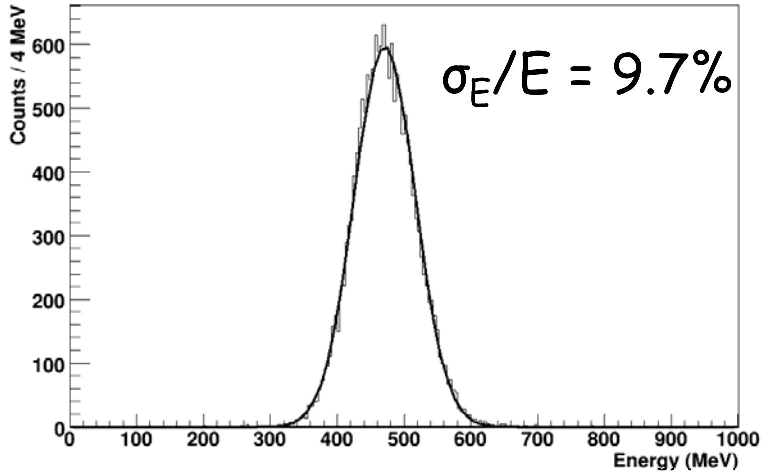
A prototype at BTF - Frascati



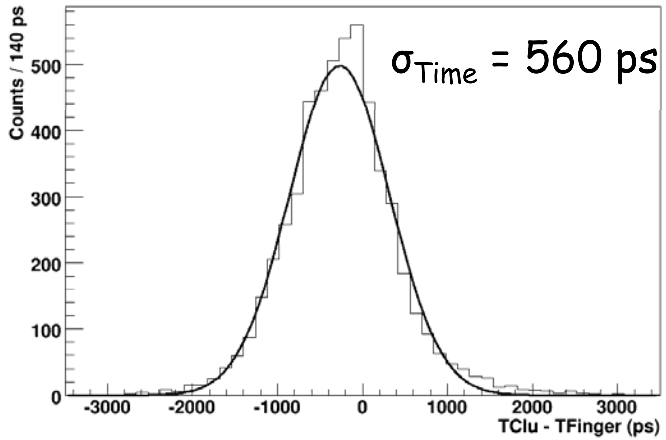
25 blocks

e^- 471 MeV

Energy Resolution

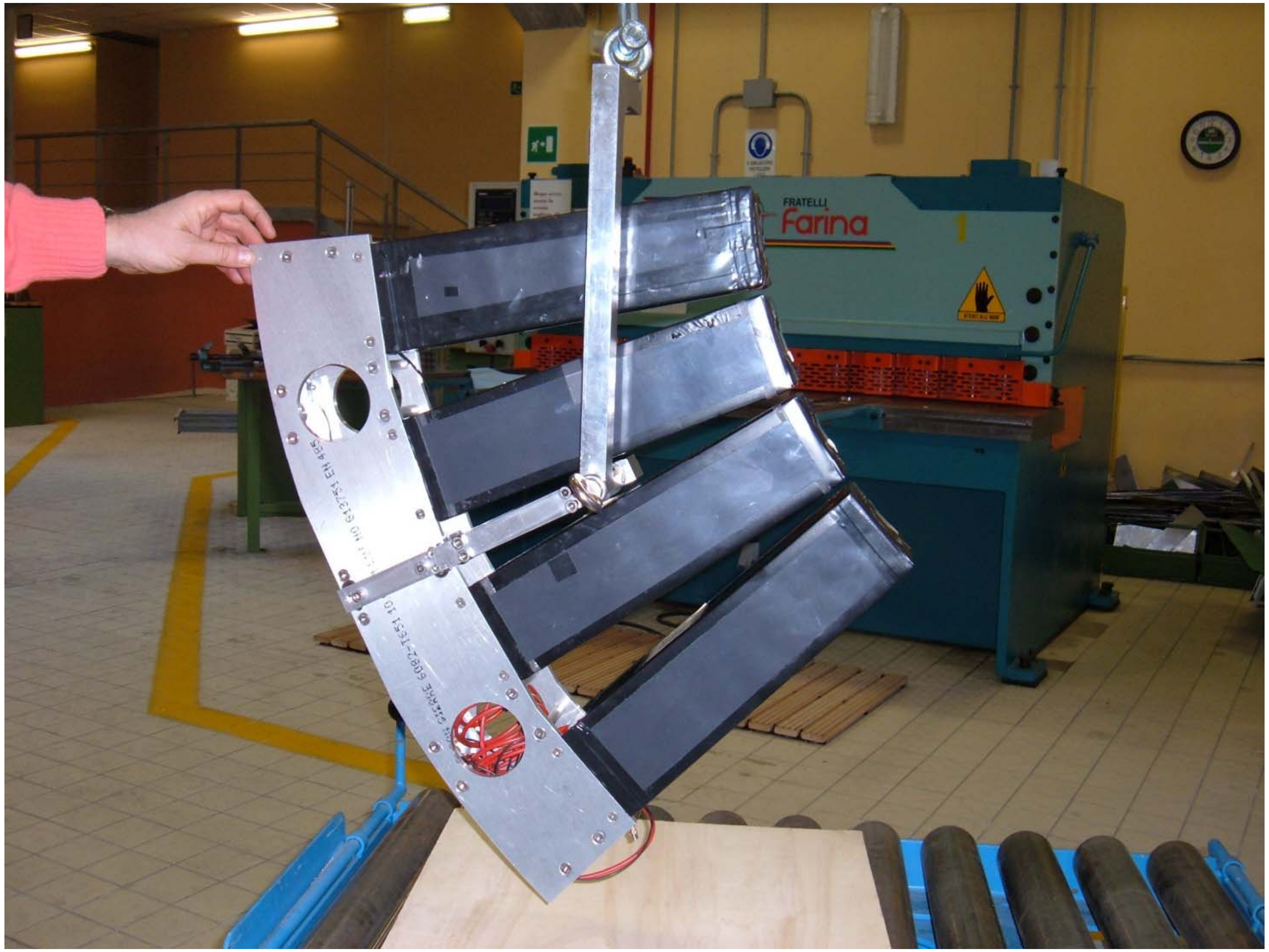


Cluster time Resolution

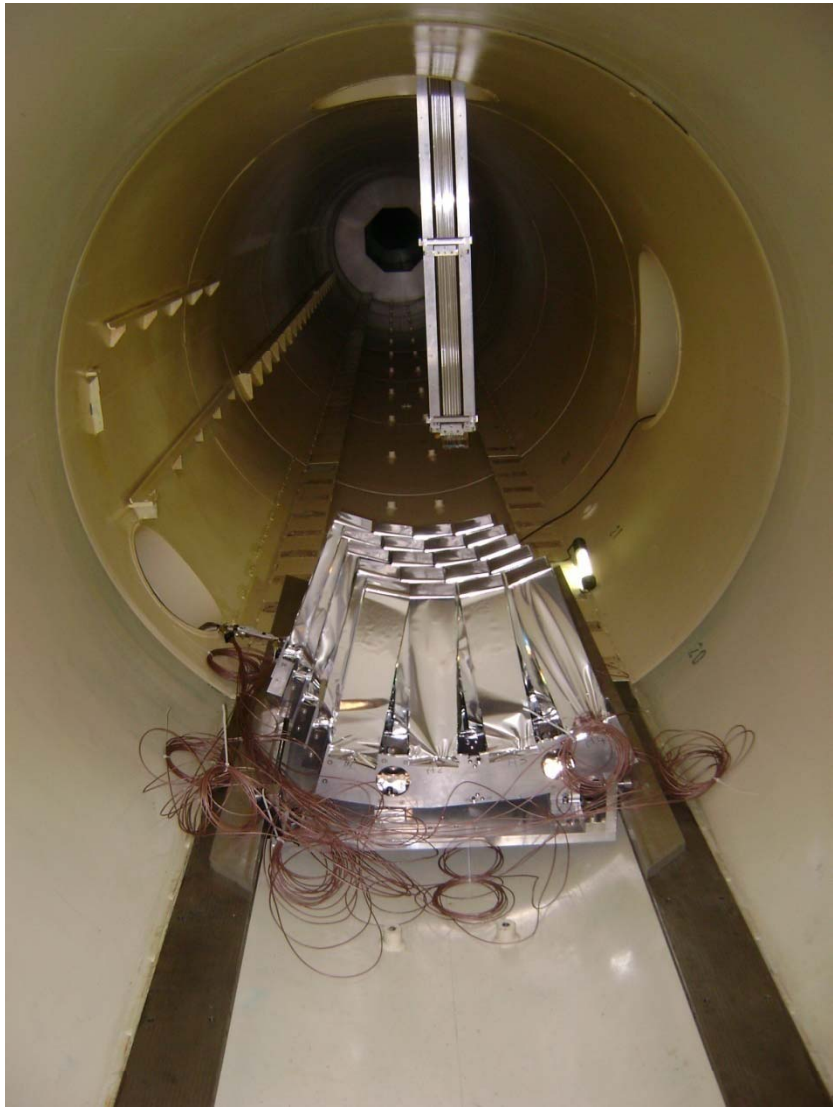


Beam Incidence	*Tagged Events*	*Inefficiency*
Central	22 703	$4.4^{+7.6}_{-2.8} \times 10^{-5}$
On edge	9 711	$1.03^{+1.75}_{-0.65} \times 10^{-4}$

LAV Mechanical Design



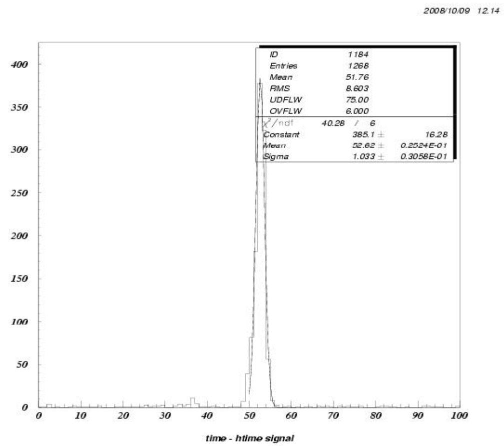
A LAV prototype tested at CERN



20 blocks installed in the NA62 vacuum tube

Muons and kaons from 2/10 to 6/10

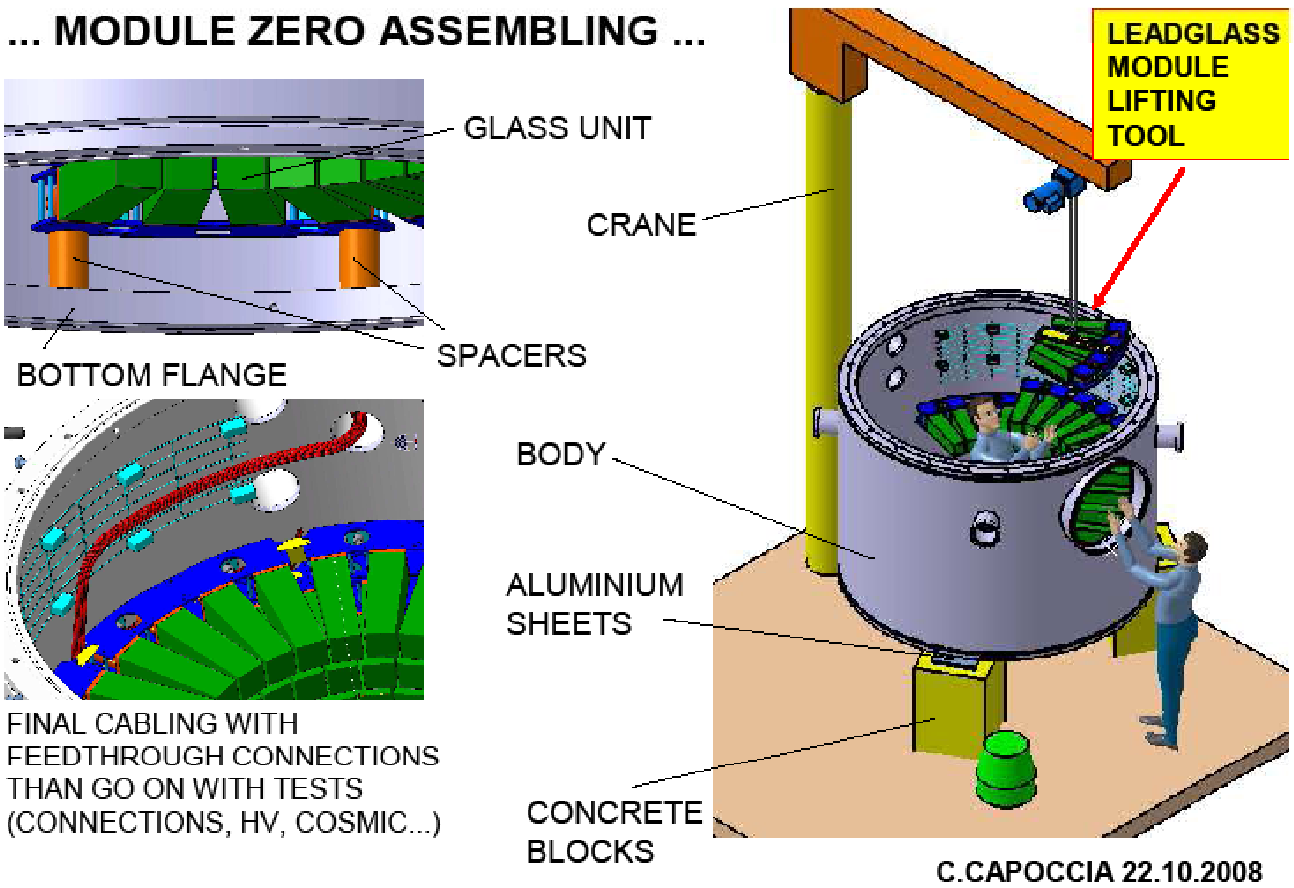
Validation of the operation in vacuum, cabling and support mechanics



