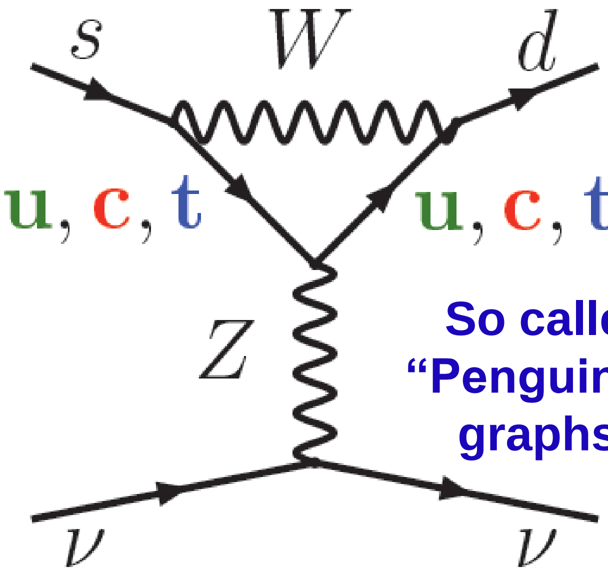
NA62/NA48 Status Report

SPSC, November 24, 2009

NA62:Ultra-rare K Decays

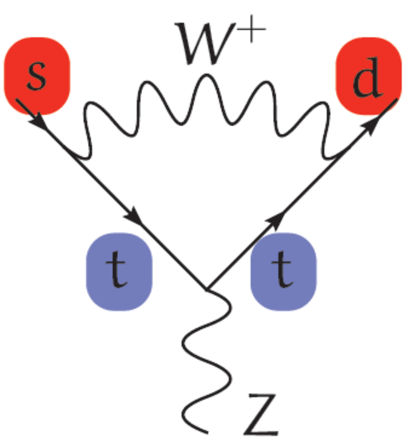
$$K \rightarrow \pi \nu \bar{\nu}$$



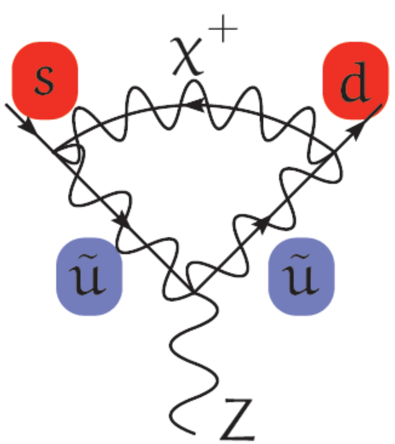
So called "Penguin" graphs

- The contribution to these processes due to the Standard Theory is strongly suppressed ($<10^{-10}$) and calculable with excellent precision (~%)

- They are very sensitive to possible contributions from New Physics



"Standard" Penguin



Possible "Super-Symmetric" Penguin

NA62: Measurement the Rare Decay $K^+ \to \pi^+ \nu \bar{\nu}$ at the CERN SPS

- **Aim to perform a 10% measurement of the Branching Ratio at the SM Sensitivity**
- **Current Status:**

Decay	Branching Ratio ($\times 10^{10}$) Theory (SM)	Experiment
$K^+ \to \pi^+ \nu \bar{\nu}(\gamma)$	0.85 ± 0.07 [1]	$1.73^{+1.15}_{-1.05}$ [2]
$K_L^0 \to \pi^0 \nu \bar{\nu}$	0.26 ± 0.04 [3]	< 670 (90% CL) [4]

[1] J.Brod, M.Gorbahn, PRD78, arXiv:0805.4119
[2] AGS-E787/E949 PRL101, arXiv:0808.2459
[3] M. Gorbahn
[4] KEK-E391a PRL 100, arXiv:0712.4164

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

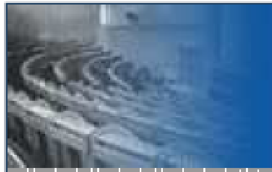
"Stopped"

- Work in Kaon frame
- High Kaon purity (Electro-Magneto-static Separators)
- Compact Detectors

"In-Flight"

- Decays in vacuum (no scattering, no interactions)
- RF separated or Unseparated beams
- Extended decay regions

Exp	Machine	Status	Meas. or UL 90% CL	Notes
	Argonne	COMP	$< 5.7 \times 10^{-5}$	Stopped; HL Bubble Chamber
	Bevatron	COMP	$< 5.6 \times 10^{-7}$	Stopped; Spark Chambers
	KEK	COMP	$<1.4 \times 10^{-7}$	Stopped; $\pi^+ \to \mu^+ \to e^+$
E787	AGS	COMP	$(1.57^{+1.75}_{-0.82}) \times 10^{-10}$	Stopped
E949	AGS	COMP	$(1.73^{+1.15}_{-1.05}) \times 10^{-10}$	Stopped; PPN1+PPN2
CKM	MI	CANC		In-Flight; Separated; RICH vel. sp.
NA62	**SPS**	**CONS**		**In-Flight; Unseparated**
P996	FNAL	PROP		Stopped; Tevatron as stretcher ring?



NA62 Interaction with the SPSC Referees

Monday 23 November 2009
from **14:00** to **17:00**
Europe/Zurich
at **CERN (32-1-A24)**

Monday 23 November 2009 |

Monday 23 November 2009

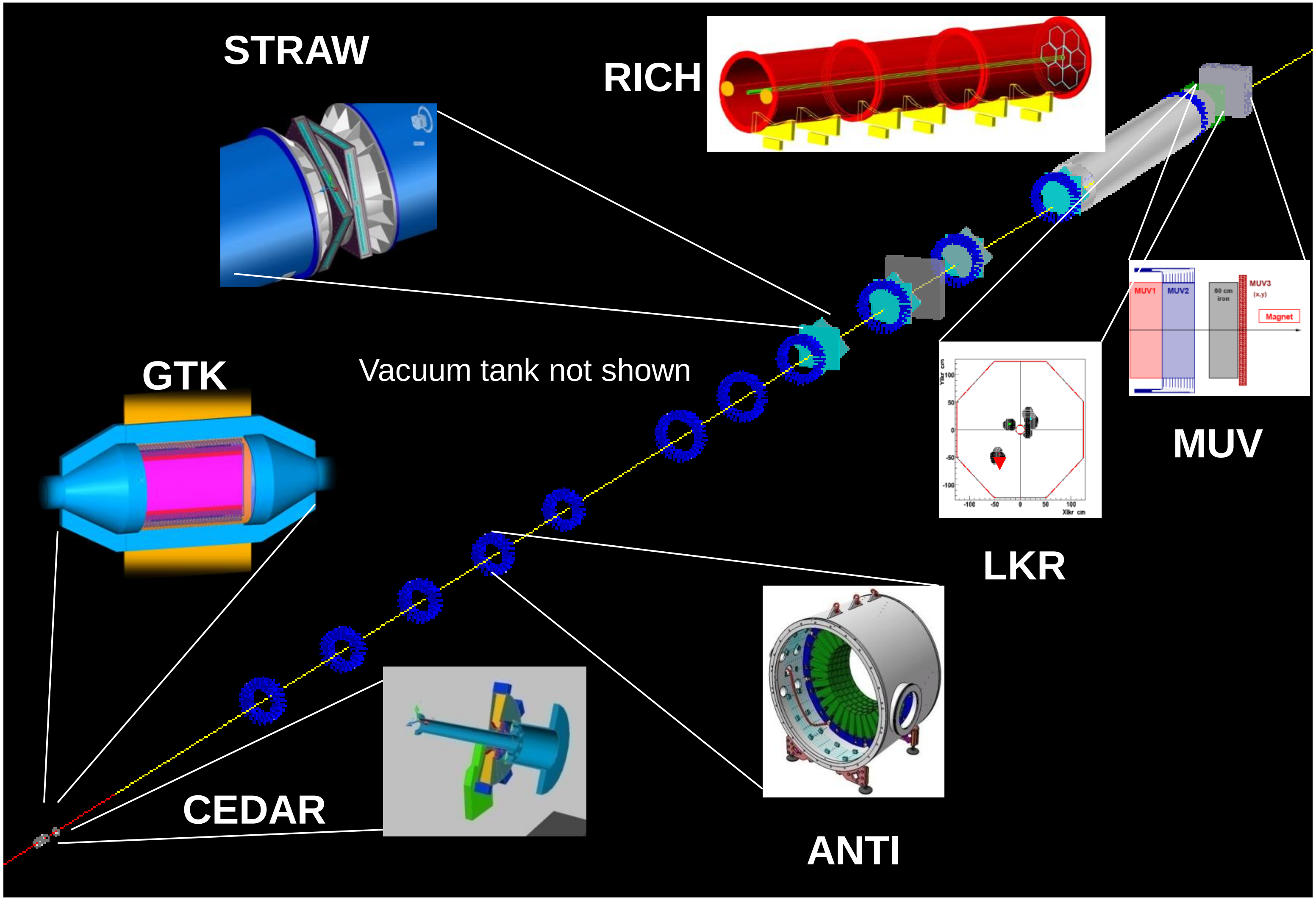
top

14:00	Introduction / Material for the Public Presentation (10') (Slides)	Augusto Ceccucci (*CERN*)
14:10	Technical Coordination / Technical Design (10') (Slides)	Ferdinand Hahn (*CERN*)
14:25	Status of the STRAW (10') (Slides)	Hans Danielsson (*CERN*)
14:40	Status of the CEDAR (10') (Slides ; more information)	Cristina Lazzeroni (*Birmingham*)
14:55	Status of the GTK (10') (Slides)	Flavio Marchetto (*Torino*)
15:10	Status of the RICH (10') (Slides)	Massimo Lenti (*Firenze*)
15:25	Status of the LAV (10') (Slides)	Antonelli Antonelli (*LNF*)
15:40	Status of the MUV (10') (Slides)	Rainer Wanke (*Mainz*)
15:55	Status of the TDAQ (10') (Slides)	Marco Sozzi (*Pisa*)
16:10	Coffee Break (10')	
16:20	Status of the NA62 R_K Analysis (20') (Slides ; document)	Evgueni Goudzovski (*Birmingham*) , Emanuele Leonardi (*Roma La Sapienza*)
16:40	Recent NA48/2 results (20') (Slides)	Vladimir Kekelidze (*JINR*) , Rainer Wanke (*Mainz*)

Collaboration News

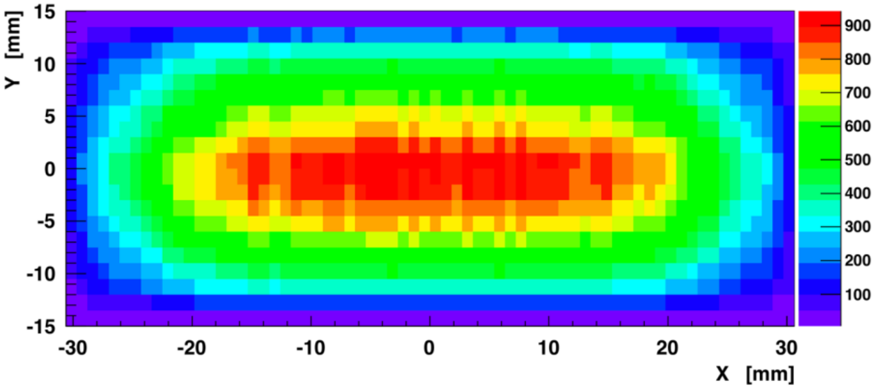
- Negotiations for new Membership:
  - Comenius University (Bratislava)
- DRAFT MoU (v3.2)
- Current number of participants: 191
- Current Number of Institutions : 25
- Technical Co-ordinator: Ferdinand Hahn
- GLIMOS: Valeri Falaleev

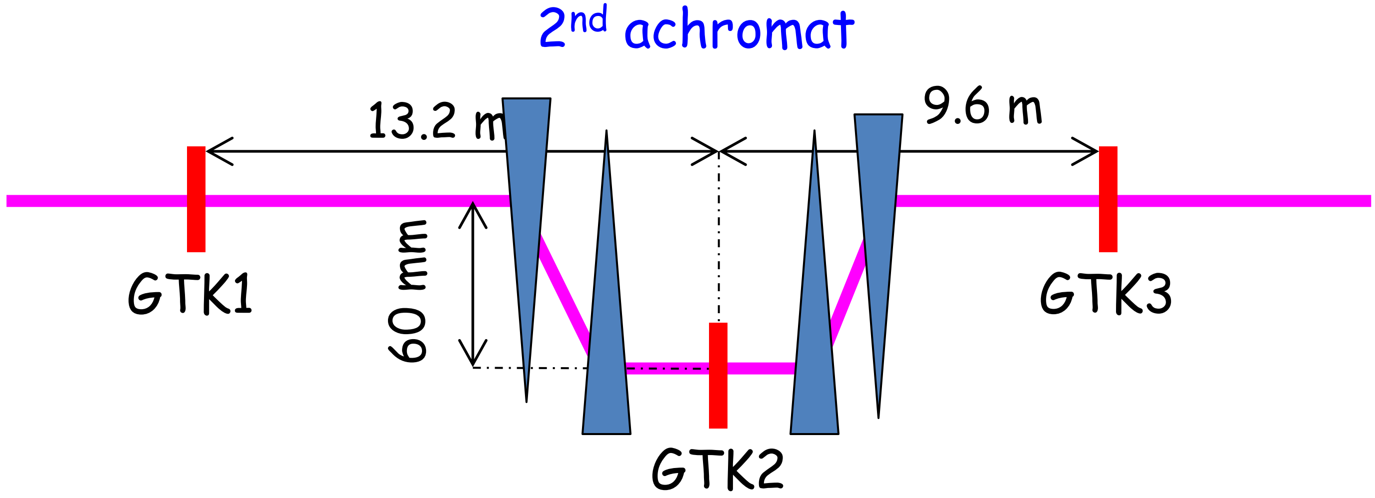
NA62 @ CERN-SPS



NA62 Beam

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

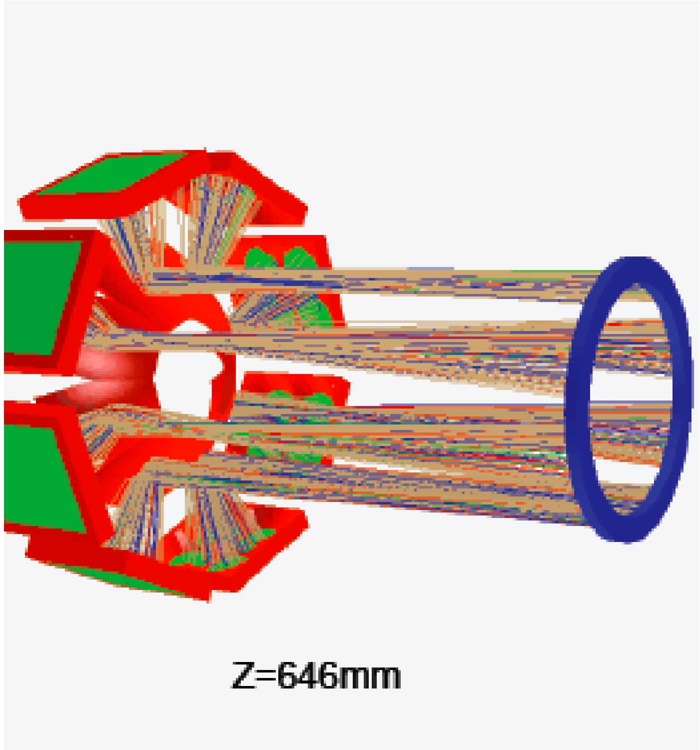




- **Sensitivity is NOT limited by protons flux but by beam (GigaTracKer (GTK)**
- **Similar amount of protons on target as NA48 (~5 10^{12} / pulse)**