Preliminary time resolution with kaons

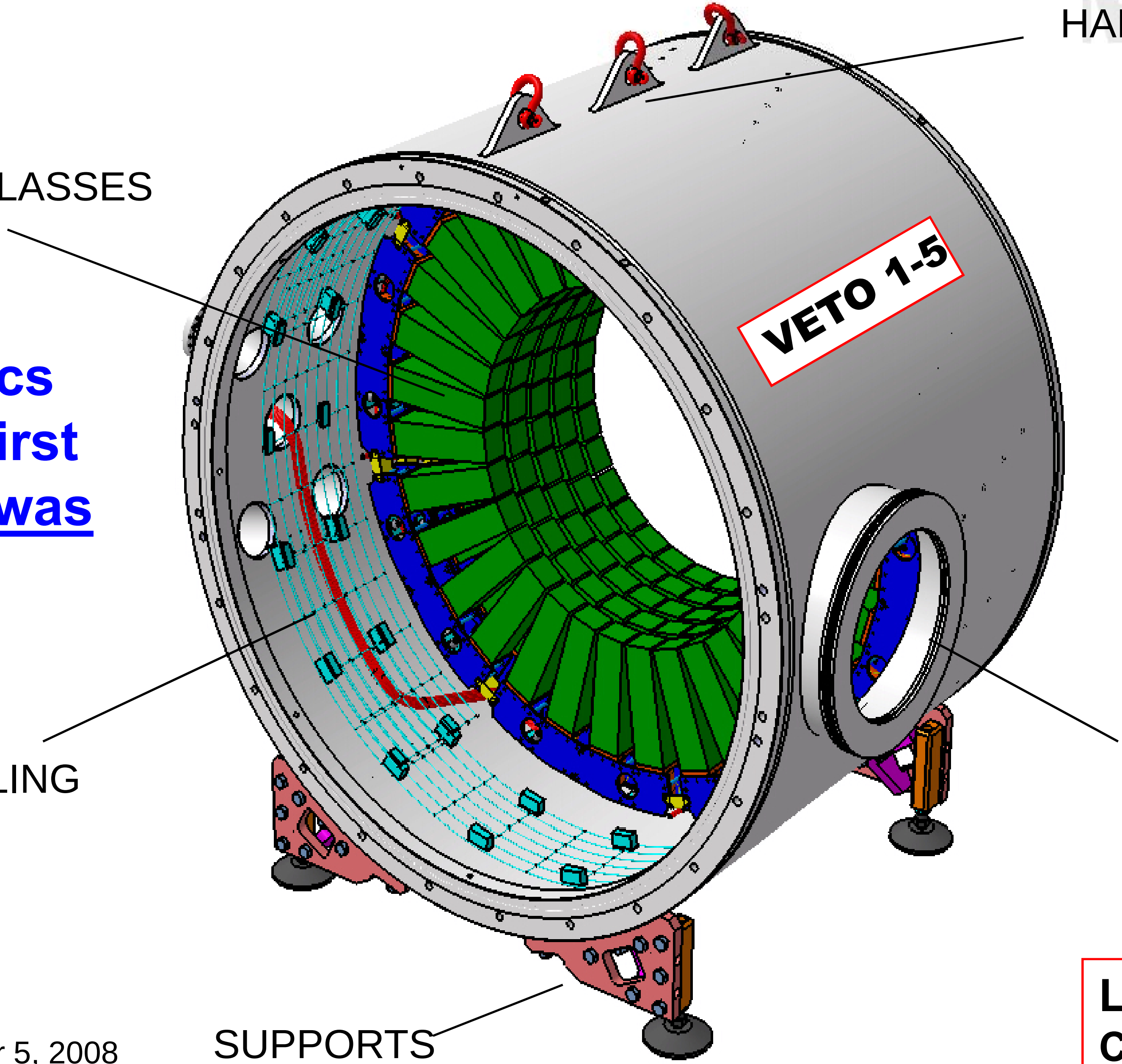
σ_t = 1.02 ns

Engineering for Installation in ECN3



LAV Mechanical Design

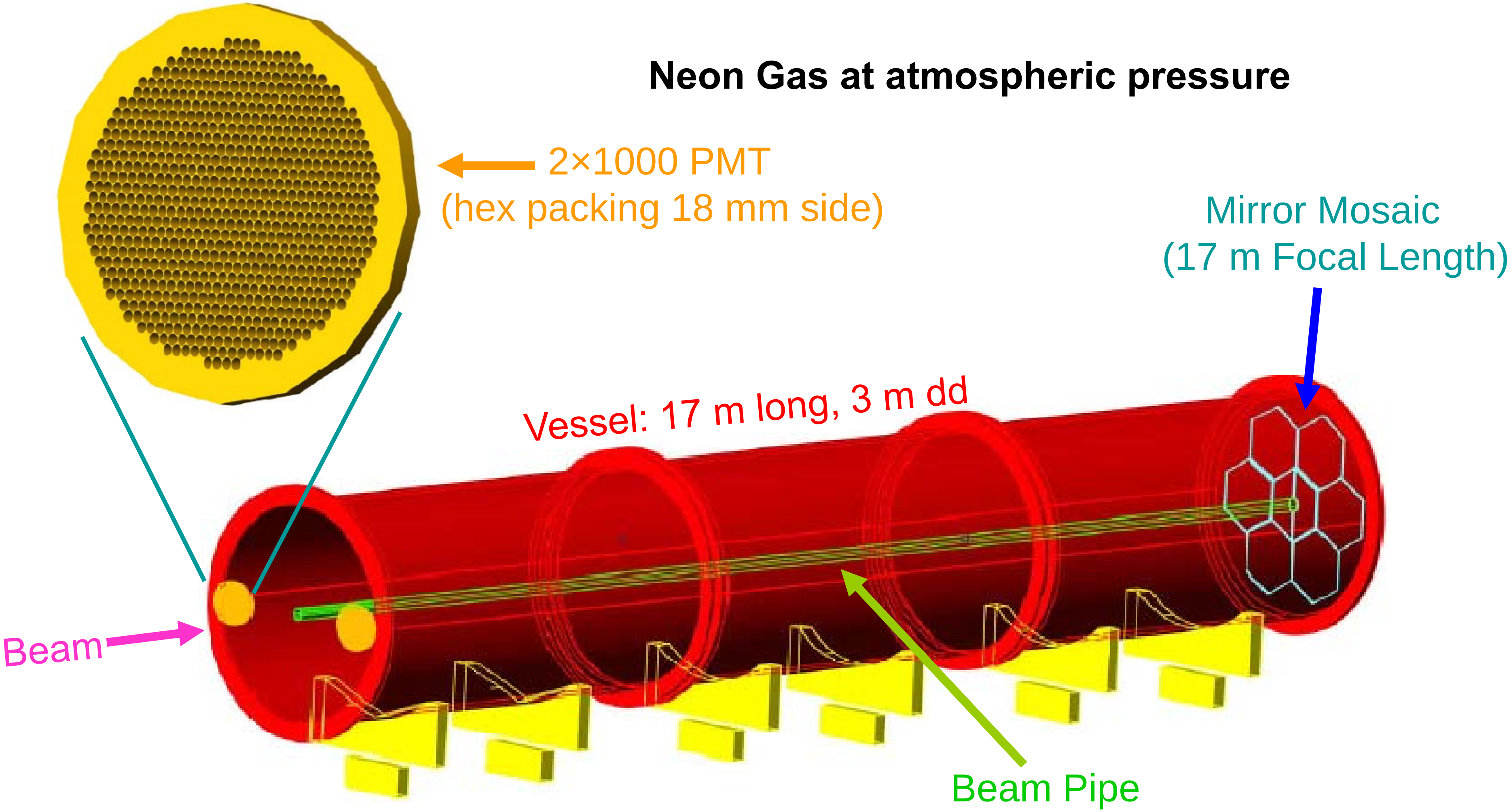
Mechanics
For the first full ring <u>was ordered</u>



LNF-SPAS
C.Capoccia

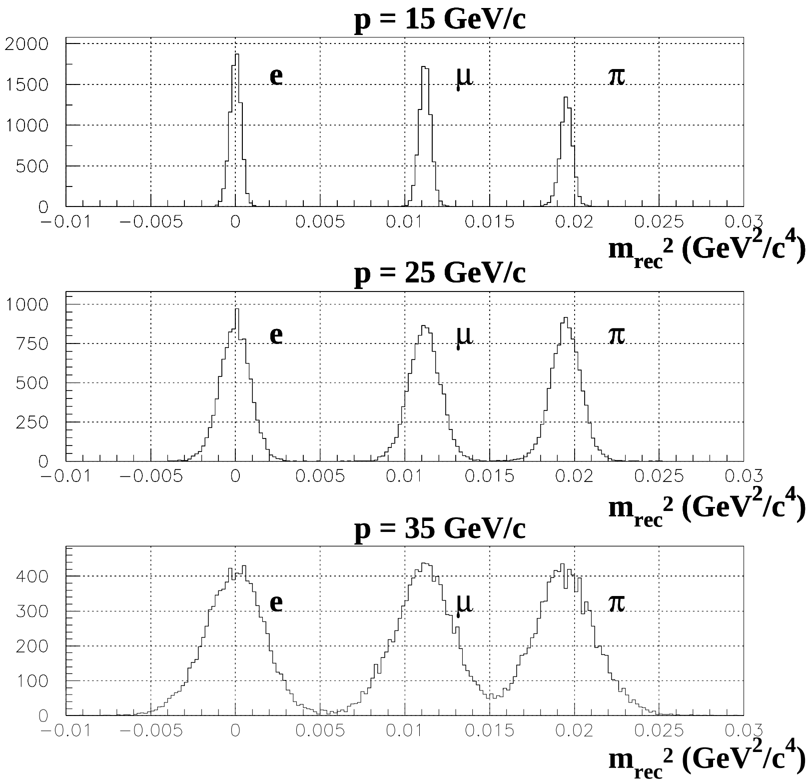
RICH

The RICH Detector

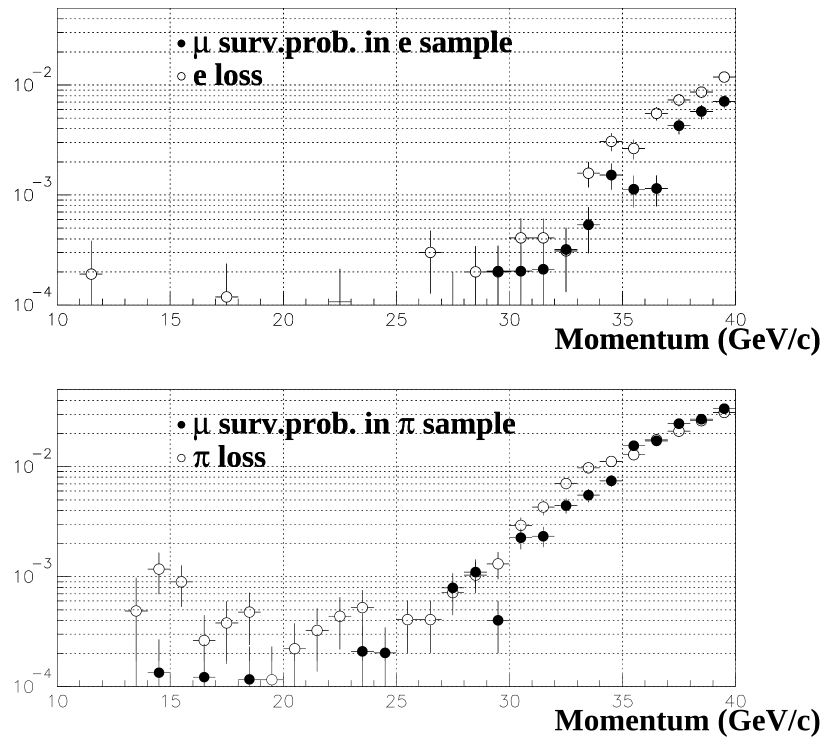


RICH Simulation: particles separation

$$m_{rec}^2 = p^2\left(\vartheta_{\max}^2 - \vartheta_c^2\right)$$

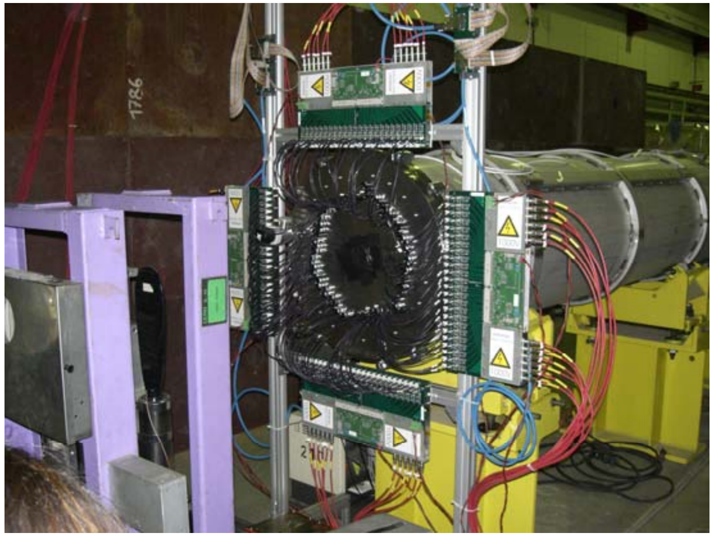


Momentum from
the magnetic spectrometer



Muon suppression in π sample (15<p<35 GeV/c): 1.3×10^{-3}

RICH-100 prototype: 2007 Test Beam



96 PMT
Hamamatsu R7400

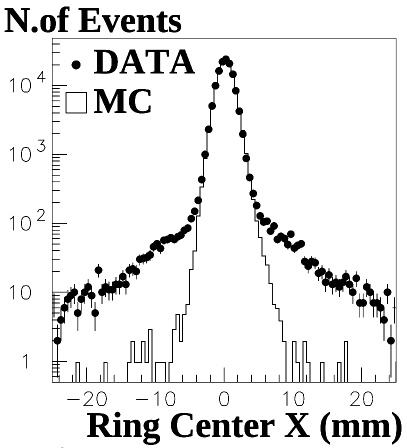
CERN
ECN3 Cavern
K12 beam line
(NA48-NA62)

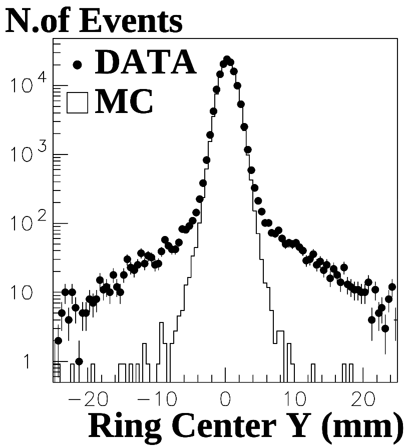
17 m long
60 cm wide
vessel,
filled with
Neon at atm.
pressure

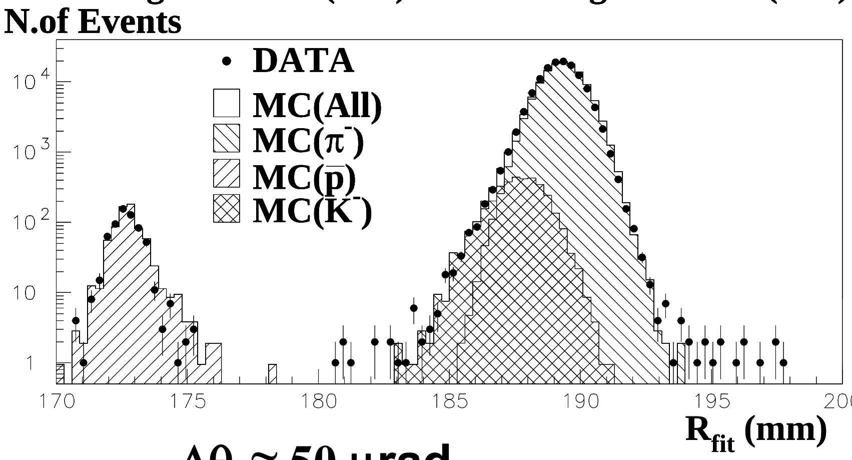
200 GeV/c negative hadron beam
from CERN SPS (mainly pions)

17 m focal, 50 cm wide,
2.5 cm thick glass mirror
by MARCON

RICH-100: 2007 Test Beam results







$\Delta\theta_c \approx 50$ μrad
(biased by PM geometry)

$N_{Hits} \approx 17$ **$\Delta t_{Event} \approx 70$ ps**

Nuclear Instruments and Methods in Physics Research A 593 (2008) 314–318

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Construction and test of a RICH prototype for the NA62 experiment

G. Anzivino [a,1], C. Biino [b], A. Bizzeti [c,2], F. Bucci [c,3], P. Cenci [a], R. Ciaranfi [c], G. Collazuol [d,4], V. Falaleev [e], S. Giudici [d,5], E. Iacopini [c,3], E. Imbergamo [a], M. Lenti [c,*], M. Pepe [a], R. Piandani [a,1], M. Piccini [e], M. Raggi [f], A. Sergi [a], M. Veltri [c,6]

[a] Sezione dell'INFN di Perugia, I-06100 Perugia, Italy
[b] Sezione dell'INFN di Torino, I-10125 Torino, Italy
[c] Sezione dell'INFN di Firenze, I-50019 Sesto Fiorentino, Italy
[d] Sezione dell'INFN di Pisa, I-56127 Pisa, Italy
[e] CERN, 1211 Geneve 23, Switzerland
[f] Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy

ARTICLE INFO

Article history:
Received 16 May 2008
Accepted 19 May 2008
Available online 28 May 2008

Keywords:
RICH
PID
Timing

ABSTRACT

A RICH prototype has been constructed and tested. The detector was cylindrical, 17 m long and 60 cm diameter, filled with neon gas at atmospheric pressure. A spherical mirror with 17 m focal length was used and 96 photomultipliers were placed in the mirror focal plane. The prototype was exposed to a 200 GeV/c momentum negative beam derived from the CERN SPS in the 2007 fall. The performances of the detector in terms of Cherenkov angle resolution, number of photoelectrons and time resolution are presented.

1. Introduction

The NA62 experiment [1] has been proposed at CERN in order to measure the branching ratio of the ultra-rare decay $K^+ \to \pi^+ \nu\bar{\nu}$. The main background is $K^+ \to \mu^+ \nu$ which must be suppressed by a factor 4×10^{-13} in order to have a background to signal ratio smaller than 10%: this goal can be accomplished by a combination of kinematical cuts and by pion–muon separation. According to the MC simulation of the experiment, a kinematical suppression of 8×10^{-6} can be reached. A muon rejection factor of 10^{-5} can be achieved exploiting the different penetration probability through matter of the two particles. A further 5×10^{-3} suppression factor can be provided by a Ring Imaging CHerenkov (RICH) detector.

The momentum range over which pions and muons must be identified by the RICH is between 15 and 35 GeV/c; the best pion–muon separation is achieved when the lowest accepted momentum is close to the Cherenkov threshold. As full efficiency is achieved only at a momentum about 20% higher than the threshold, the latter has to be 12.5 GeV/c for a pion, i.e. the index of refraction n must be such that $(n-1) \approx 60 \times 10^{-6}$. Neon gas at roughly atmospheric pressure fulfills this requirement and also guarantees a small dispersion [2]. On the other hand, the tiny $(n-1)$ implies a small number of emitted Cherenkov photons per unit length and therefore a long radiator is mandatory. A 10 m long neon RICH was built and operated by the SELEX experiment [3] and a longer one was proposed by the CKM collaboration [4]. The available space for the RICH in the NA62 experiment setup is about 18 m: a detector of about this size is foreseen.

In a RICH detector [5] the Cherenkov light, emitted at an angle θ_c by a charged particle of velocity βc larger than the speed of light in the crossed medium (c/n), is imaged by means of a spherical mirror onto a ring on its focal plane. The ring radius r is related to the Cherenkov angle as $\theta_c = r/f$ for small n (as it is the case for gas radiators), where f is the mirror focal length. The relation between Cherenkov angle and momentum p of a charged particle of mass m is given by

$$\theta_c^2 = \theta_{c\,MAX}^2 - m^2c^2/(m^2c^2 + p^2) \qquad (1)$$

where $\theta_{c\,MAX} = \sqrt{2(n-1)}$ is the Cherenkov angle for $\beta = 1$. The θ_c resolution must be better than 80 μrad in order to achieve the requested pion–muon separation.

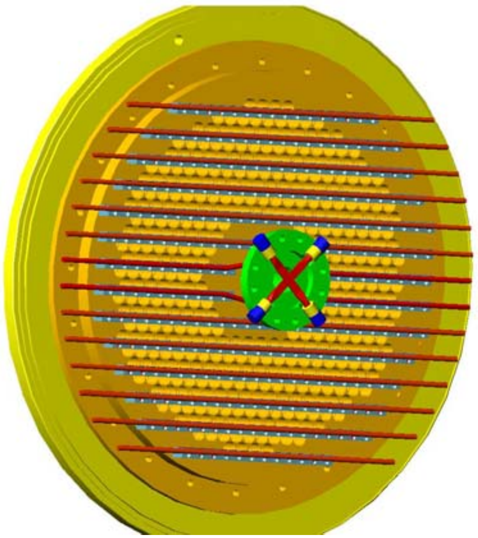
Besides pion–muon separation, the NA62 RICH detector must fulfill two other very important tasks: provide the time of pion crossing with 100 ps resolution (in order to suppress accidental

* Corresponding author. Tel.: +39 055 457 2270.
E-mail address: lenti@fi.infn.it (M. Lenti).
[1] Dipartimento di Fisica dell'Università di Perugia, I-06100 Perugia, Italy.
[2] Dipartimento di Fisica dell'Università di Modena e Reggio Emilia, I-41100 Modena, Italy.
[3] Dipartimento di Fisica dell'Università di Firenze, I-50125 Firenze, Italy.
[4] Scuola Normale Superiore di Pisa, I-56127 Pisa, Italy.
[5] Dipartimento di Fisica dell'Università di Pisa, I-56127 Pisa, Italy.
[6] Dipartimento di Fisica dell'Università di Urbino, I-61029 Urbino, Italy.