CEDAR

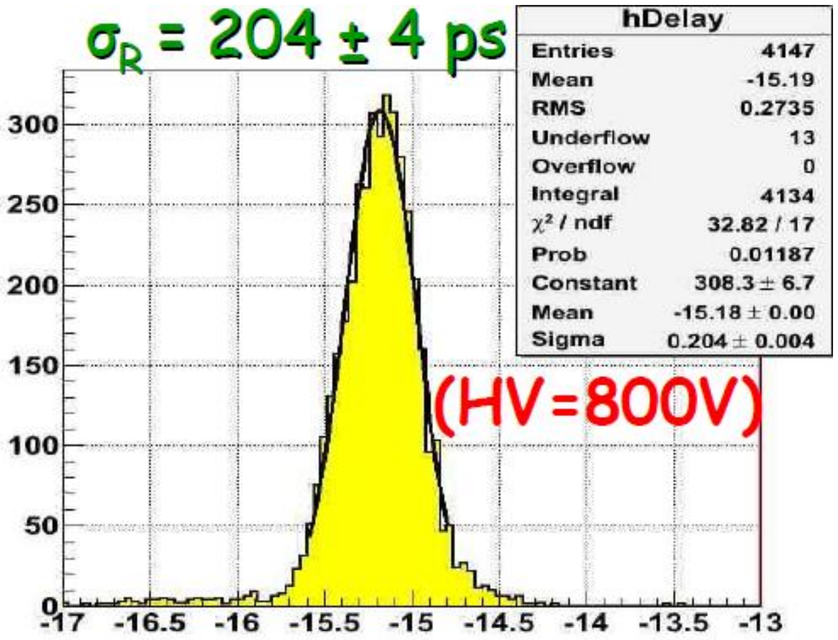
Differential Cherenkov Counter for positive Kaon Identification



- **50 MHz kaons**
- **100 photons/kaon**
- **Simulated (FLUKA) mean dose: 26 G/y**
- **H_2 instead of Nitrogen**
- **New Optics, photodetectors and electronics**
- **Photo detector baseline: Photube Hamamatsu R7400**

CEDAR – Choice of Photodetectors

Hamamatsu R7400-U3

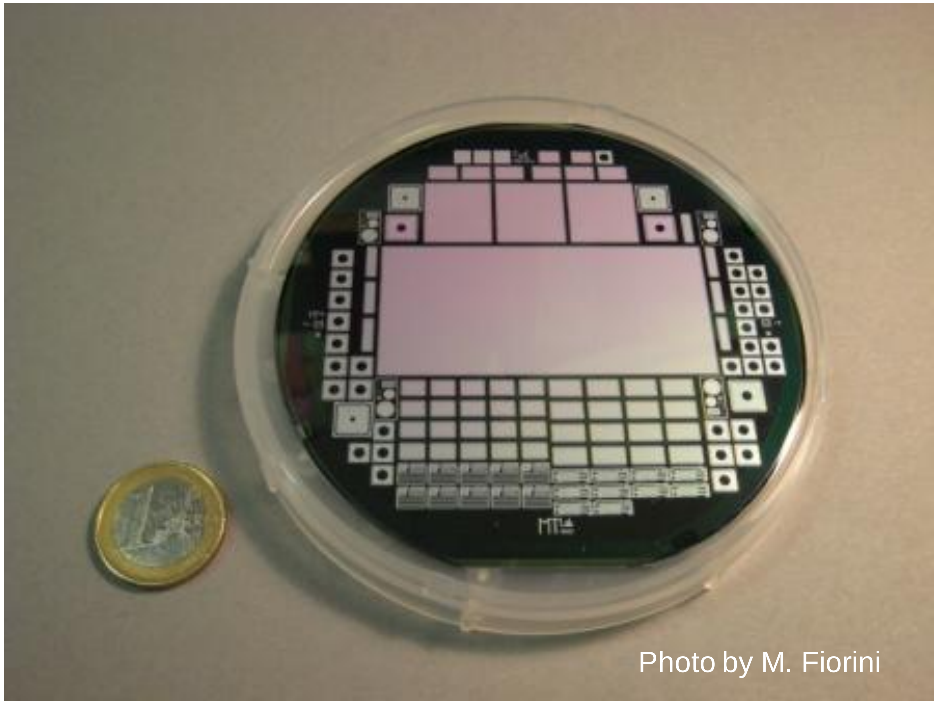


- **Comparison of PMT and SiPM using PicoQuant laser**
  - 405 nm
  - FWHM 50 ps
  - Rep up to 80 MHz

	σ_R@ 5 MHz 800V	σ_R @ 20 MHz 800V	σ_R @ 40 MHz 800V	σ_R @ 5 MHz 900V	σ_R @20 MHz 900V	σ_R @40 MHz 900V
PMT R7400-U3	211 ± 5 ps	185 ± 3 ps	154 ± 4 ps	200 ± 3 ps	184 ± 3 ps	152 ± 2 ps
PMT R7400-U6	212 ± 4 ps	186 ± 3 ps	129.1 ± 1.4 ps	186 ± 3 ps	175 ± 3 ps	121.6 ± 1.3 ps

GigaTracKer (GTK)

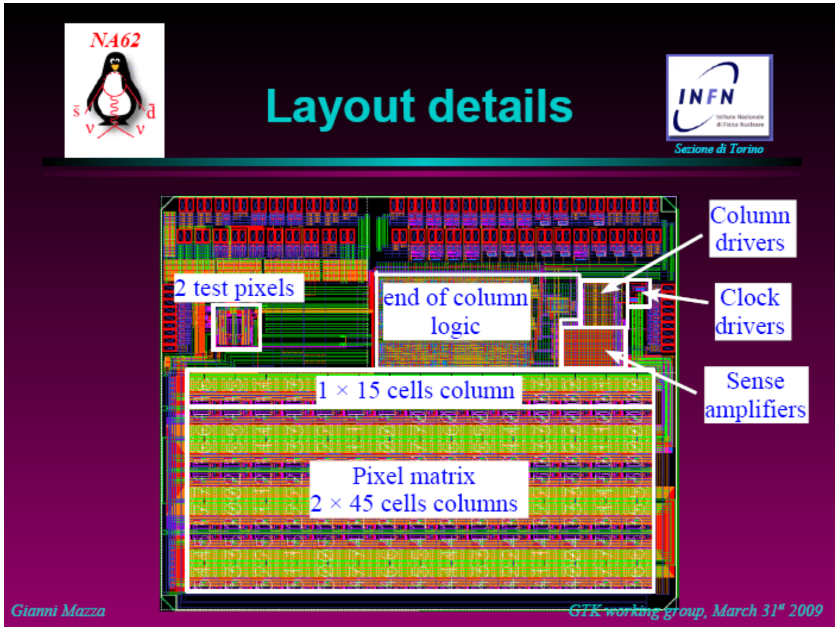
- Tracking and timing of all incoming part ~750 MHz

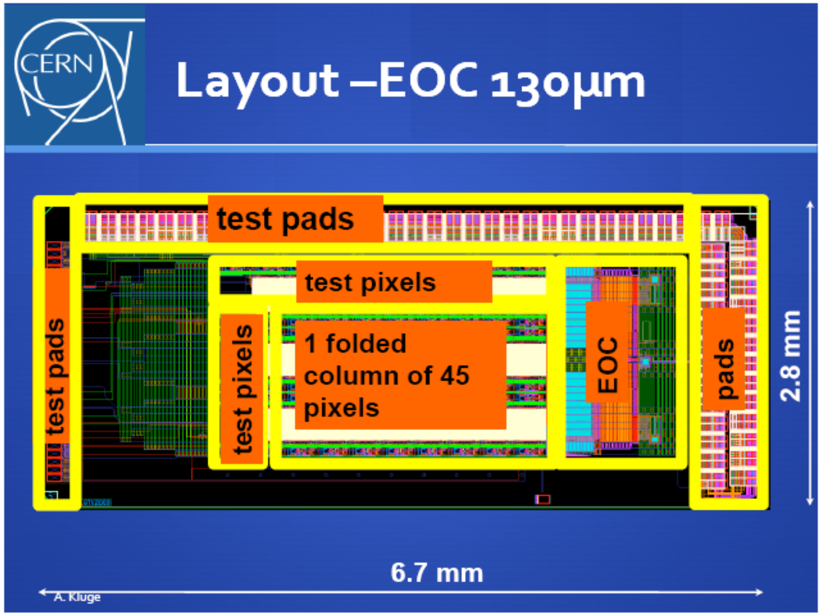


First GTK wafer (FBK)

- Si μ–pixel detector with excellent time resolution
- Received first sensor wafers from FBK
- Performed Marked Survey for bump bonding of sensor to R/O chips
- Completed Price Inquiry for bump-bonding of the prototypes
- Testing Prototype R/O chips

GTK R/O Prototypes





INFN Design: One TDC / pixel

CERN Design: End of Column TDC

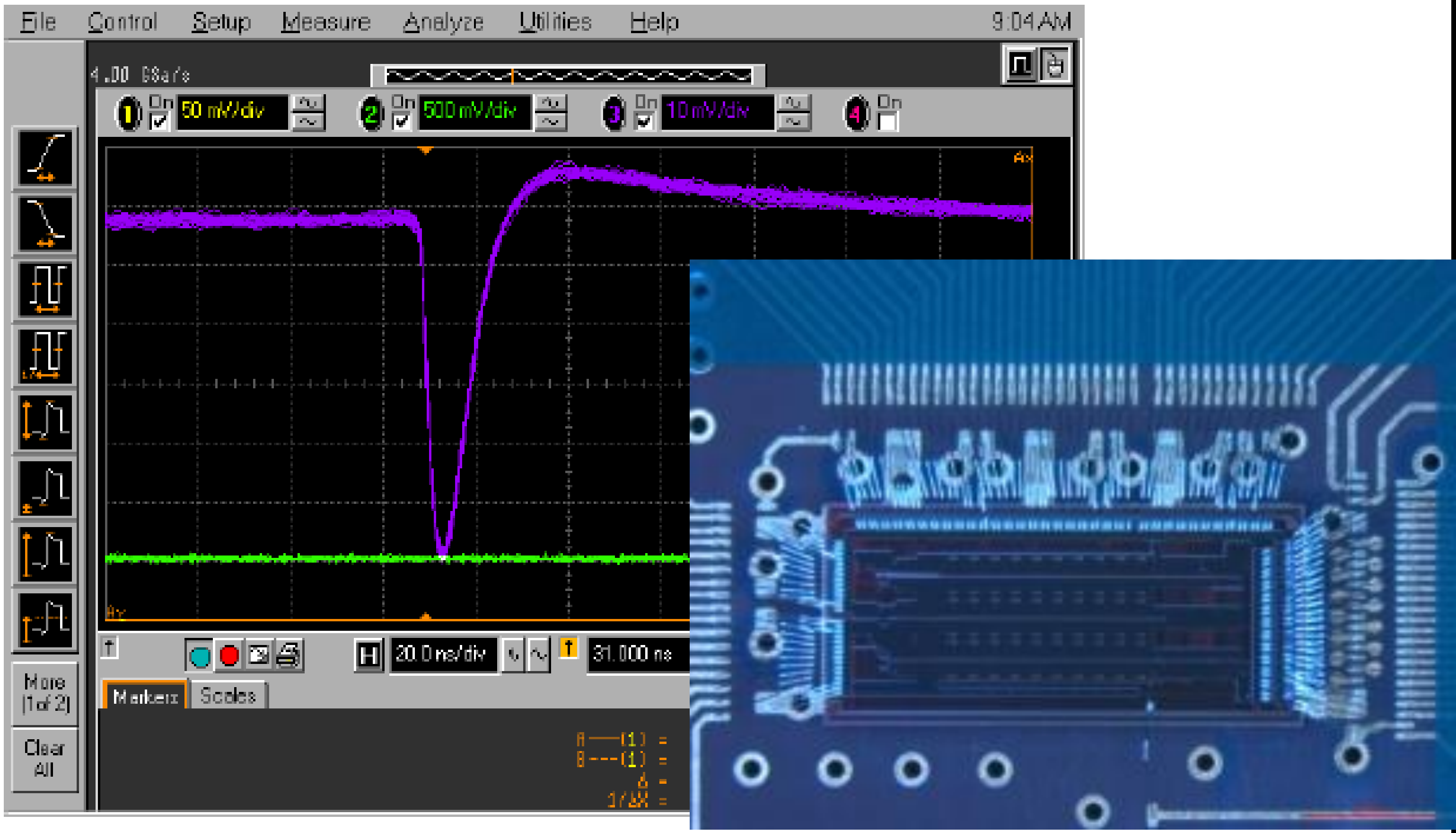
Both Designs in 130 nm IBM CMOS

•Prototypes delivered in July, 2009

See reports at the latest IEEE NSS (Orlando, FA, US)