0168-9002/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2008.05.029

The RICH-400 prototype

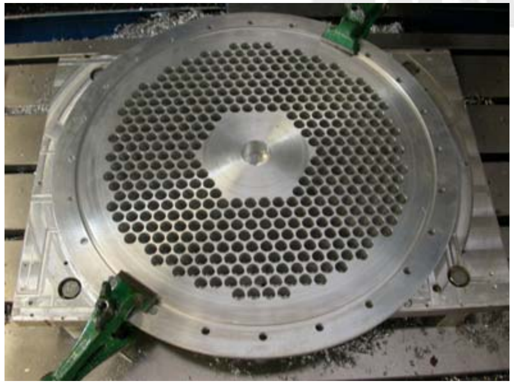
- **PM endcap changed**
- **414 PM (20% of final detector)**
- **Validate π–μ separation in 15<p<35 GeV/c**
- **Improve PM cooling**



Test scheduled: Oct 19 – Nov 12, 2008

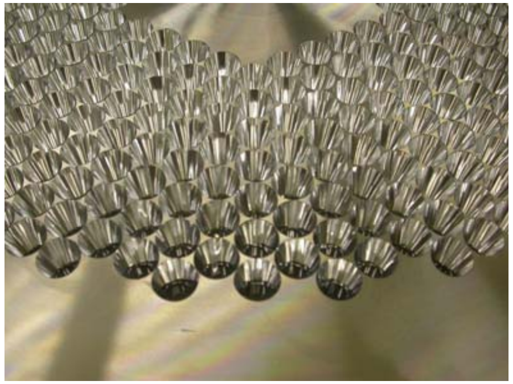
Postponed to 2009 (LHC incident)

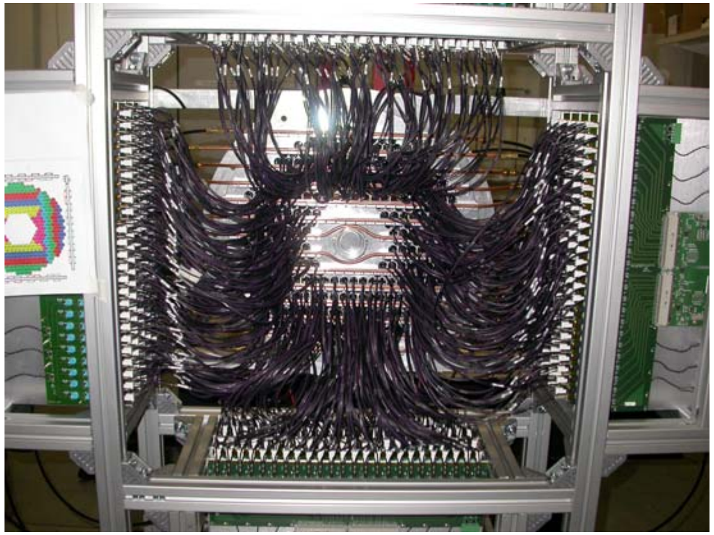
RICH-400



PM holder

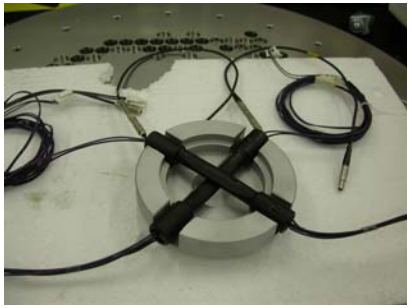
PM endcap





Electronics and cooling

Trigger counters

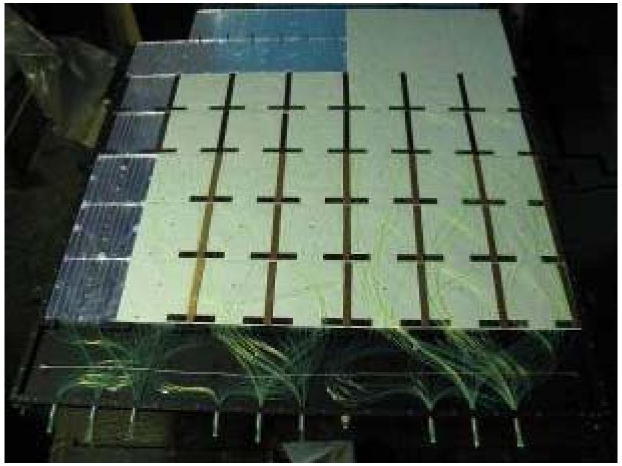


RICH: Summary

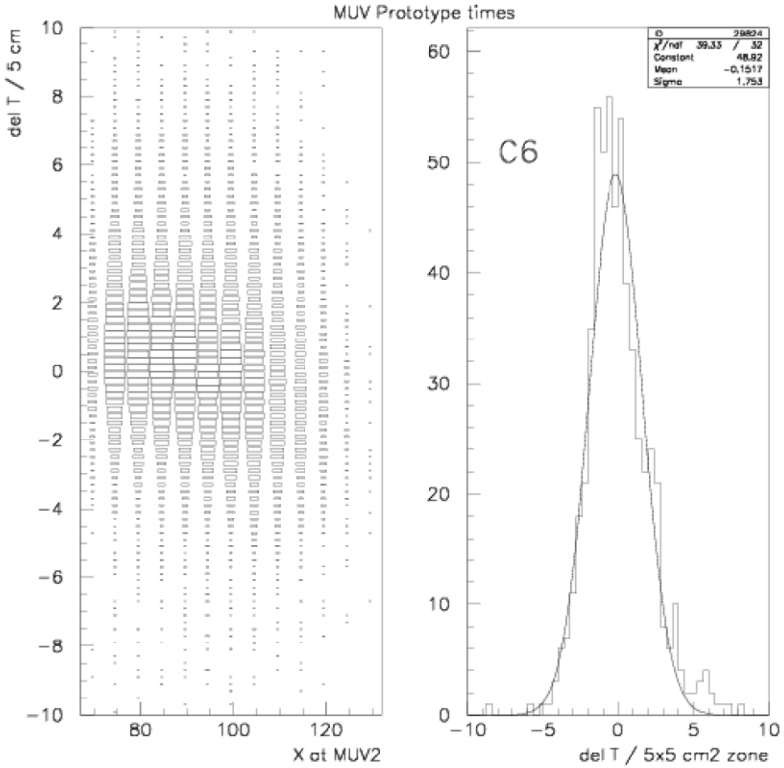
- A very demanding RICH is needed for NA62
- A valuable project has been developed
- A prototype has been tested in 2007
- An improved prototype will be tested in 2009
- About two years needed from "green light"
  - ➢ PMT production > 100/month
  - ➢ Mirror production > 1/month
  - ➢ Vessel procurement, services and installation: two years

Fast Muon Detector

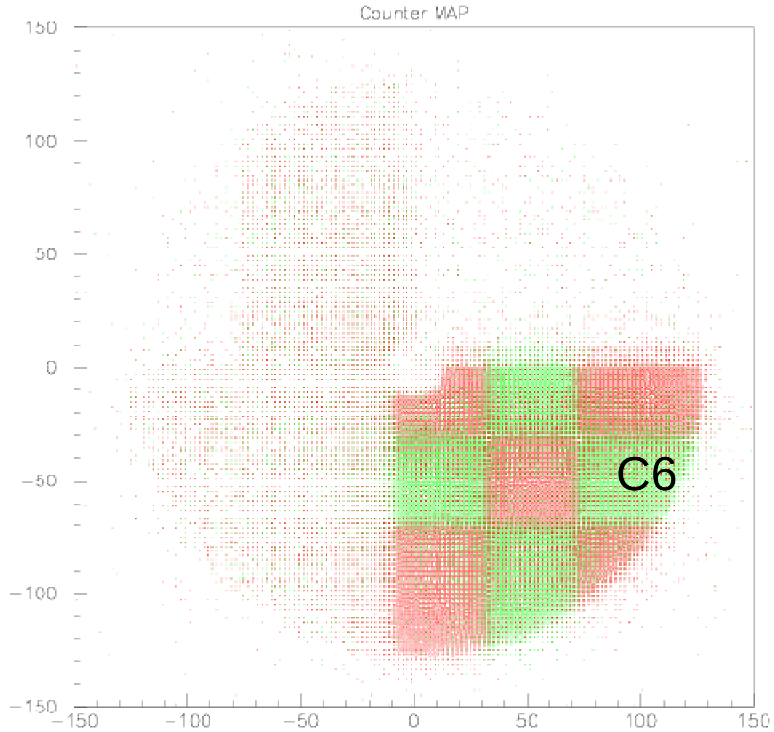
MUD Prototype from INR/Protvino




R.M.S.~1.8 ns



PMT position



Counters map. Cuts are
due to trigger configuration

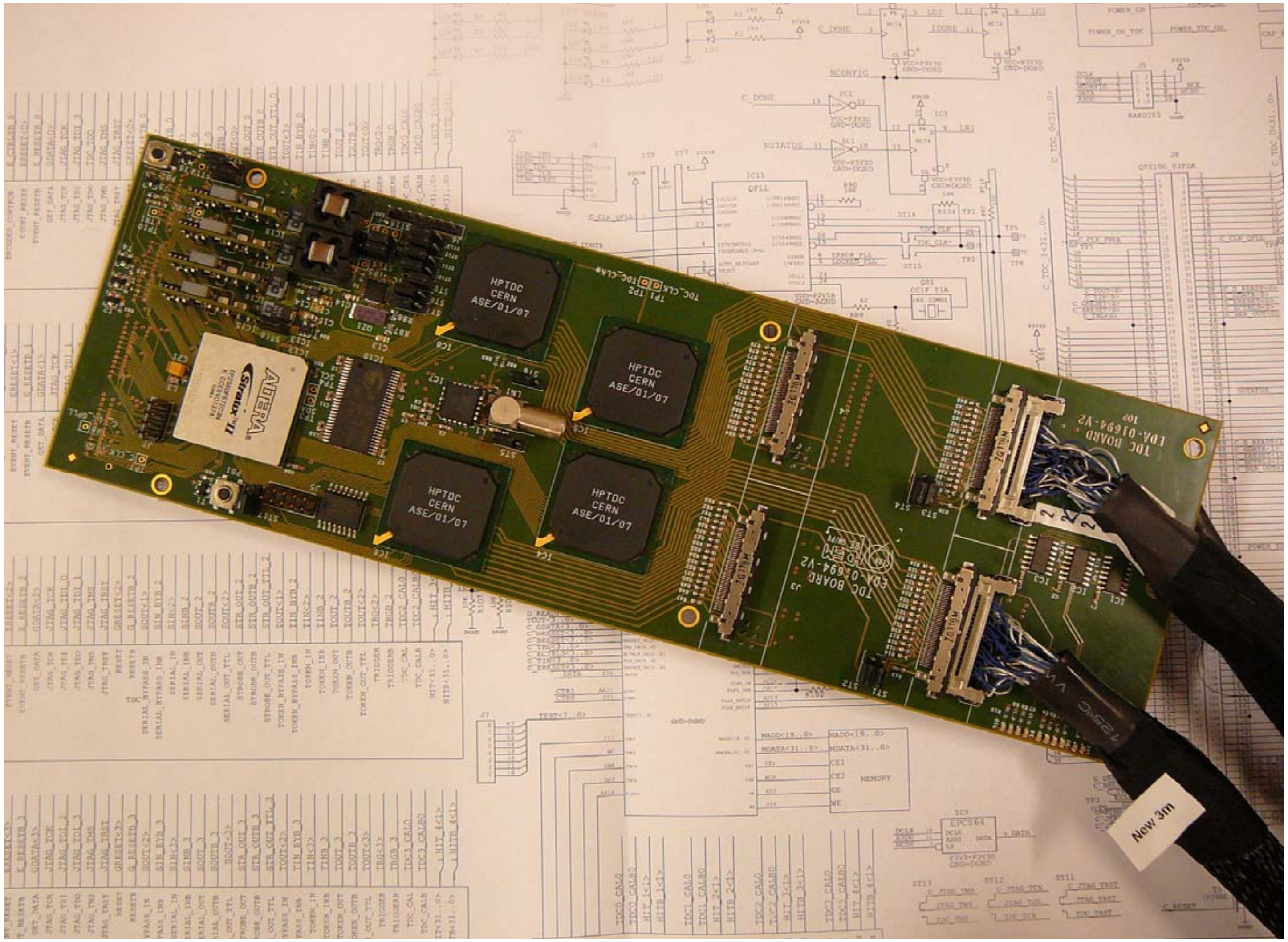
TDAQ

TDC Board V2 (Pisa)

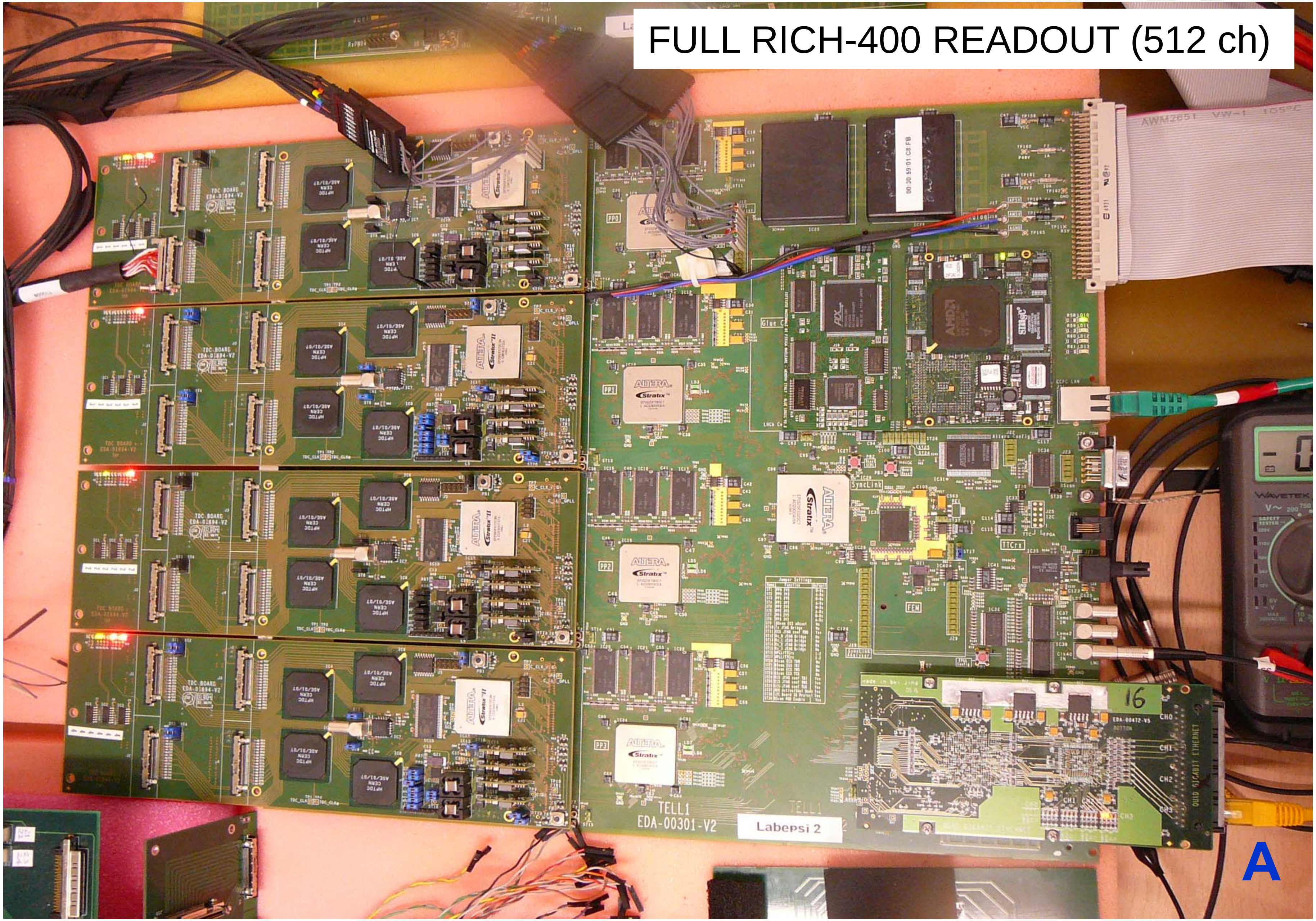
- Reminder: 128 HPTDC channels/board
- Design in Pisa, Layout (10 layers) at CERN, PCB and mounting in Italy
- 18 PCB produced, 6 boards mounted and tested, firmware development

Clock jitter performance slightly improved < 30ps

No more random glitches which degraded the jitter



TELL1 fully equipped with TDCs

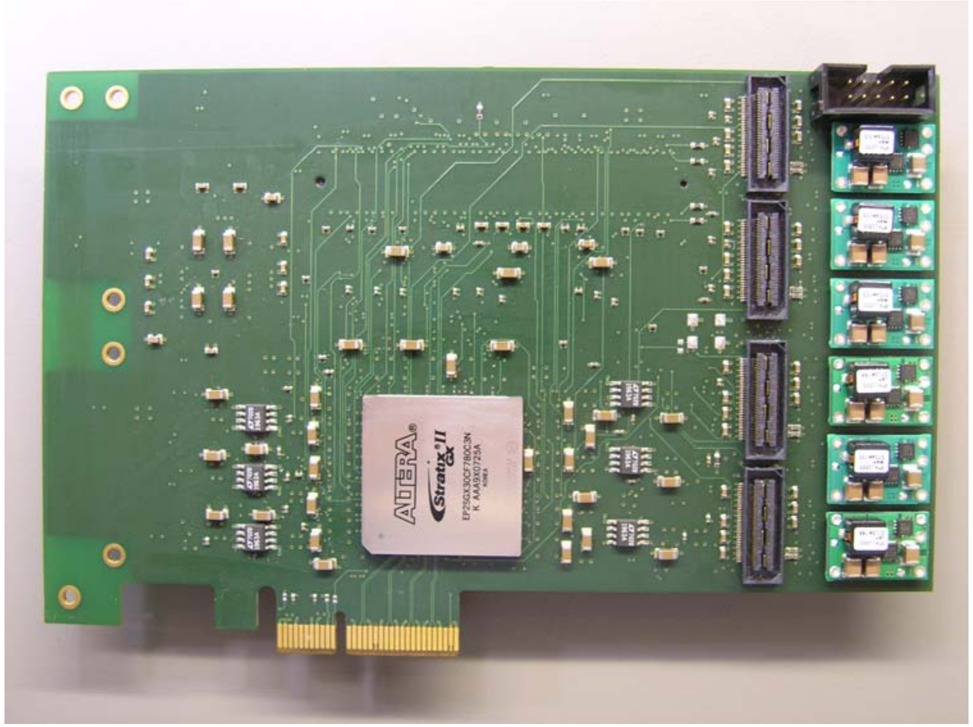


Smart PCI receiver (Roma 2)

12 layers board with 4x 2.5 Gbps links, DDR2 memory, FPGA, PCI 4x

Can be used for:

- LKr readout
- Central L0 processor
- TELL1 data receiver



Prototype mounted, to be tested

Optical IN: 4 x 16 bit @ 75-156 MHz (1.2-2.5 gbit/s)

Copper IN: 2-4 x 48 bit @ 66-133 MHz (3.1-6.3 gbit/s) depending on cable length o

OUT: PCI-E 4 x 16 bit @ 125 MHz (2.0 Gbit/s)

TELL1-based TDAQ for RICH, MUD, STRAWS, VETO, CEDAR, GTK(?)

NEW!

- *Issues: the delay in the approval is starting to raise problems for the use of LHC-based solutions:*
- *Need to secure the chips (HPTDC, TTC, TELL1), otherwise need to restart from scratch*

Beam Request 2009

1. East Hall T9

- two weeks from mid September
- two weeks from mid October

Purpose: Test of the Gigatracker prototype with beam particles

2. North Area P0

- We need compensation for the time lost in 2008 due to the LHC incident (four weeks). Two weeks will be devoted to the test of the RICH-400 prototype and should be scheduled as soon as possible. The other two weeks can be scheduled with more flexibility and a typical good time would be mid-June mid-July.
- In addition we request two weeks as late as possible in 2009 to test the first full LAV station and to test the Gigatracker prototype with the 75 GeV/c secondary beam

Summary

- The physics case remains very strong
- The proposed sensitivity is confirmed
- Significant technical progress was reported while -at the same time- a major physics result based on 2007 data is being prepared
- We have recovered from a setback (Floods in BB5 building)
- The Gigatracker prototypes were fully funded
- Detailed plans are being made for the construction of the main detectors (further progress depends on recommendation)
- Collaboration-wise, major steps forward were made:
  - A draft MoU is proving helpful as a base for negotiation
  - New groups are joining (e.g. Louvain)
  - A major partner (INFN) has approved the experiment at the Scientific Committee level

SPARES

Detector Status (I)

Detector	Function	Status	Current Collaboration
CEDAR	•Event by event K^+ identification (50 MHz)	•CEDAR Exists •To be modified for H_2 •Needs New Front end •Needs New Read – out	Birmingham
GTK	•Gigatracker for beam tracking •Three Stations of Si μpixels 300 x 300 μm •~200 ps per station time resolution •0.5 % radiation length per station •800 MHz beam	•Sensor qualified after irradiation •Prototype R/O chips in 0.13 μm CMOS to be submitted • 8 x 8 pixel array to be beam tested in 2009	CERN Ferrara Louvain Torino
LAV	•12 Ring Calorimeters for photon detection	•Beam tested prototype with OPAL lead glass recovered from floods •First full station being builts	Frascati Pisa Roma 1 Naples
STRAW	•4 Large (6 m^2) straw tracker stations to track ~10 MHz particles from kaon decays	•Front-End Technology under study •Engineering study	CERN Dubna

Detector Status (II)

Detector	Function	Status	Current Collaboration
RICH	•Pion muon separation up to 35 GeV/c •Fast timing of the outgoing charged track	•Full length prototype (96 PMT) tested Oct-Nov ’07 •Timing demonstrated •400 PMT ready2008	CERN Florence Merced Perugia San Luis Potosi George Mason
LKR	NA48 Liquid Krypton Calorimeter for forward photon. 20 tons of liquid krypton. Available!	•Validated as veto •Cryogenics was consolidated •First update of electronics	CERN Pisa Roma II
MUD	•Muon Detector based on the NA48 Hadron Calorimeter + iron and a fast veto plane for triggering	•Prototype tested in 2008	Protvino INR Stanford George Mason
IRC/SAC	•Intermediate Ring and Small Angle Calorimeter to detect photons at small angle	•Shashlik prototype (SAC) tested in 2006	Sofia INR

Estimated Cost (MCHF)*

BEAM	0.6
CEDAR	0.5
GTK	2.9
RICH	3.0
STRAW	2.1
VETOES	5.4
LKR	1.7
MUD	1.7
TDAQ	3.3
GRID/COMP	2.5
COMMON INFRA. + VAC	2.4
TOT	26.1