Preliminary: Analogue Output

M. Noy

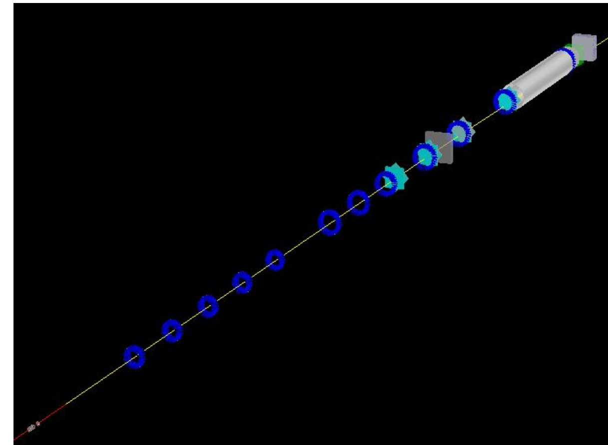


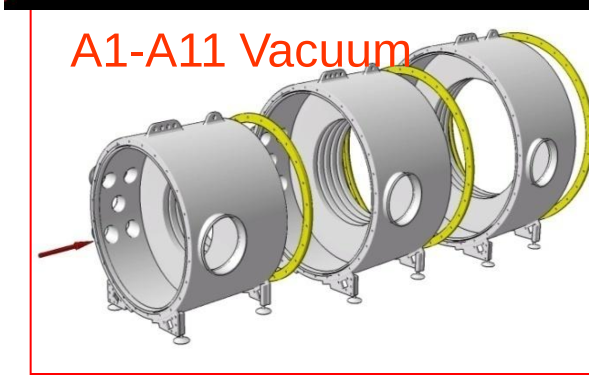
- Analogue test pixel output with ~2fC of charge injected
- 100mV pulse into ~20fF capacitor, rise time ~0.5ns,
- Front End amplifier ~56 mV/fC

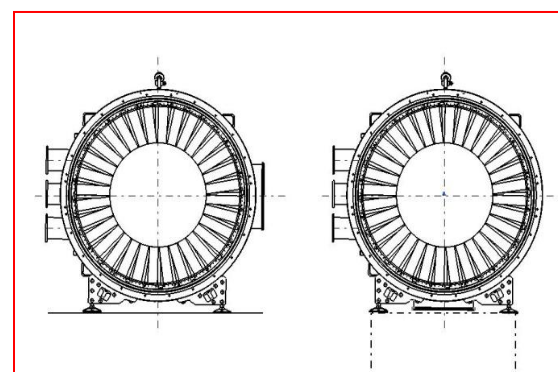
LAV "Post-card"

- 12 LAV stations mounted along 120 meter decay region 6 meters apart
- 4 different types:
  - 160, 240 blocks; 5 layers in vacuum
  - 240 blocks; 4 layers in vacuum
  - 256 blocks; 4 layers in air
- Angular coverage 7-50 mrad
- Inefficiency < 10^{-4} from few hundred MeV to 35 GeV
- Building blocks: OPAL calorimeter lead glass blocks, for a total of 2500 crystals
- 2007 efficiency measurements with electron beams:

  $1-\varepsilon<10^{-4}$ for 200 MeV<E<500 MeV







LAV slides adapted from A. Antonelli INFN-LNF

LAV ANTI-A1

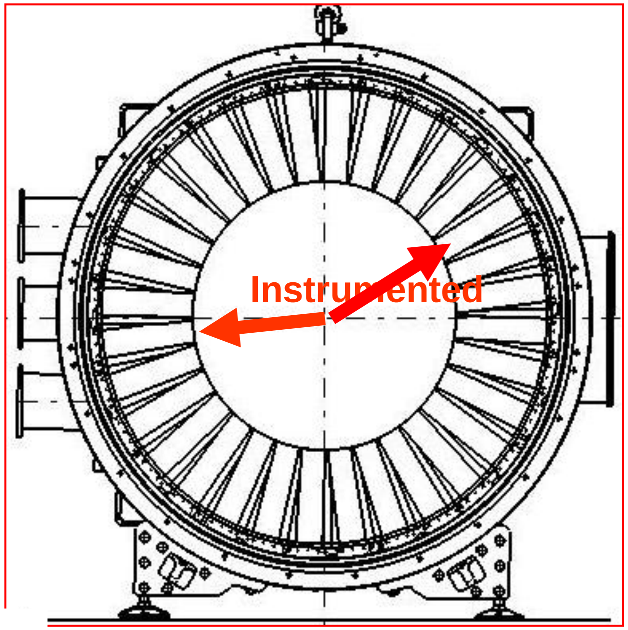
- In summer 2009 the first station A1 was built at LNF and shipped to CERN. It is now mounted on the blue tube
- A test beam run with the complete system including prototype front-end electronics (FEE) was performed at the end of October 2009

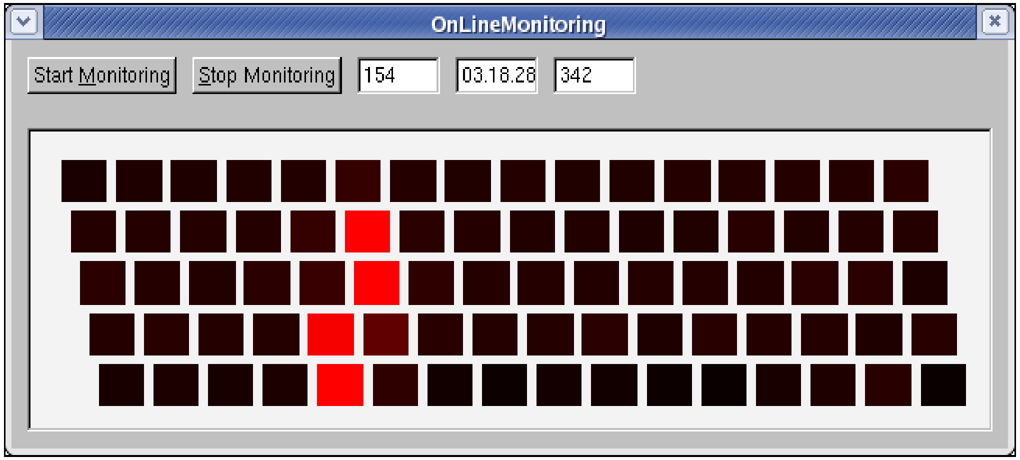
LAV 2009 test beam

- Entire veto with HV ON, use nominal values from equalization with cosmic rays
- 80 channels instrumented for readout: 16 per layer, summing up to 5 half-rings
- Dual readout: (active spitting)

  Clamping + discriminator board output → HPTDC

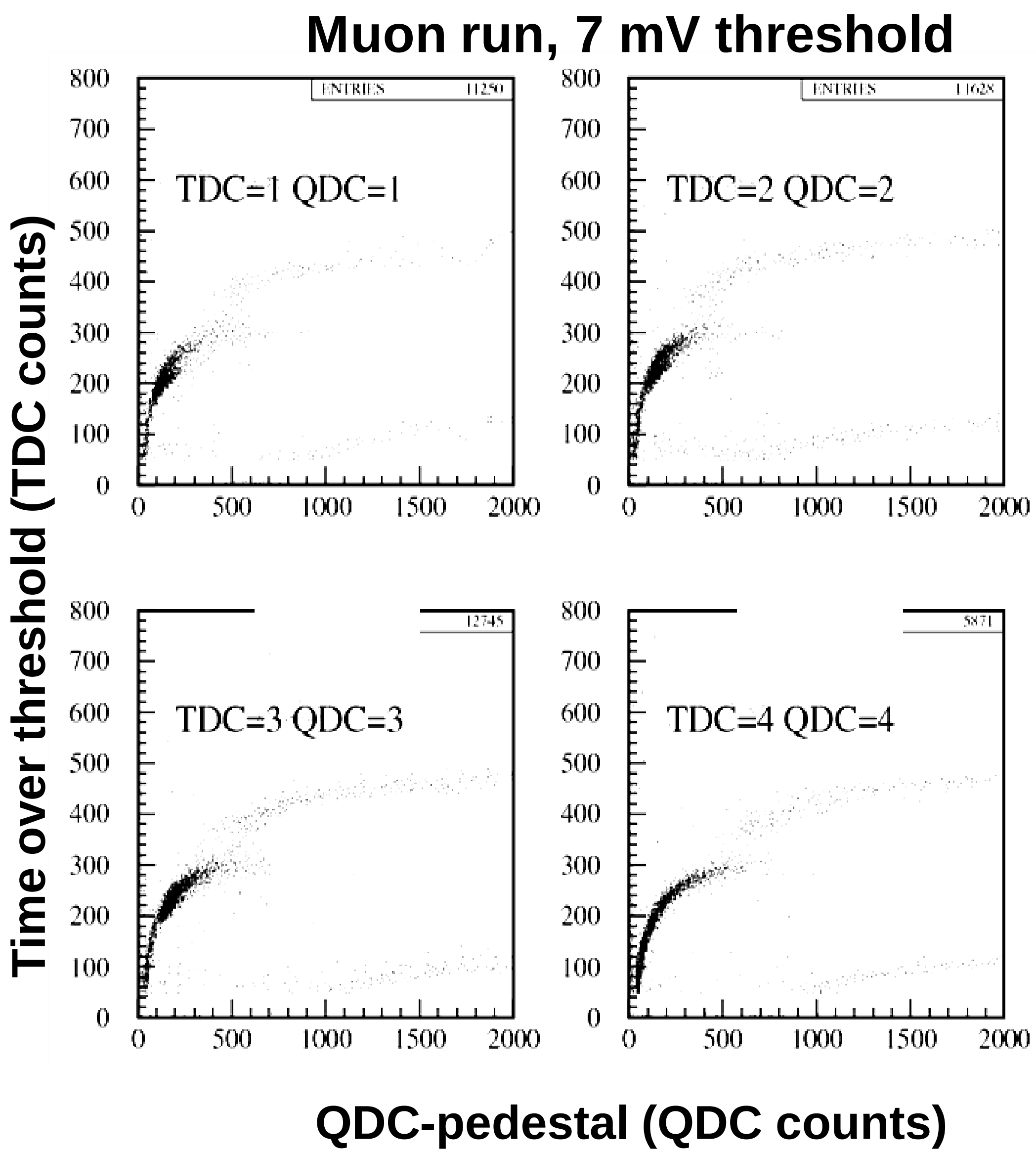
  Analog output → QDC (80 ch's)
- Trigger with logical OR of signals from first half-ring (low-threshold discriminator)
- Dedicated DAQ, SPS signals used





Time over threshold TOT

- Reconstruct TOT from closest pair of leading-edge/ trailing-edge hits from TDC
- Same dependence for each channel