*As of DRAFT MOU 1.3   April, 2008

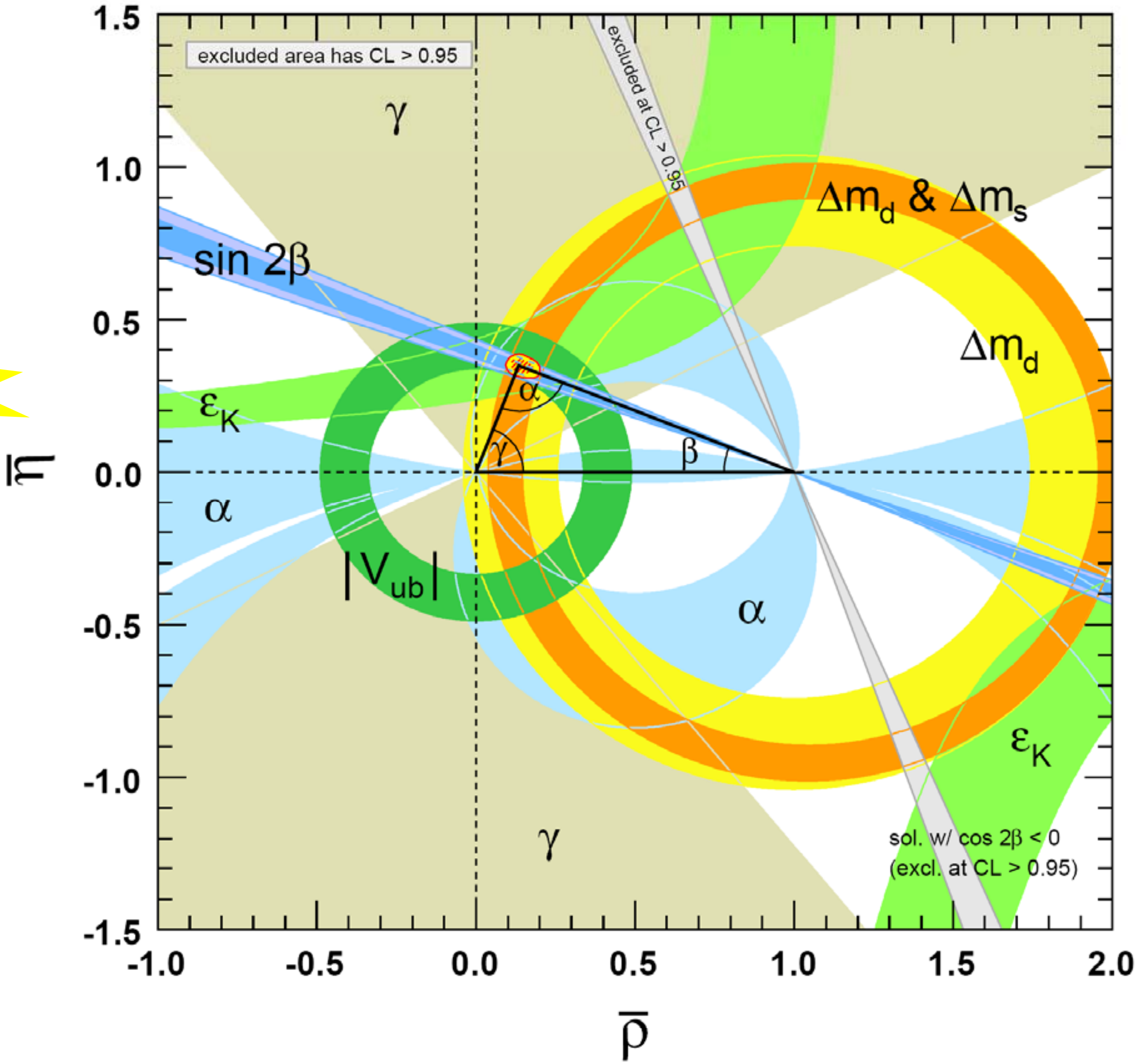
Proposed CERN Contribution*

System	(MCHF)
Beam Line	0.6
Gigatracker	1.3
Straw	0.6
LKR	1.7
RICH	0.6
Infrastructure	0.9
TDAQ	0.5
Total	6.2

*As of DRAFT MOU 1.3 April, 2008

Constraints on the $\bar{\rho}$ $\bar{\eta}$ plane

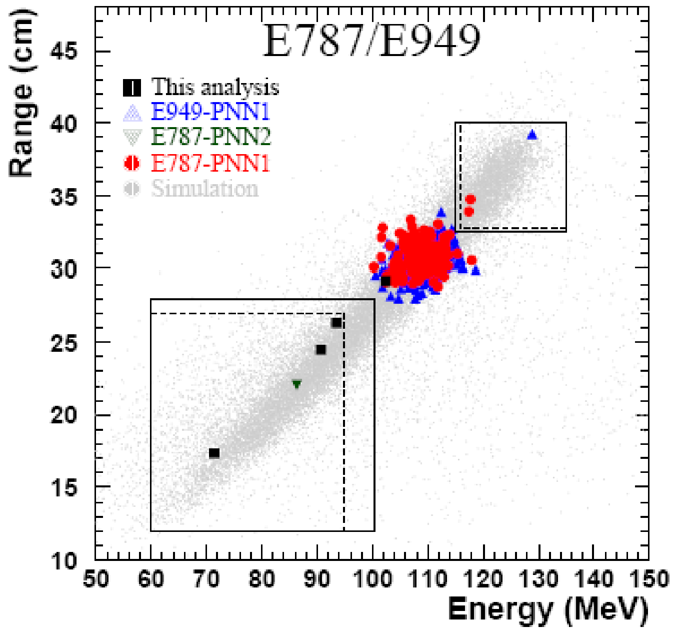
Highlight



Experimental Status: New measurement of the $K^+ \to \pi^+ \nu\nu$ branching ratio (BNL E949)

Three events for the decay $K^+ \to \pi^+ \nu \bar{\nu}$ have been observed in the pion momentum region below the $K^+ \to \pi^+ \pi^0$ peak, $140 < P_\pi < 199$ MeV/c, with an estimated background of $0.93 \pm 0.17(\text{stat.})^{+0.32}_{-0.24}(\text{syst.})$ events. Combining this observation with previously reported results yields a branching ratio of $\mathcal{B}(K^+ \to \pi^+ \nu \bar{\nu}) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$ consistent with the standard model prediction.

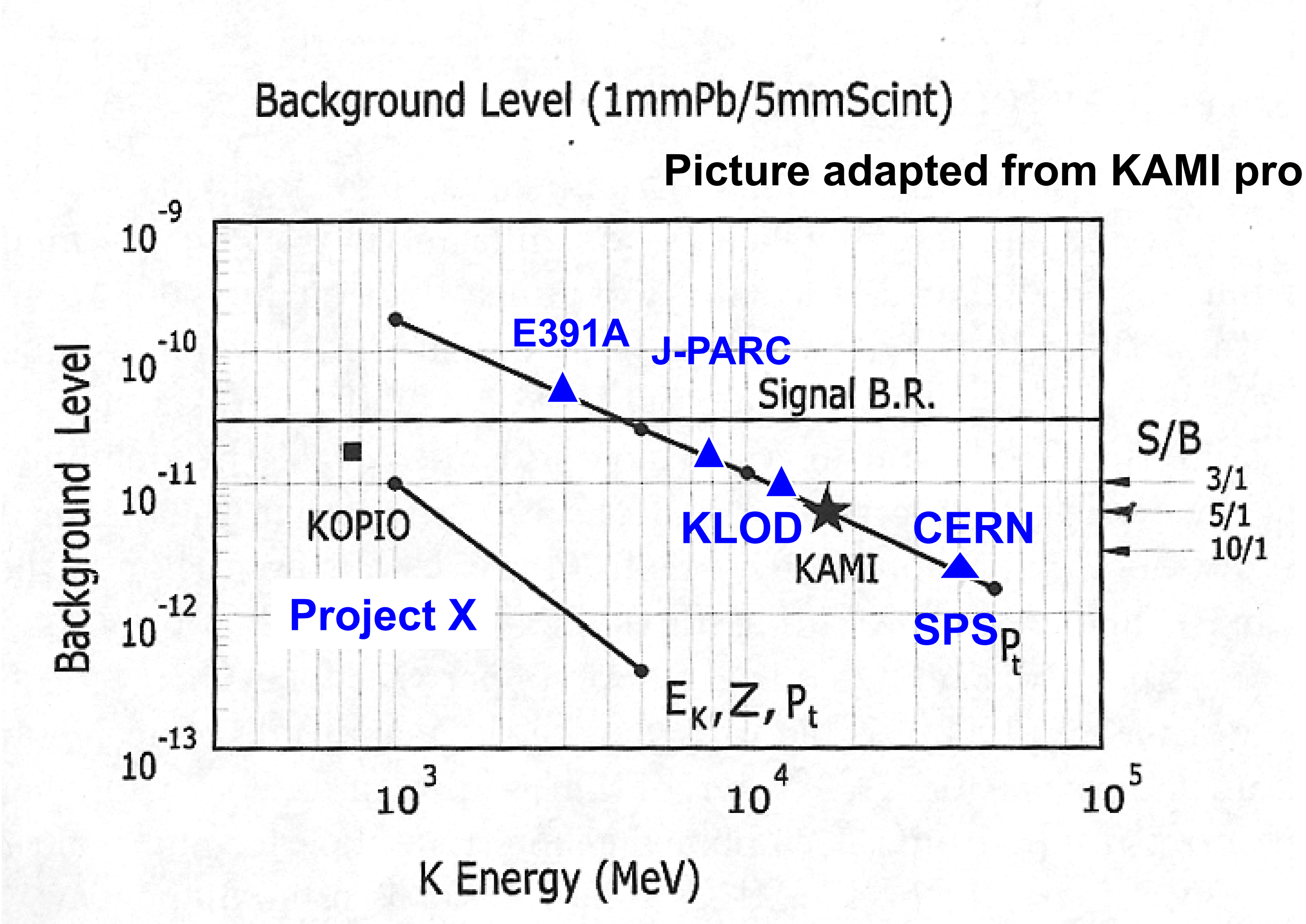
2



Process	Background events
$K_{\pi 2}$ TG	$0.619 \pm 0.150^{+0.067}_{-0.100}$
$K_{\pi 2}$ RS	$0.030 \pm 0.005 \pm 0.004$
$K_{\pi 2 \gamma}$	$0.076 \pm 0.007 \pm 0.006$
K_{e4}	$0.176 \pm 0.072^{+0.233}_{-0.124}$
CEX	$0.013 \pm 0.013^{+0.010}_{-0.003}$
Muon	0.011 ± 0.011
Beam	0.001 ± 0.001
Total	$0.927 \pm 0.168^{+0.320}_{-0.237}$

TABLE I: Summary of the estimated number of events in the signal region from each background component. Each component is described in the text.

$K_L \to \pi^0 \nu\nu$ Long Time Prospects



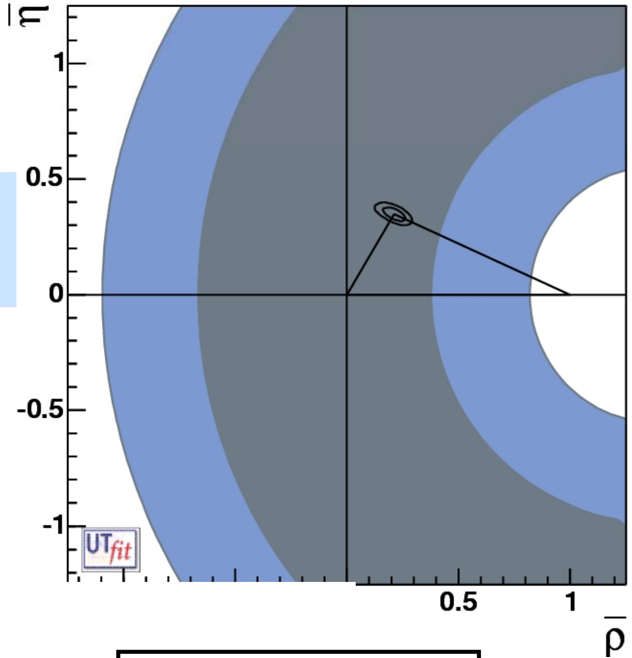
CERN is competitive if the E391A technique is established