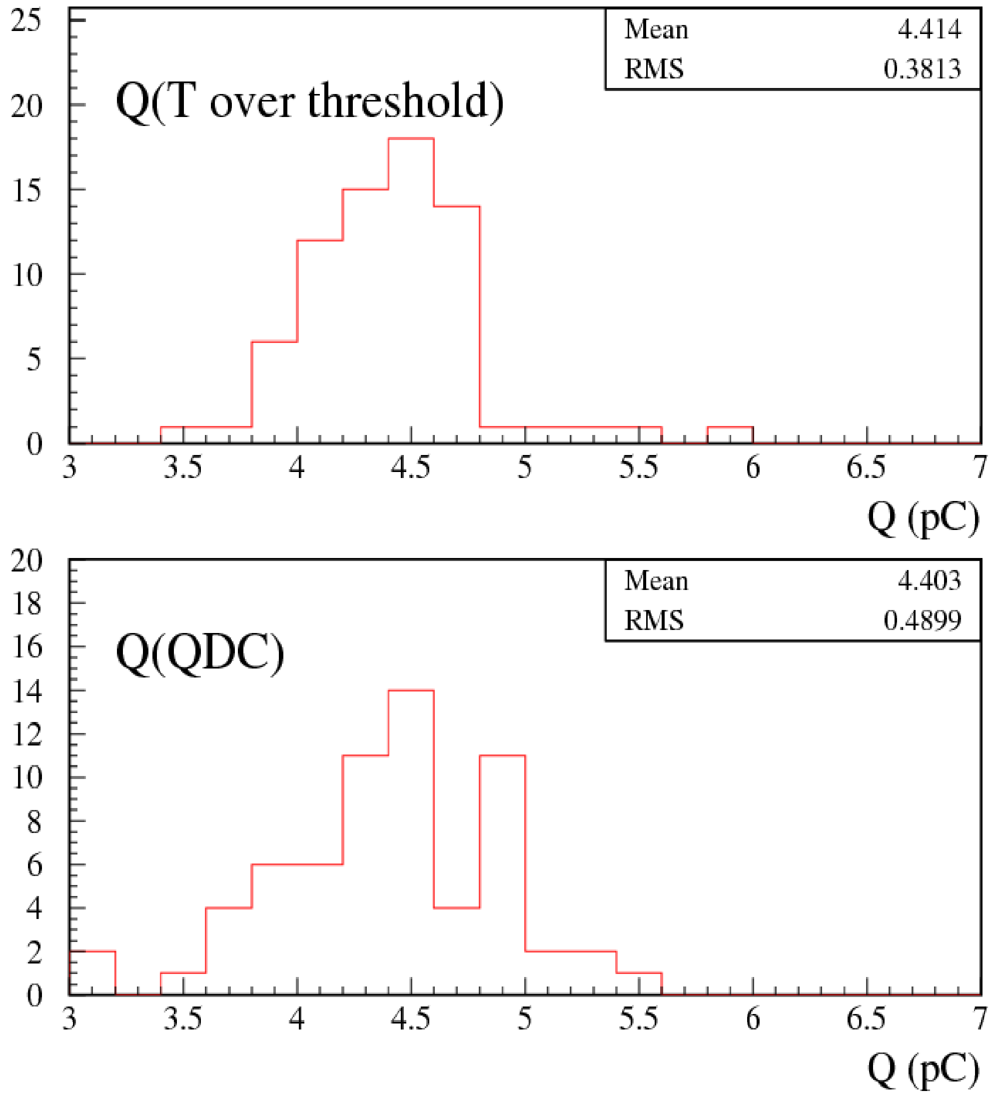
Equalization performances

•muon run

•Select straight muons using isolation cuts

•Reconstruct the charge from the time over threshold

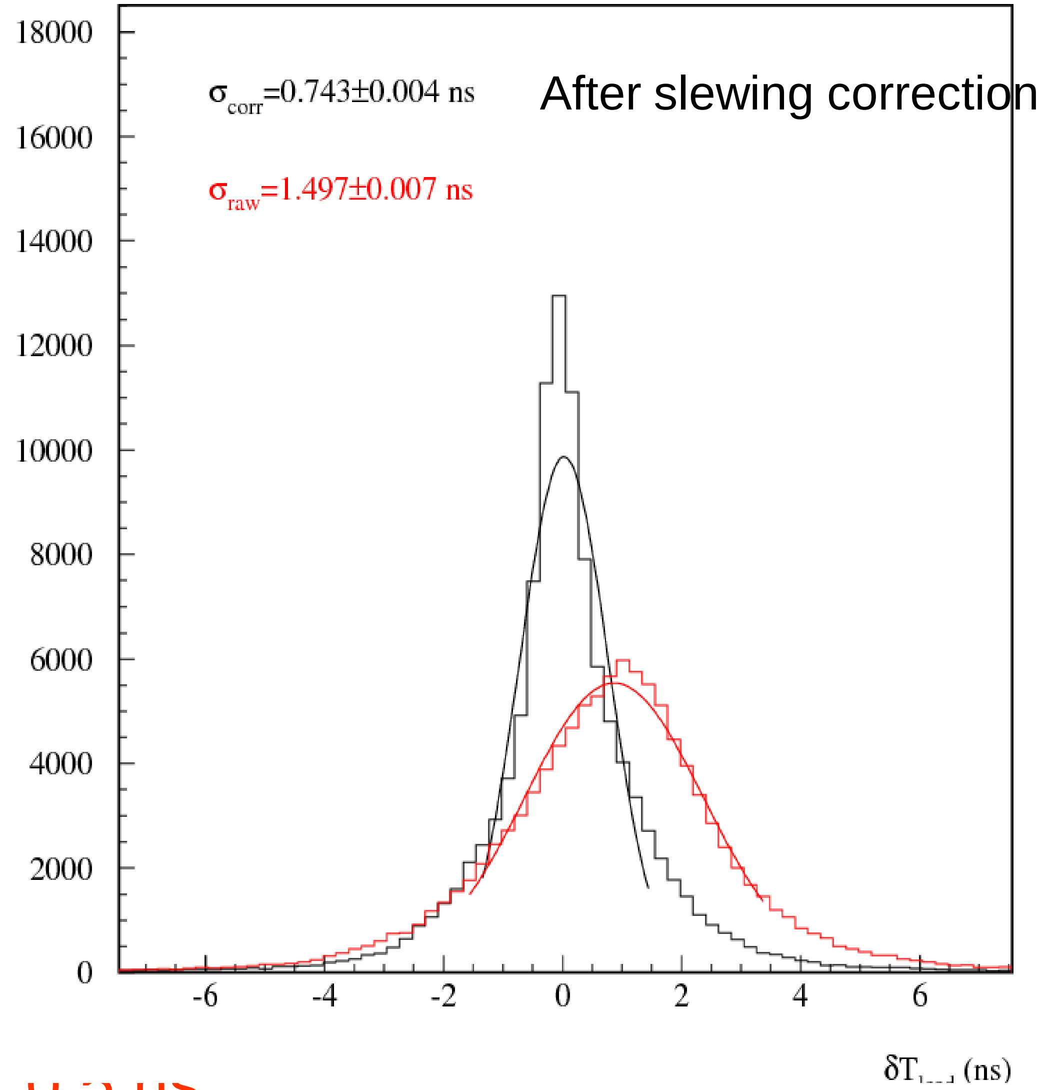
Offline cosmic-ray calibration gives a MIP 4 pC



Time resolution

- 2 GeV electrons run
- Time differences between two nearby blocks
- Slewing correction
- Q obtained from time over threshold

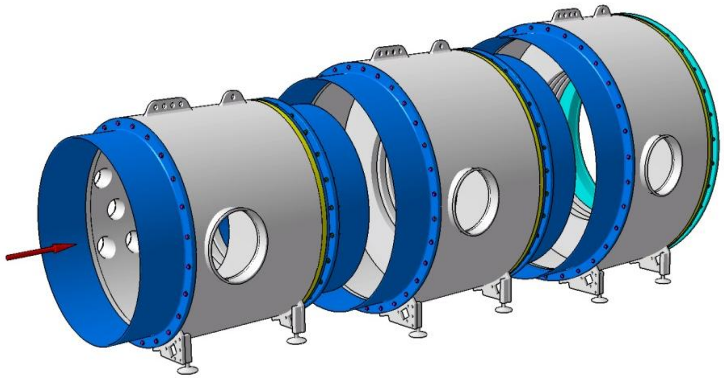
Very preliminary

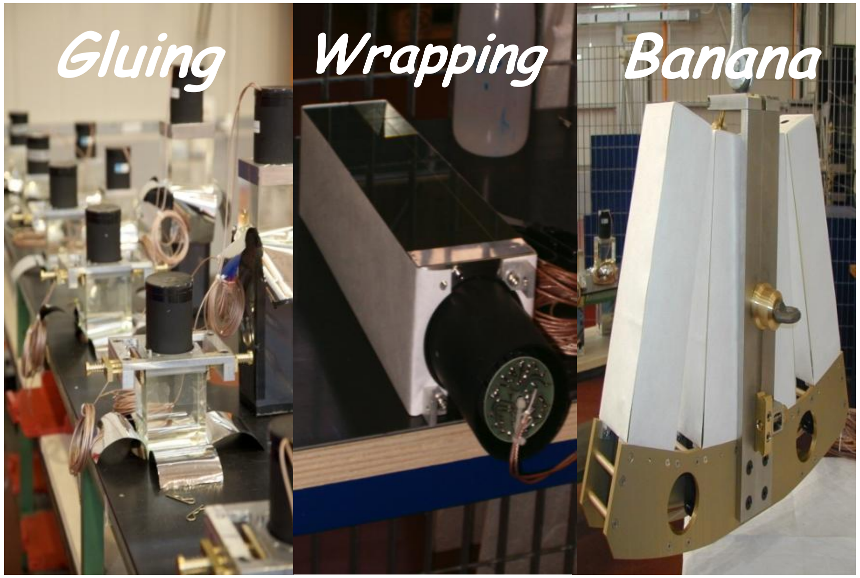


σ_t singleblock=1.1/sqrt(2)–0.8 ns

LAV Future work

Comprehensively revising LAV design based on our experience in constructing and testing ANTI-1.
Schedule is very tight: Must build and commission 11 LAV modules in 2-2.5 years
The complete set of designs will be ready by the beginning of 2010
All construction tools have been optimized to make this schedule feasible
The front end electronics design will be frozen by the end of the year.

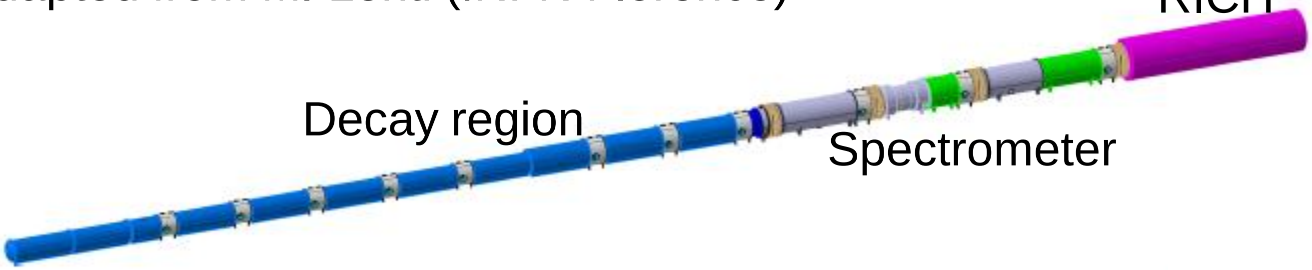




RICH requirement

- Muon suppression at % level on top of MUV suppression
- Track time at 100 ps level to suppress wrong combination with Gigatracker
- Charged trigger option

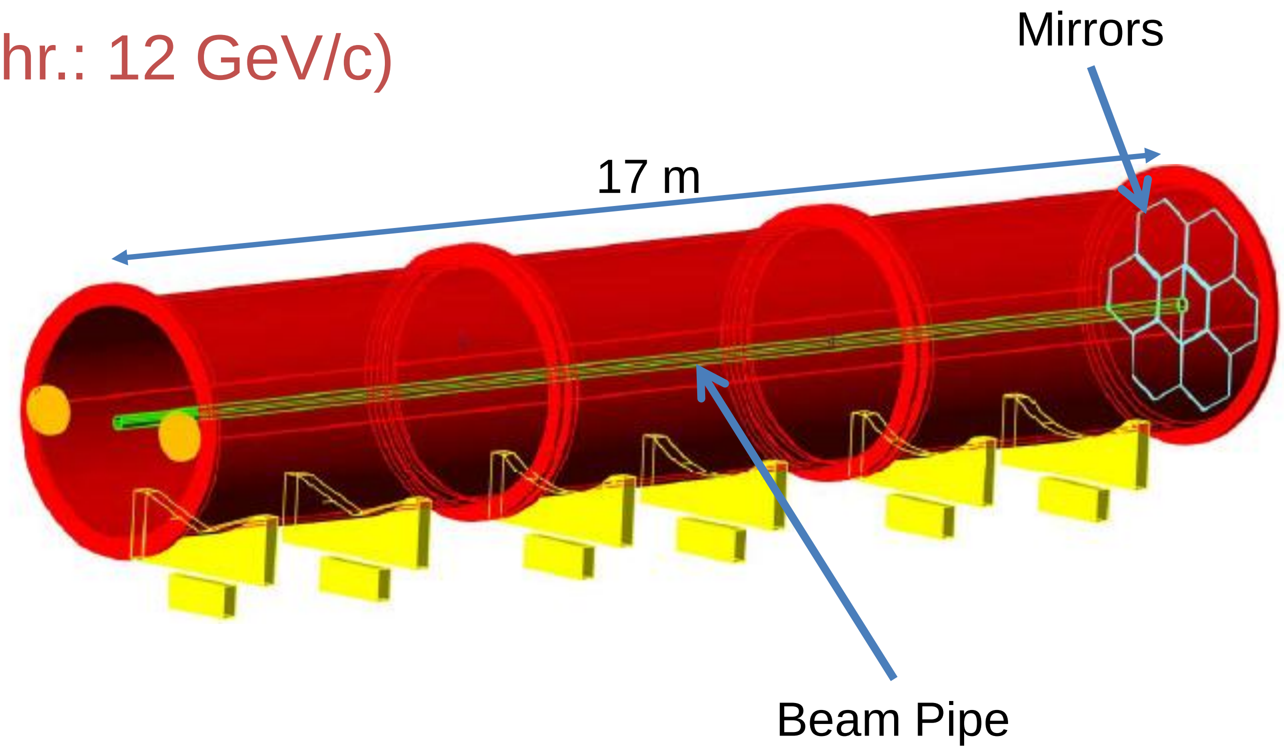
Slides adapted from M. Lenti (INFN Florence)

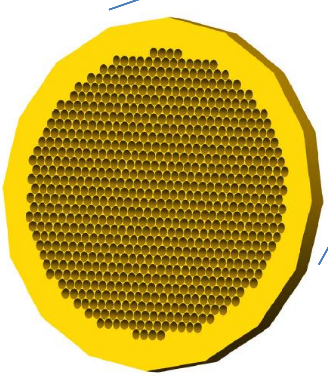


RICH

$\pi-\mu$ 3σ separation 15-35 GeV/c

- Neon at 1 atm (π thr.: 12 GeV/c)
- 2000 PMT
- 18 mm pixel
- 100 ps

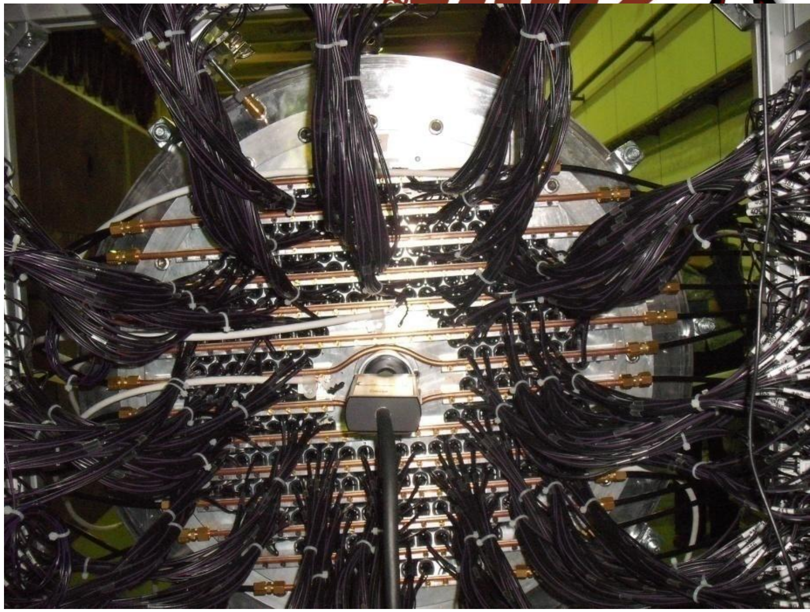


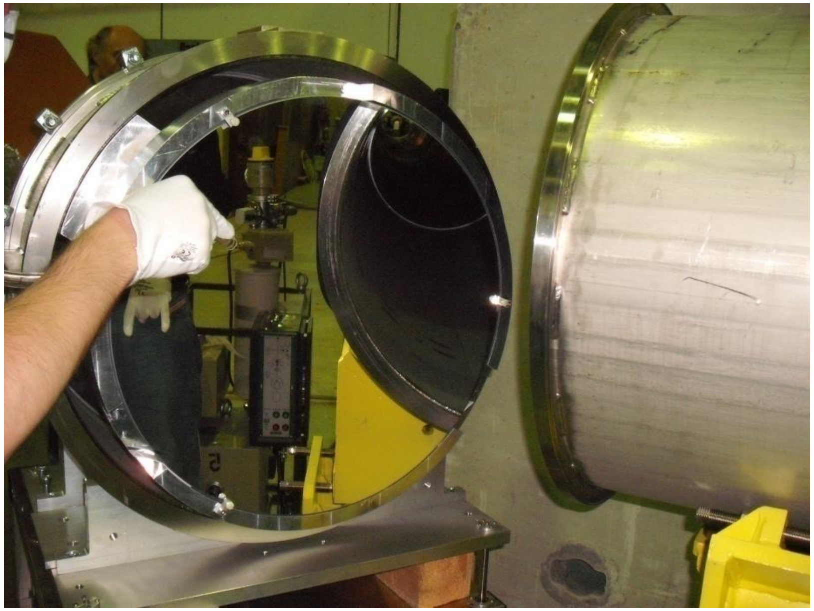


PMT: Hamamatsu R7400 U03

2009 prototype test beam

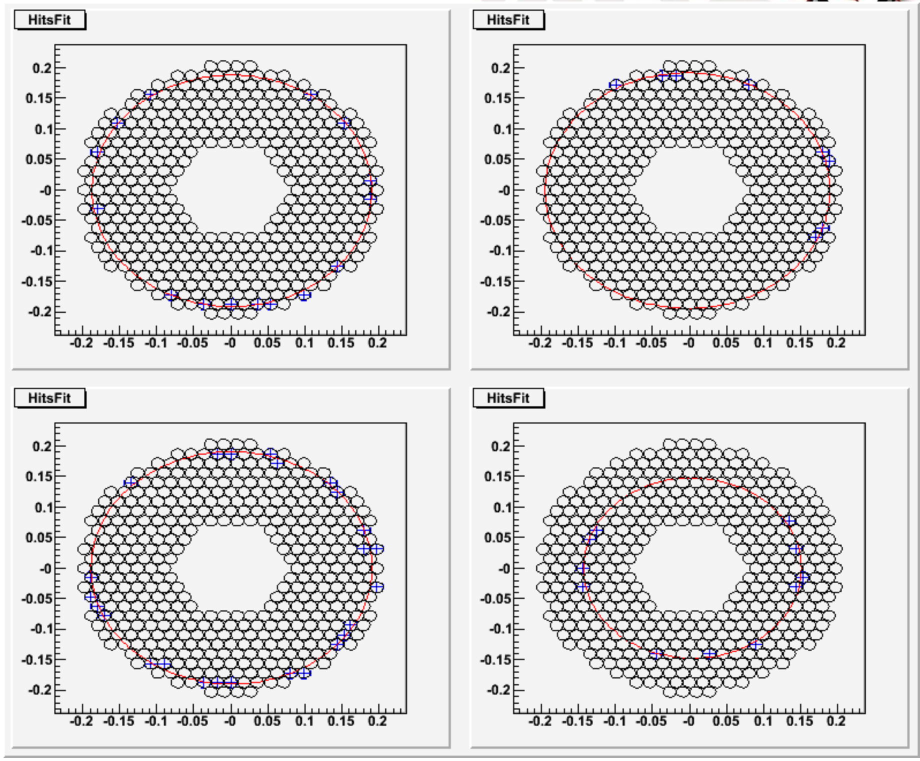
- **12.5.-27.6.2009: test beam**
- **1 mirror with f=17m, 50 cm wide**
- **414 PMT + full electronics chain**