Fuga

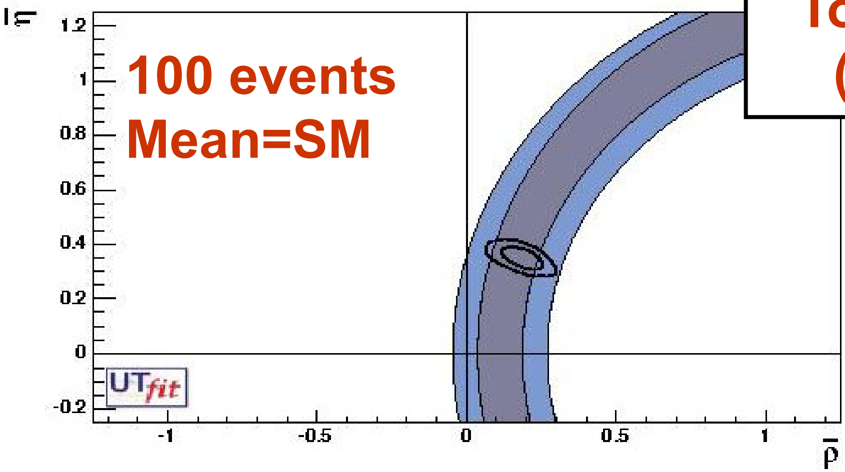
$K^+ \to \pi^+ \nu\bar{\nu}$

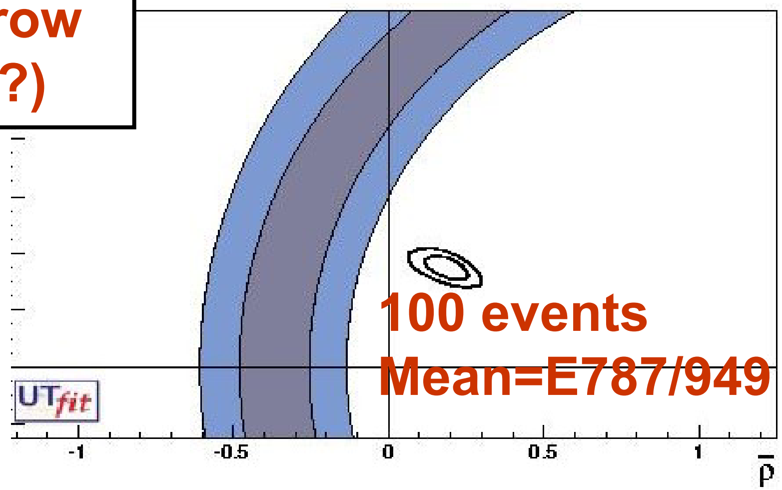
("4.4" events)
BR(exp) = 2 x BR(SM)

Today

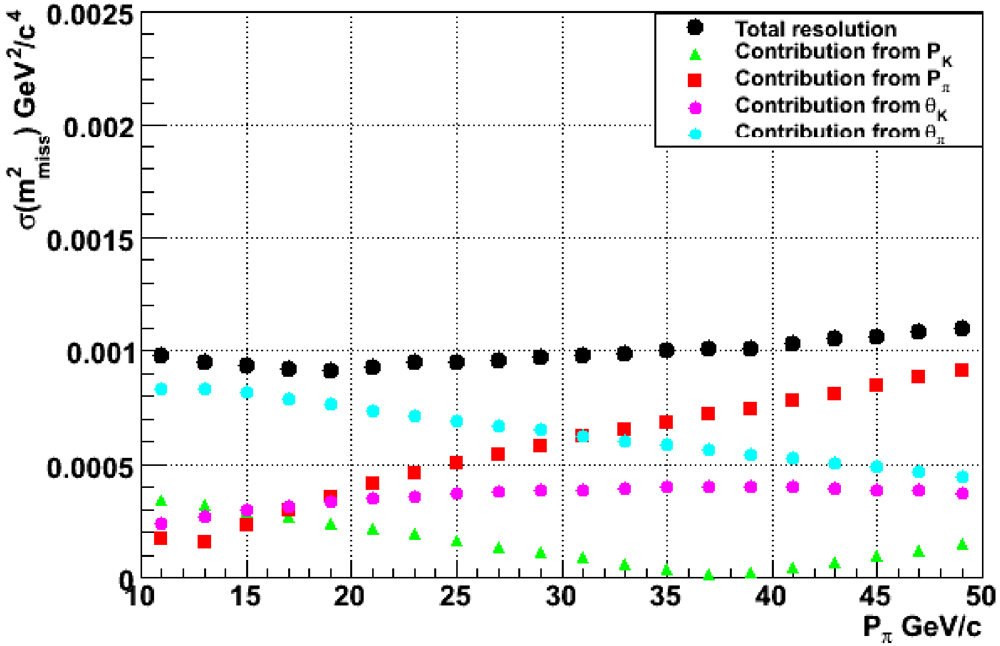


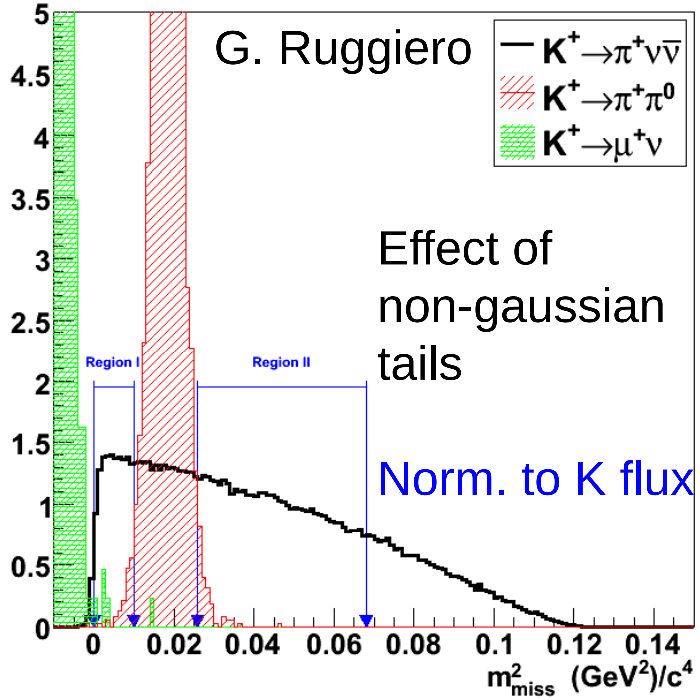
Tomorrow (2012?)





Missing Mass Resolution



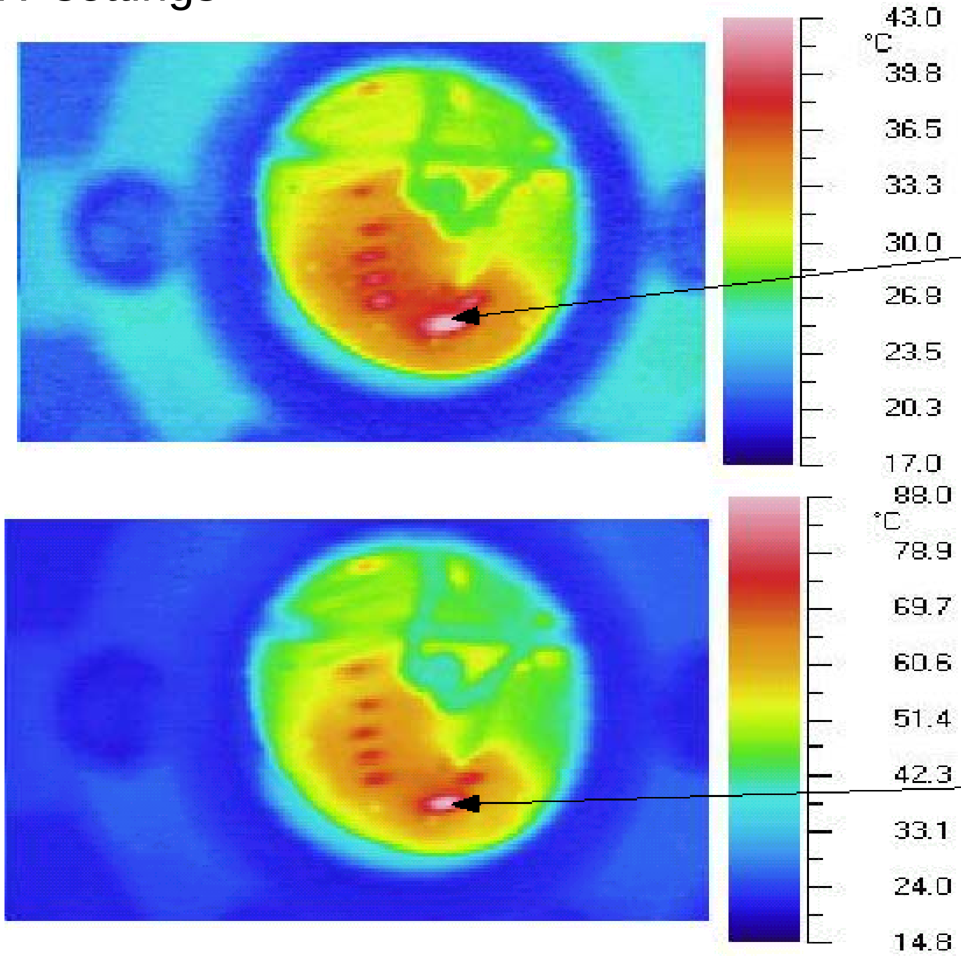


Non-gaussian tails can be induced, for instance, by the wrong association between the incoming kaon and the pion

~100 ps time resolution In Gigatracker is required

LAV PMT operation in vacuum

One PMT base operated in vacuum seen through an infrared camera.
All components stay within their temperature operating range for typical HV settings



HV= 1500 V

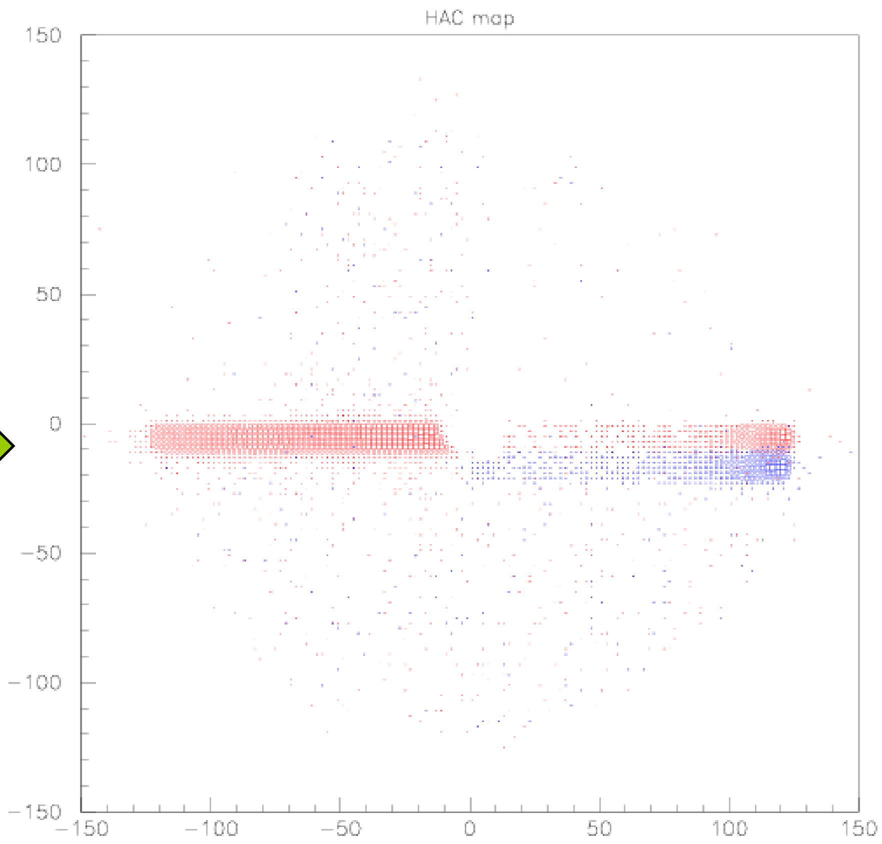
Measured temperature of R1 ~ 45 °C corresponding to 70°C after calibration (correction due to the CaF_2 window. See next slide)

HV= 2500 V

T_{R1} ~ 130 °C (calibrated)

HAC: New (front) vs. Old scintillators test.