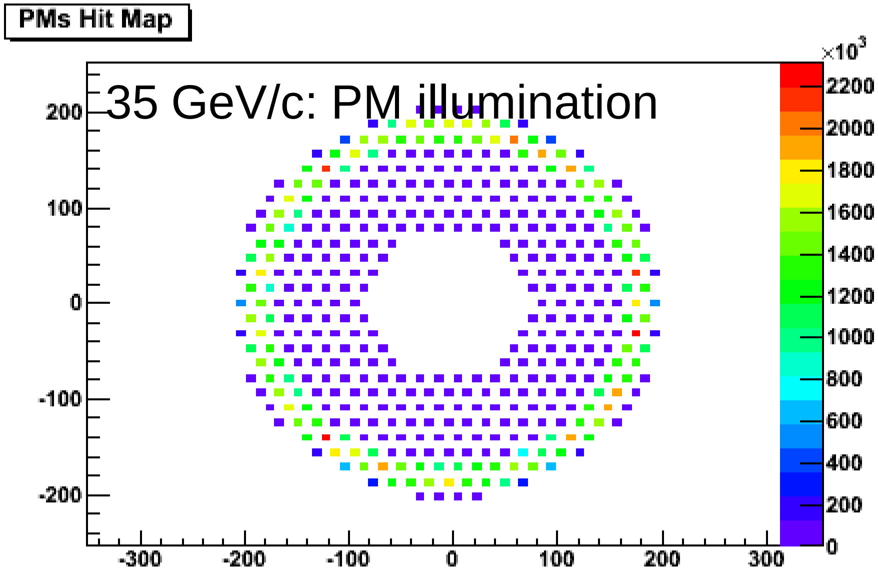




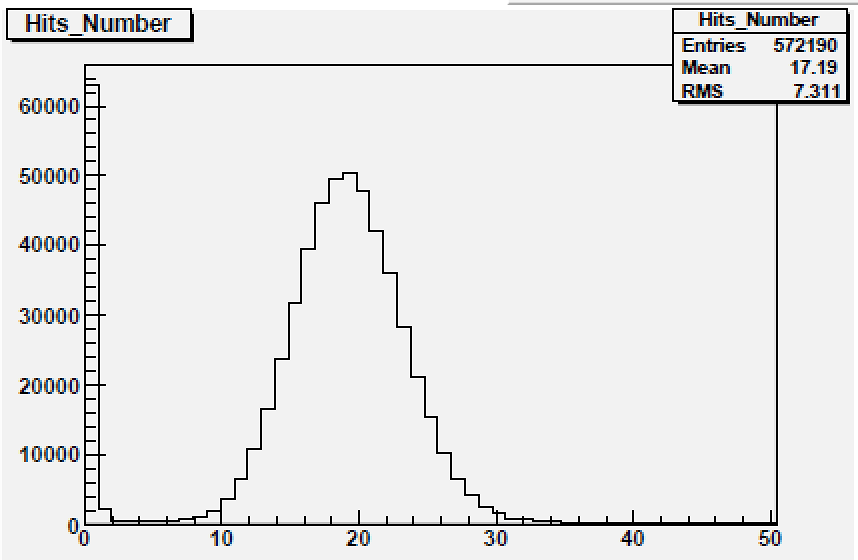
2009 test beam

20 GeV/c: 3 positrons and 1 pion events

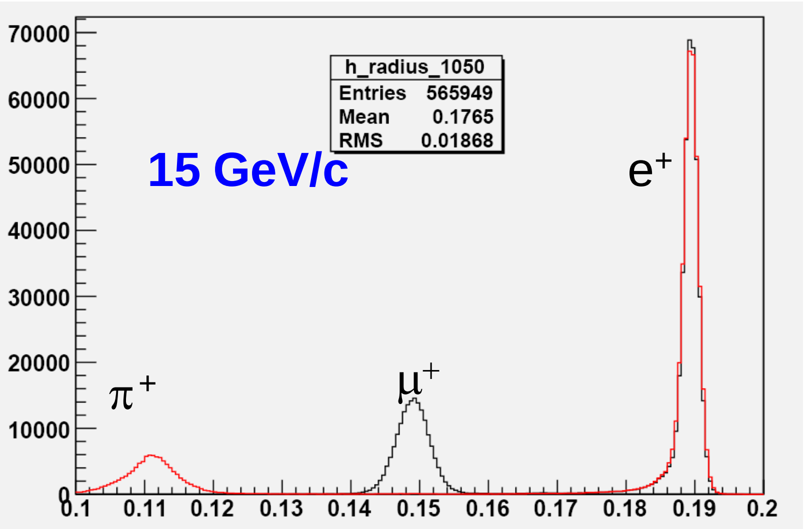


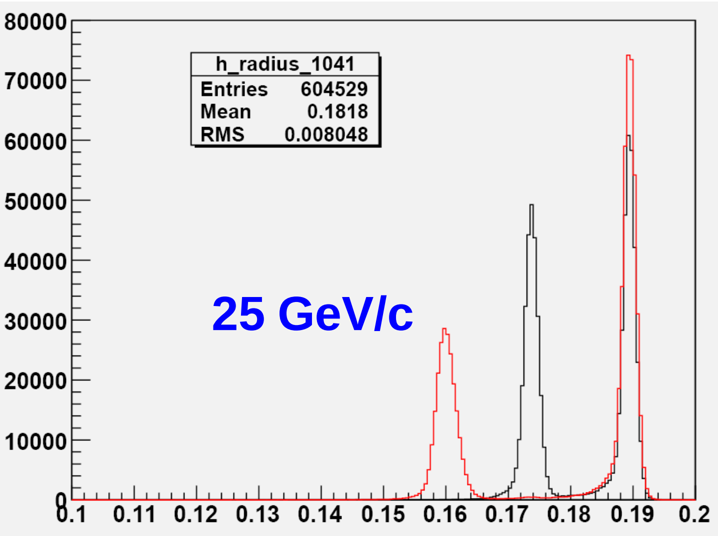


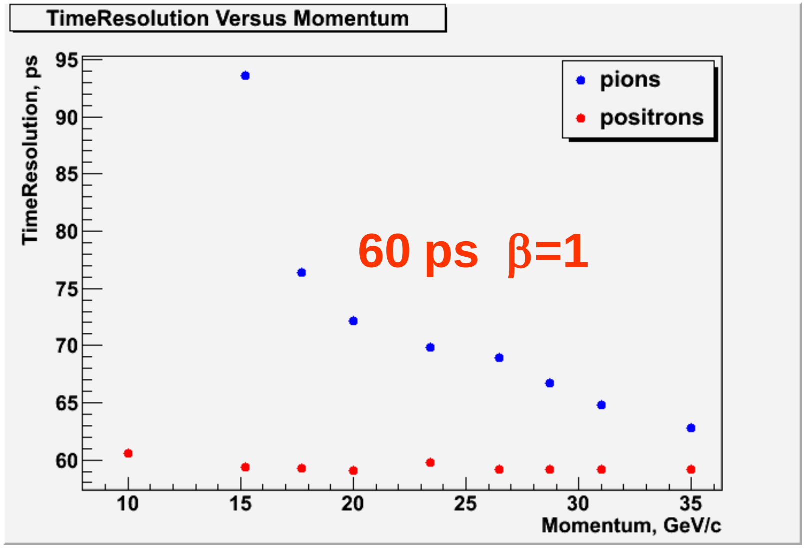
N. of hits per event at 35 GeV/c

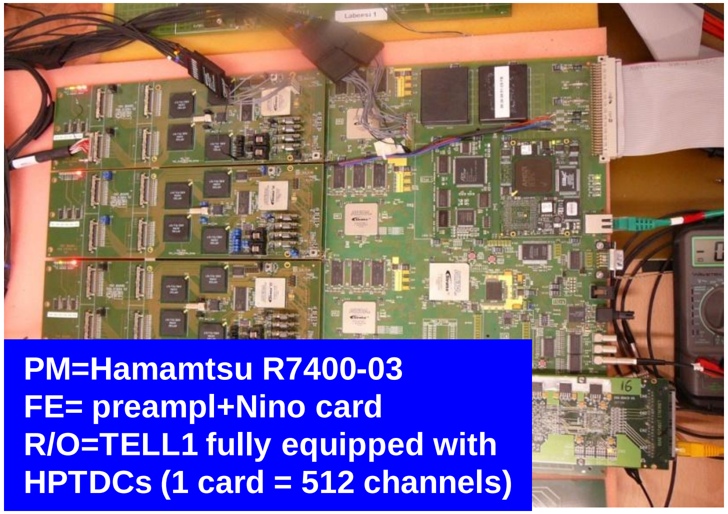


RICH Test, June 2009, Preliminary



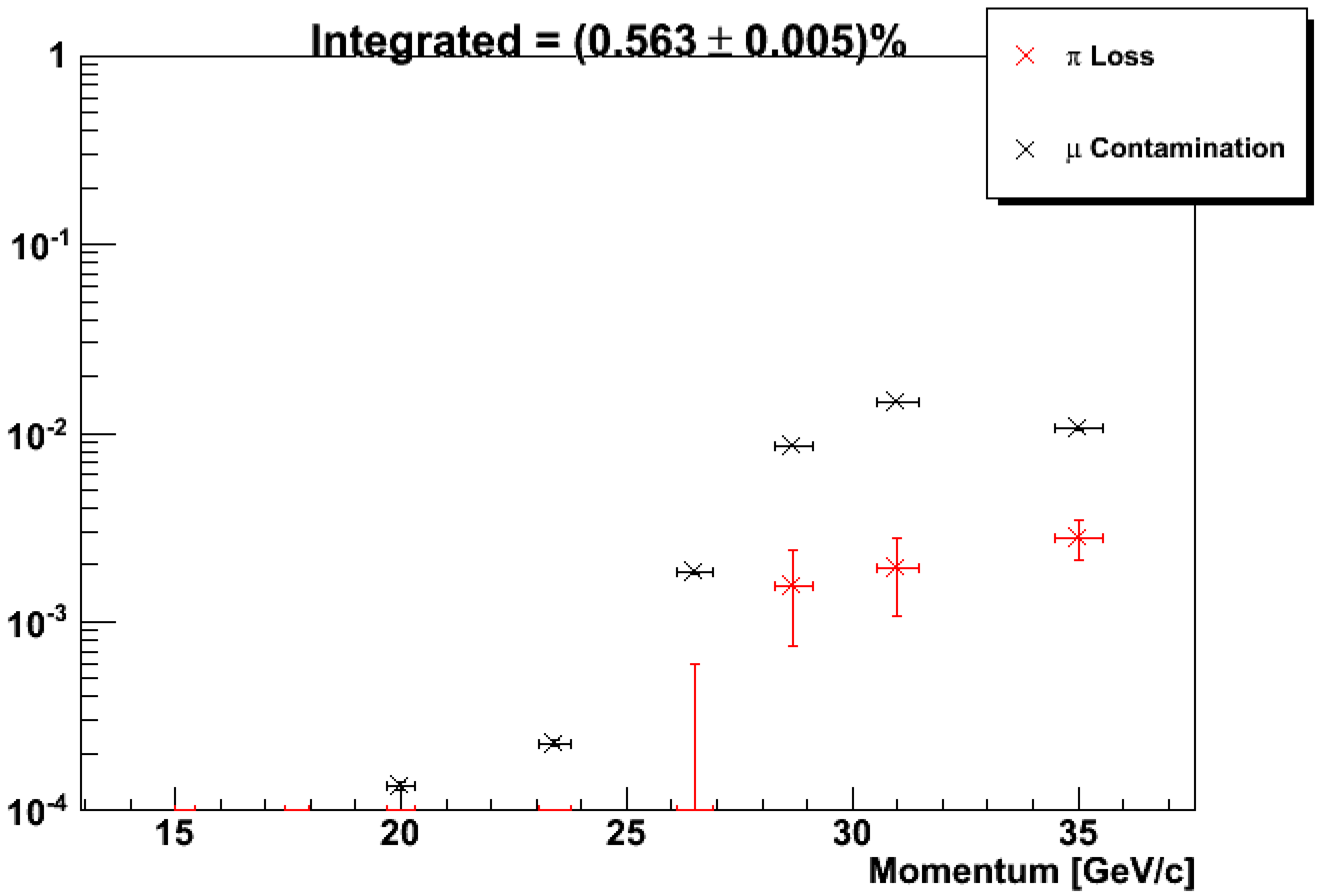






PM=Hamamtsu R7400-03
FE= preampl+Nino card
R/O=TELL1 fully equipped with HPTDCs (1 card = 512 channels)

Prototype: muon suppression



Mirror in (0,0)

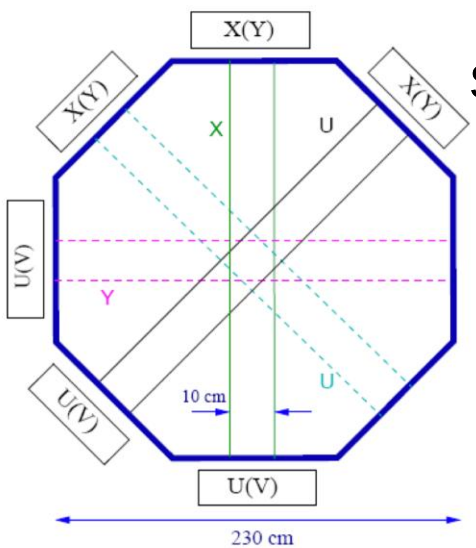
RICH Schedule

- **Mirror procurement: end of 2010**
- **Mirror Support structure: beginning 2011**
- **PMT procurement: 90% (w/o spares) end of 2010**
- **FE, DAQ, HV: 2011**
- **Vessel: 2011**
- **Gas system: 2011**
- **RICH commissioning: beginning 2012**

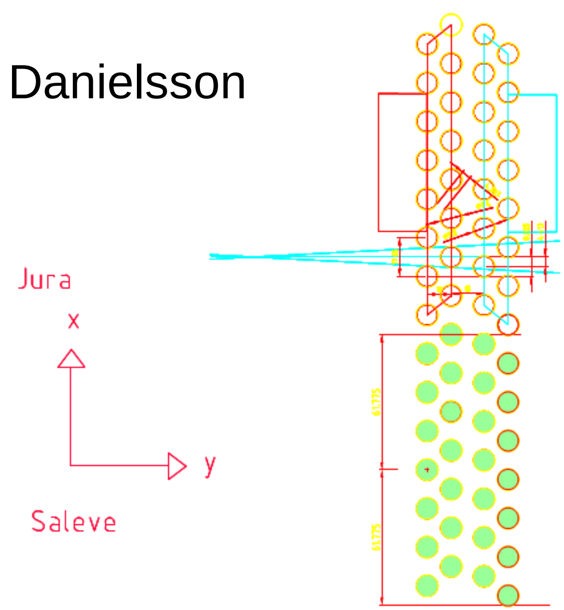
STRAW tracker

- Operate in vacuum, 2.1m long and D_i =9.8mm
- Precise tracking (<130 μm)
- Straw rate: up to 0.5 MHz
- Non-flammable gas mixture. :
  - Base line: CO_2 (90%)+CF4 (5%)+Isobutane (5%)
  - Alternative: Ar/CO_2

- 4 chambers
- 4 views in each chamber
- 448 (4x112) straws in each view
- Total 7168 straws
- Straw material:
  - 50 nm Cu, 20 nm Au on 36 μm of Mylar

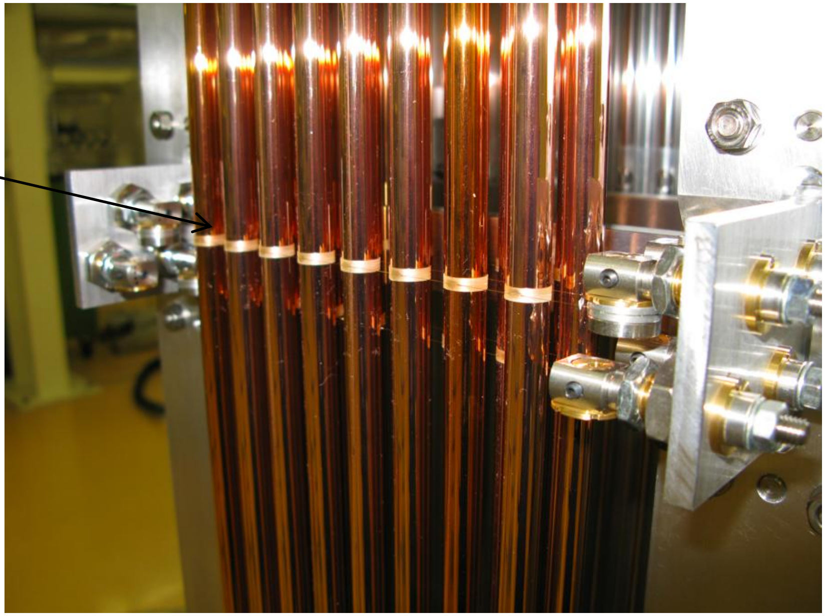


Slides adapted from H. Danielsson



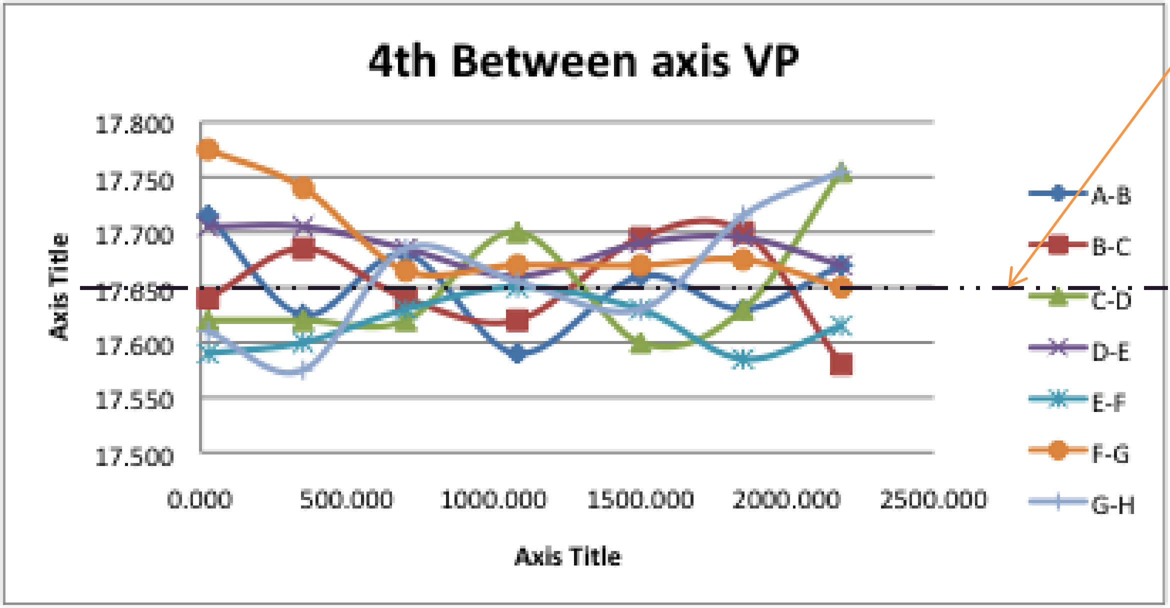
64 Straw technology Prototype

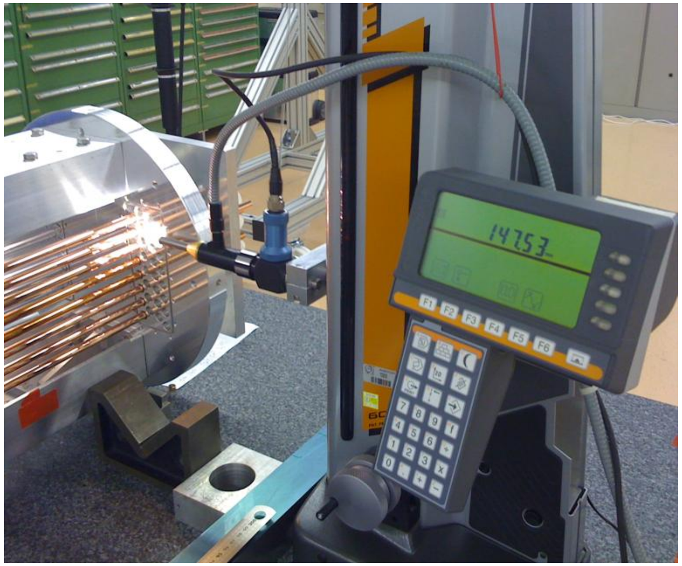
- The straws are installed in vertical position
- Pretension is 1.5 kg
- Spacer validated over 2.1 m.

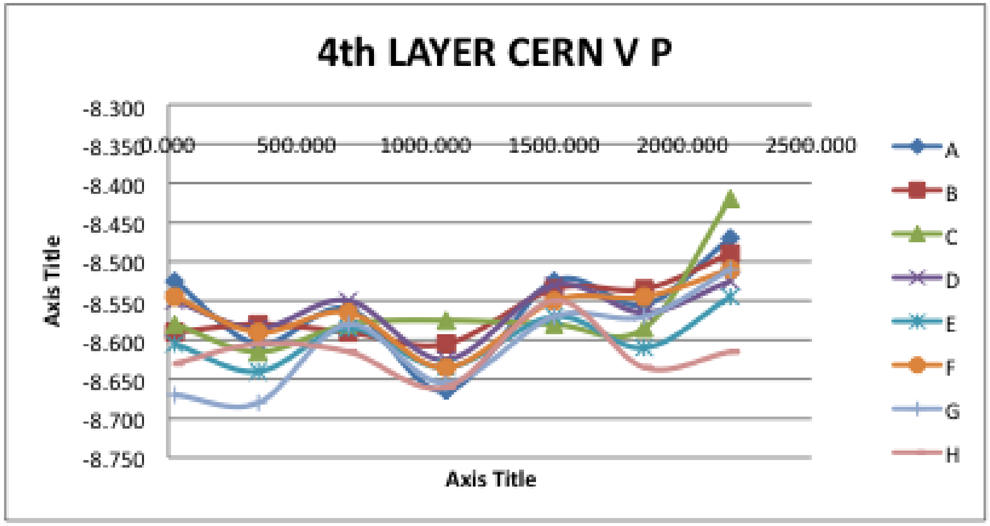


Straw straightness

Nominal







Straw rate capability study (Beam test 2009)

Gas mixtures:

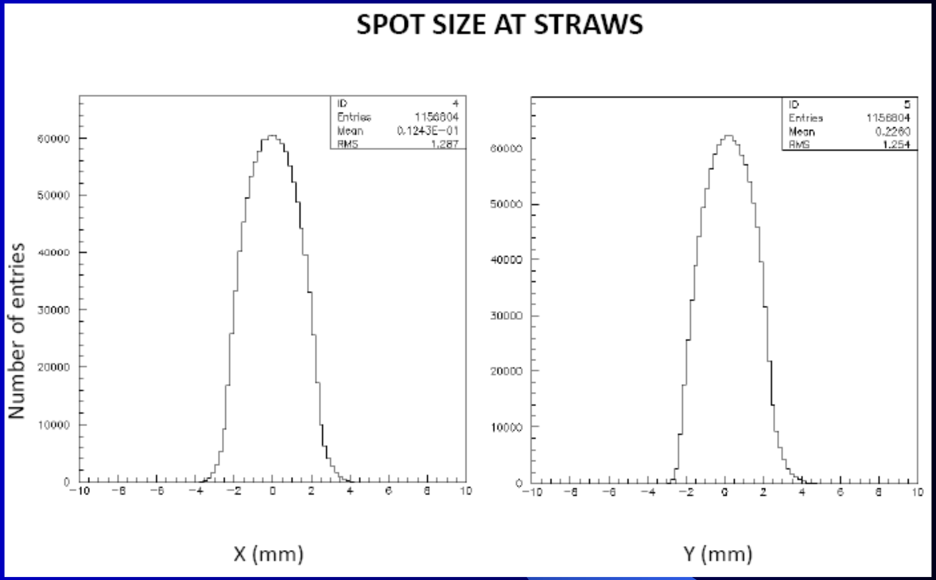
- CO2/isoC4H10/CF4 (90:5:5) - base line
- Ar/CO2 (70:30)