New tile

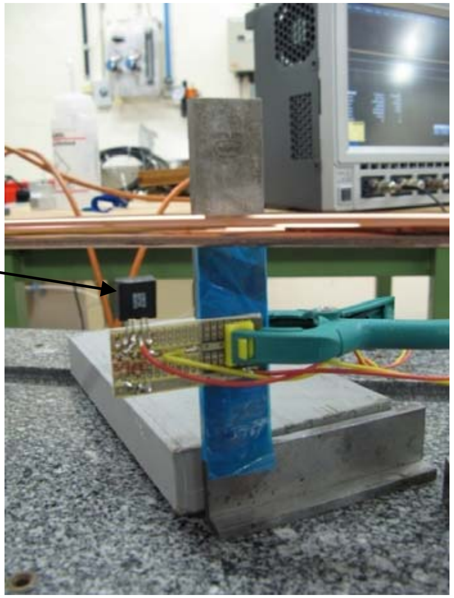


Old tiles

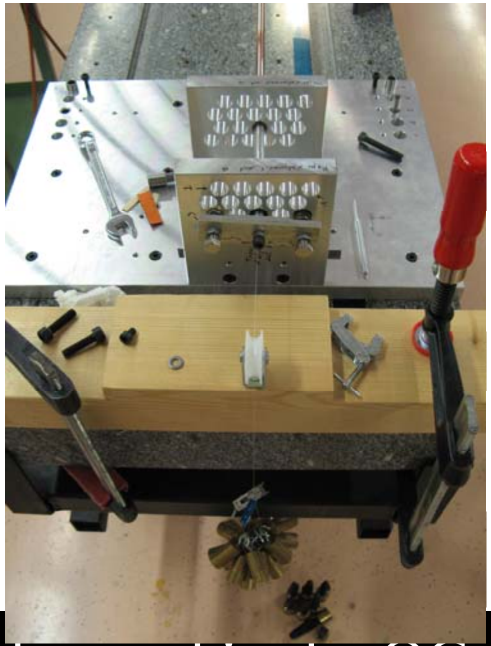
Clean strong attenuation in old tiles as well as significantly lower efficiency

A set-up to measure the straw tension

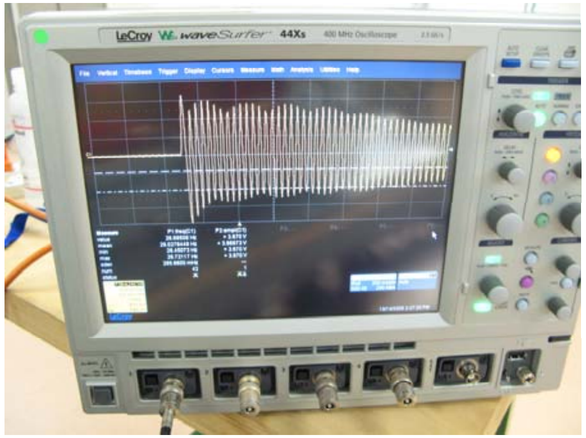
This method was developed to study the straw straightness under tension and pressure
An IR light sensitive sensor gives a voltage proportional to the reflected IR light from the LED



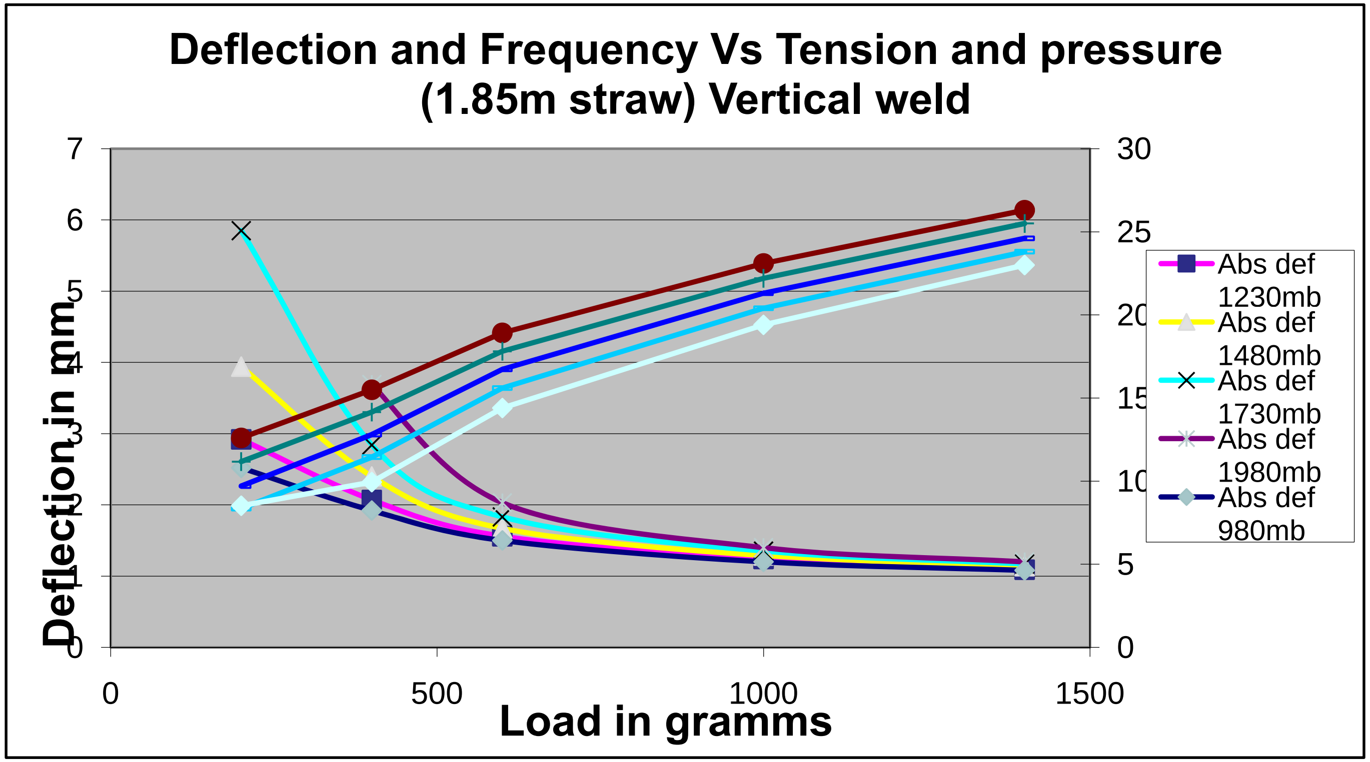
Tension $\propto w \times f^2$
where w is the weight per unit length and f the frequency



To be used in the QC of the chamber production



Deformation of the straw as a function of pressure for different pre-tension

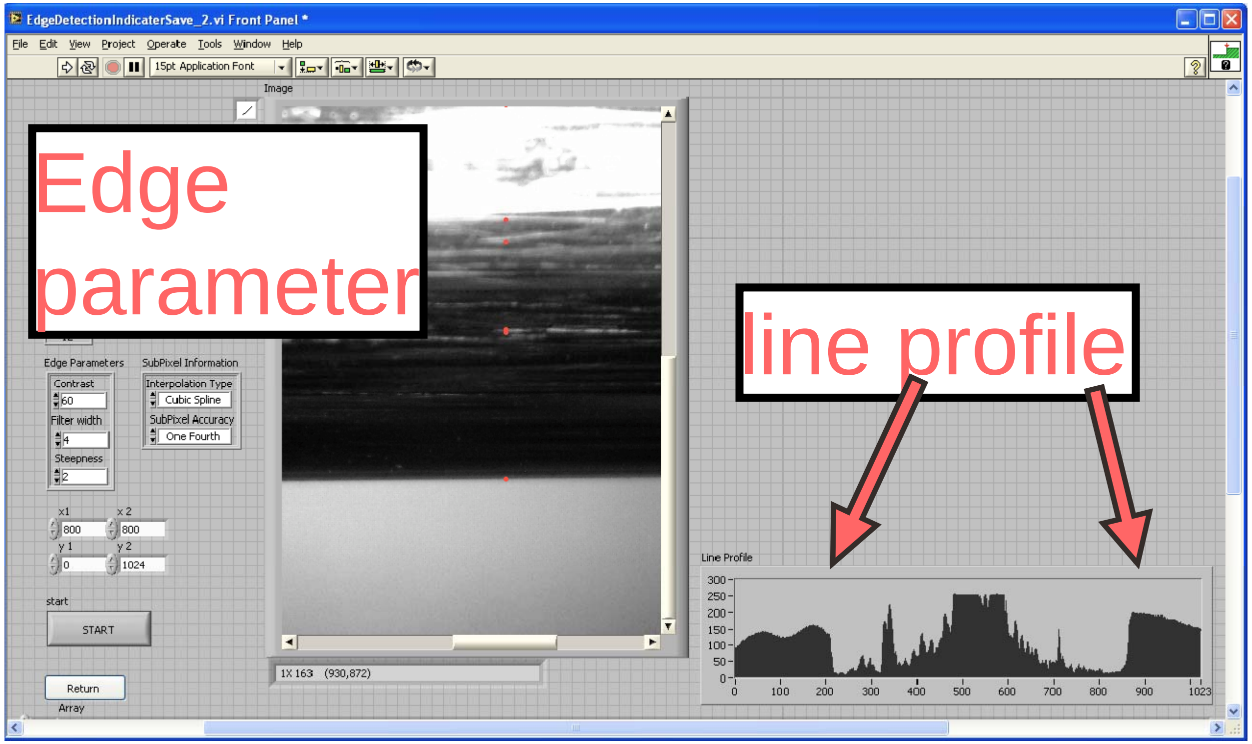


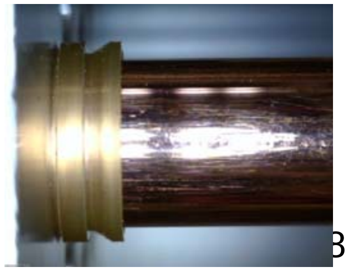
Negative Poisson's ratio! which results in a loss of tension when pressurized

εx=-υ×εy

Straw straightness with 50 μm precision

LabVIEW program panel of edge detection

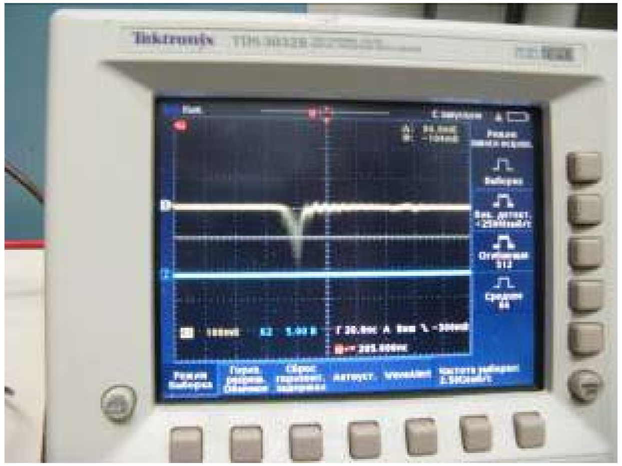


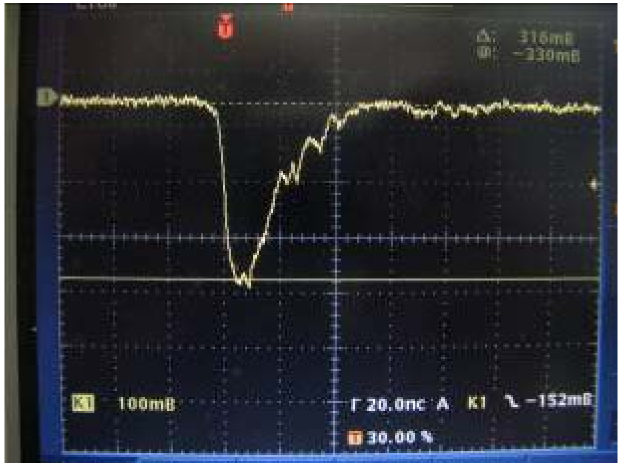


To be used in the QC of the chamber production

LAV Conclusions

- The operation in vacuum has been validated
- Work is going on for the definition of the readout electronics
  - Expect to have protoypes for few channels in November
- We are ready to proceed with the construction of the entire set of rings
  - Basic points defined, only adjustments needed to the design


Tektronix


100mВ
Г 20.0нс A K1
30.00 %