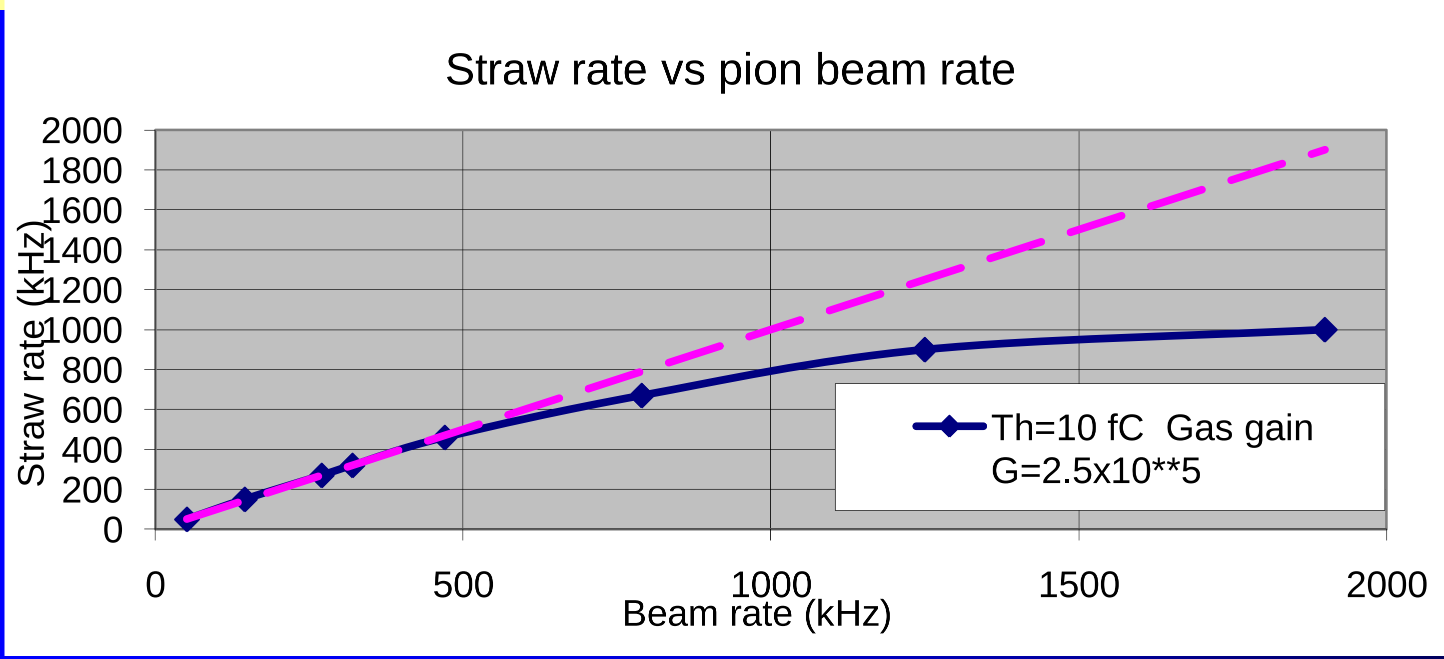
Gas gains:

- G=5x10**4 (Th=6 fC)
- G=2x10**5 (Th=10 fC)

Pion beam size:

- FWHM ~ 4 mm





The analysis is going on!

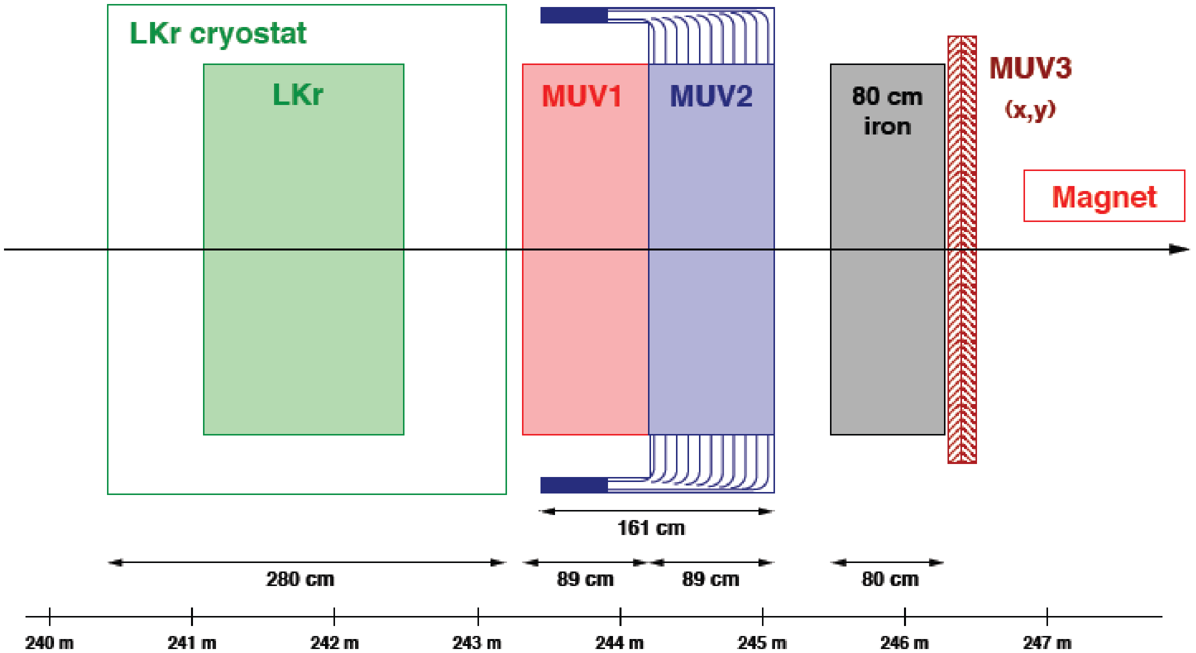
STRAW Plans for 2010

- React on conclusions from the straw review (23/11/2009)
- Terminate the analysis of the 2009 test beam
- Terminate the detailed study on the straw material and conclude at end of this year
- Detailed FEM analysis of the straw frame
- Finalize the layout of the straw frame
- Build a full-scale chamber
- Restart straw production in May 2010
- Test the 64-straw prototype and measure its performance in the beam in May 2010
- Aging component validation started and will continue in 2010

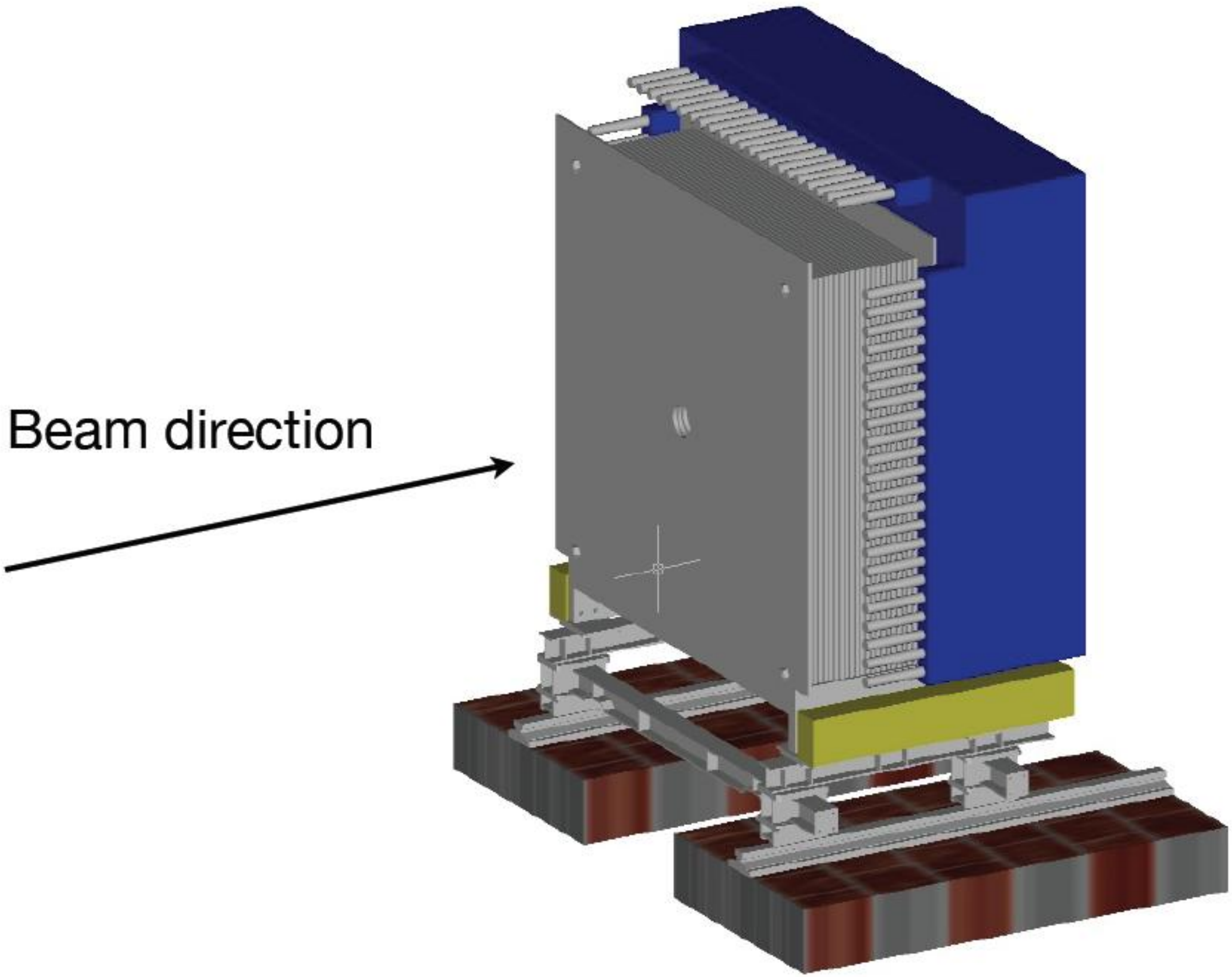
New Muon Veto System

Slides from R. Wanke

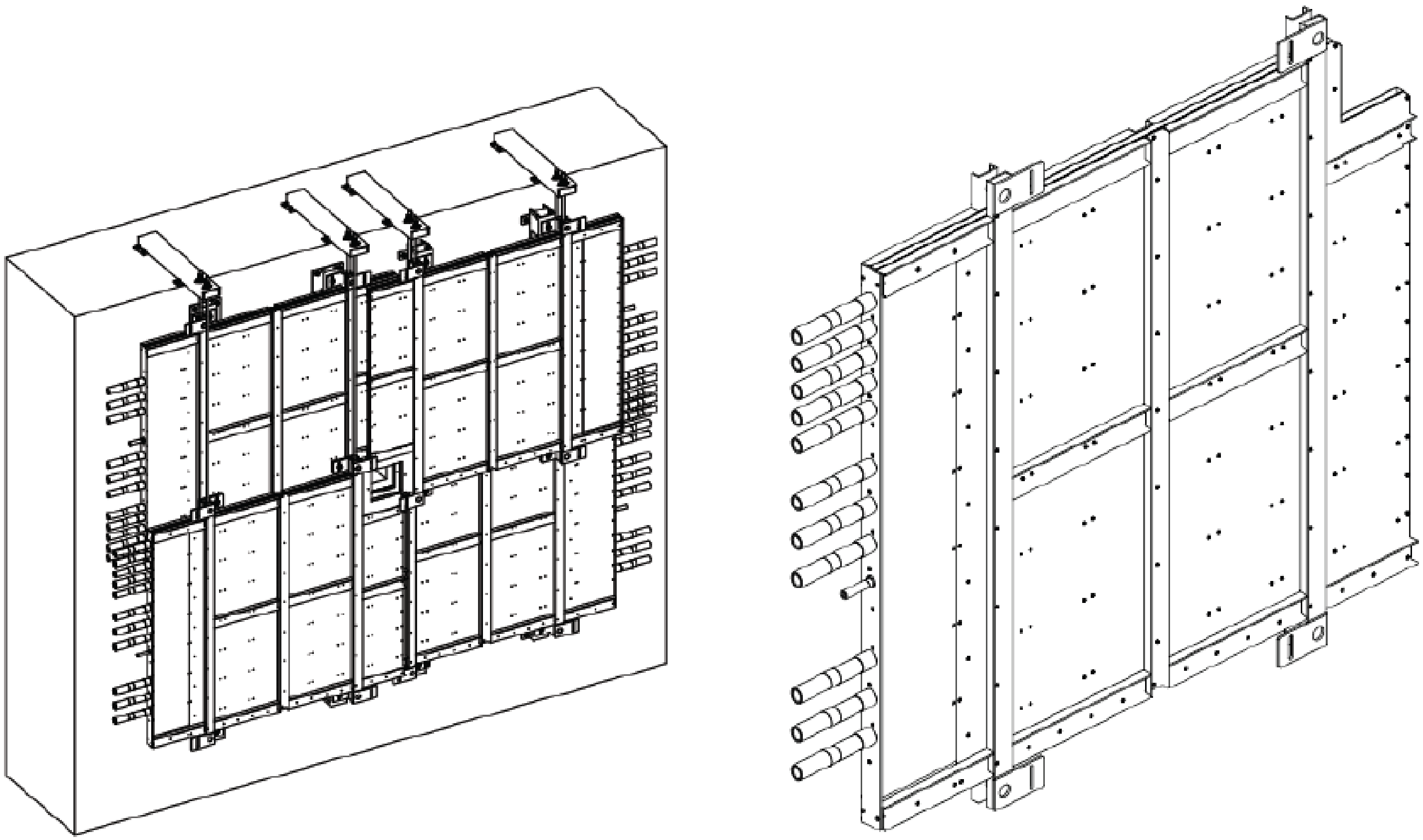
- **MUV1: New module** with different layout and light collection w.r.t. old HAC.
- **MUV2: NA48 HAC front module**, turned by 180°, serves as veto only.
- **MUV3: New fast MUV** after 80 cm iron wall for trigger.



Layout of MUV1 and MUV2



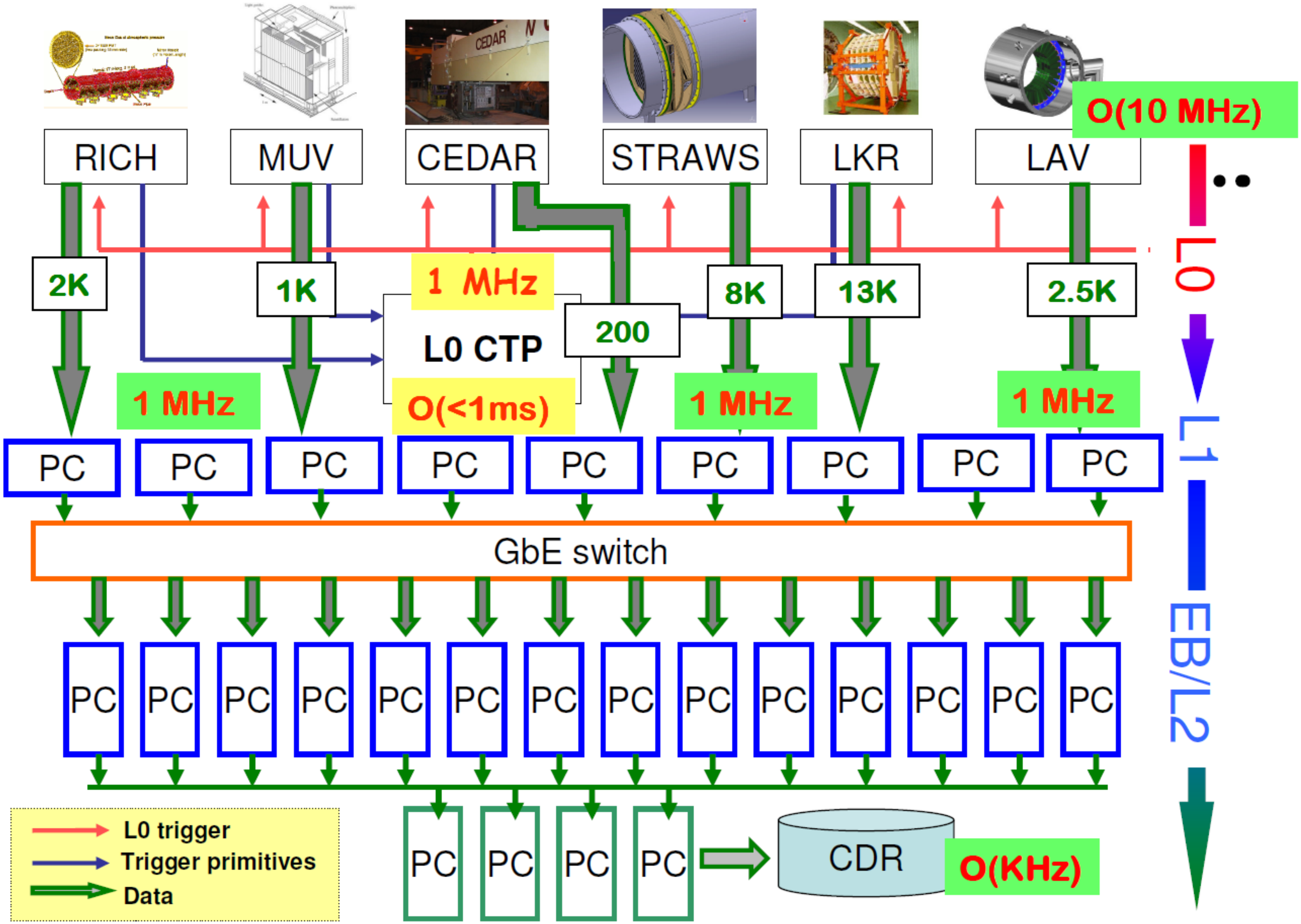
Layout of MUV3 (Fast MUV)



- Fast MUV will be included in L0 trigger
- Design (tiles or strips) to be decided by end of this year

M. Sozzi, Pisa

NA62 TDAQ - OVERVIEW



M. Sozzi

At a glance

- **Review** of TDAQ 04/2009 with external experts (H. Christiansen, LHCb colleagues, etc.)
- Still quite evolving:
  - consolidated design for some SD (RICH, LAV, LKr)
  - advancing for others (CEDAR)
  - still somewhat vague for some (STRAWS, MUV), but fall-back solution to default system possible
- Technical Document being written: first draft exists
- The push for a "common" system (TELL1-based TDCs) was succesful: RICH, LAV, CEDAR, CHOD; possibly all subdetectors except LKr and GTK
- Some new contributions/responsabilities:
  - **TTC** (clock/trigger): Birmingham
  - **Trigger simulation**: US coordination
  - **Online farm**: Mainz

M. Sozzi

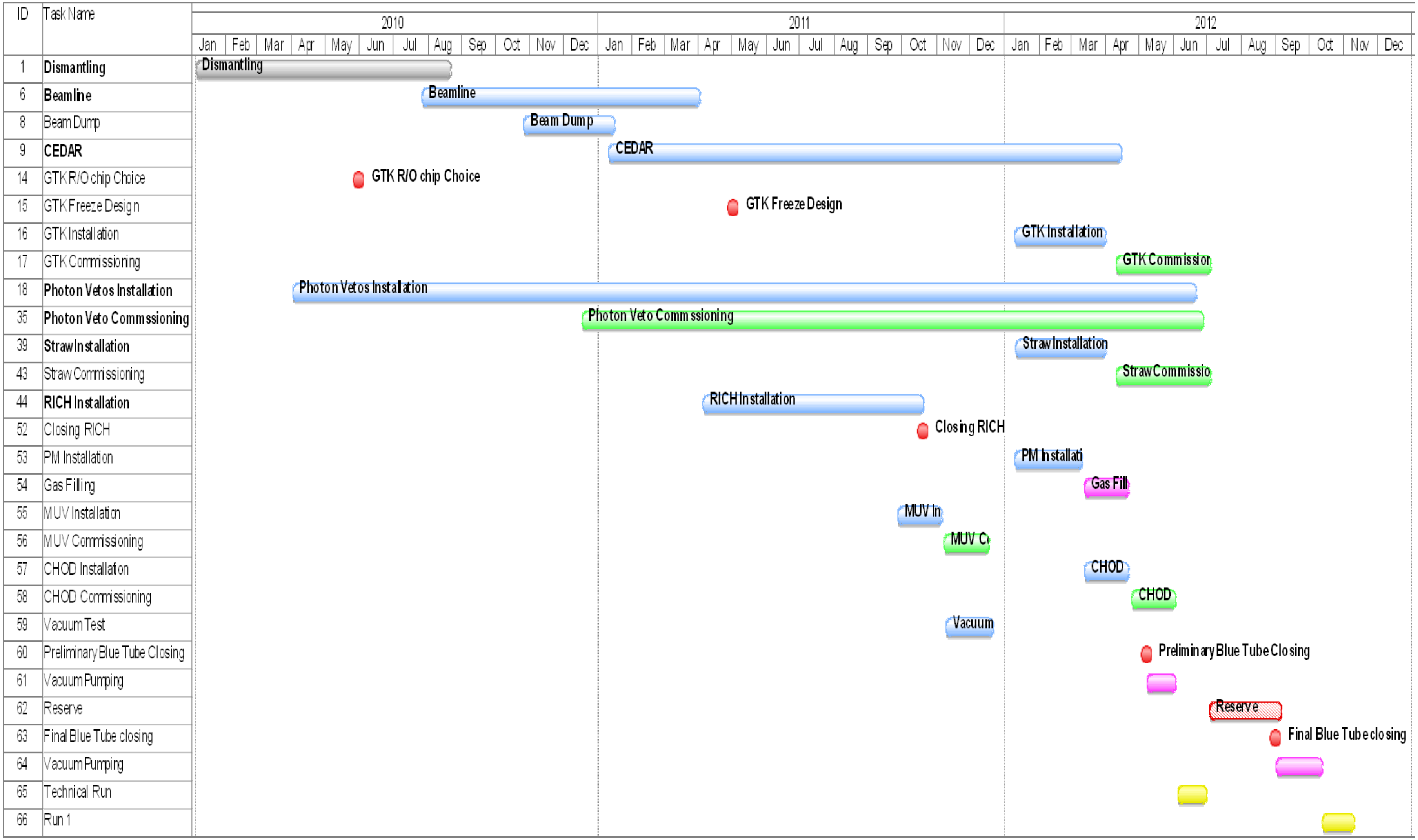
Some crucial issues

Some of the required **components** (e.g. TTC-related ones) are starting to become obsolete:
Need to secure a sufficient stock for the whole of NA62
Some sub-detectors still not committed to a DAQ solution
This started already.

The software part of the trigger (L1, L2) has not been detailed and **simulated** yet:
While confident that the required suppression can be achieved, sub-detector groups have not yet defined the specific cuts/algorithms required. This has important implications on the dimensioning and design of the online farm, which is still missing.
Work is now starting on this

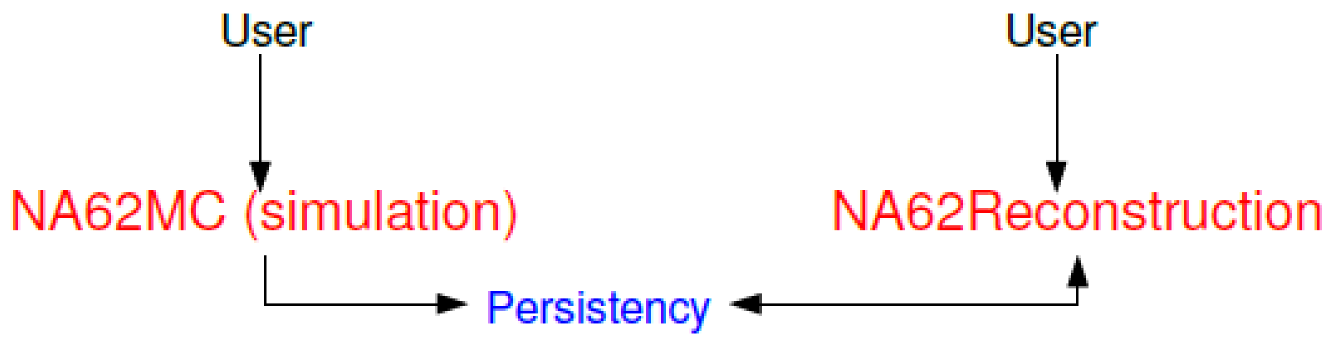
ECN3 Installation Planning

Preliminary (by Ferdinand Hahn)



The NA62 simulation and reconstruction

A. Sergi



- Status of the NA62MC
  - Detectors still at a conceptual stage: IRC, SAC, HAC/MUV, CHOD
  - Missing items: CEDAR, Blue Tube, part of the Beam Pipe, Mechanical Frames, shower libraries
- Status of the NA62Reconstruction
  - Implemented: Gigatracker, Straw, RICH, LKr
- General infrastructures
  - Missing items: Database

The NA62 simulation and reconstruction

- Updates to the NA62MC
  - Some technical work to improve the code and its usability.
- Updates to the NA62Reconstruction
  - Common interfaces developed for raw decoding and digitization
  - Common interface for the output objects (both reconstructed and raw info accessible)
  - Multiversioning implemented
  - Preliminary trigger simulation mechanism added
- Documentation
  - Started using Doxygen (accessible via we page)
    - Easily writable by the developers
    - Easily understandable by the users
    - Web page: http://sergiant.web.cern.ch/sergiant/NA62FW/html

Main Page | Related Pages | Namespaces | Classes | Files | Directories

Search

NA62 Framework

Description

NA62 FrameWork consists at this time of two packages:

NA62MC	Geant4 based framework for NA62 detector full simulation (now includes ANTI0, CHOD, GigaTracker, IRC, LAV, LKr, MUV RICH, Spectrometer and Cedar as an empty box, all of them with persistency of hits)
NA62Reconstruction	Root based reconstruction package, modularized in libraries for individual subdetectors (now includes GigaTracker, RICH, Spectrometer, and ANTI0, GigaTracker, IRC, LAV, LKr as empty boxes). It contains also an example for writing analysis (NA62Analysis.cc) and a visualization tool (NA62EventDisplay)

The **tabs** above gives you access to autogenerated source code reference documentation; have a look at the **Related Pages** and **Class Index** sections.

Getting the source code

To checkout (download) an SVN working copy for these packages, simply issue

svn co svn+ssh://svn.cern.ch/reps/na62fw/trunk/NA62MC
or
svn co svn+ssh://svn.cern.ch/reps/na62fw/trunk/NA62Reconstruction

from lxplus (it works also from any linux system, adding, if needed, <*your lxplus username*>@ before **svn.cern.ch**).
Have a look at **README** and **HISTORY** files to be aware of the known issues and the status of the development.

Compile

The **scripts** are ment to work on **lxplus**, relying on afs installations of **Geant4.9.2** and **Root 5.24.00**; for **local installations** Geant4.9.2 is mandatory and Root 5.24.00 recommended.
The needed environment variables are set by **scripts/env.csh** in both packages; be careful not to mix Root or G4 configuration with something in your **.tcshrc**. By default **G4LIB_BUILD_SHARED** is not set anymore, so **static libraries** are built; you can build **shared libraries**, if you wish, by uncommenting one line in **scripts/env.csh**.

For what concerns MC

```
[lxplus] ~/Source/svn/NA62MC> source scripts/env.csh
[lxplus] ~/Source/svn/NA62MC> make
```

while, as Reconstruction relies on Persistency libraries included in MC, you have to compile **NA62MC** and set the correct paths to the source code in **Reconstruction/scripts/env.csh**, then

```
[lxplus] ~/Source/svn/NA62Reconstruction> source scripts/env.csh
[lxplus] ~/Source/svn/NA62Reconstruction> make
```

Run

NA62MC

You probably need to issue a **rehash** to let tcsh find the **NA62MC** executable; given that, **scripts/run.csh** lets you run using **macros/StandardRun.mac** (self documented macro, which generates 10000 $K^+ \to \pi^+ \nu \bar{\nu}$ events by default)

NA62Reconstruction

NA62Analysis executable has few command line options to control input and output (-h for help); the reconstruction itself is controlled via configuration files in the config dir (**config/NA62Reconstruction.conf** controls the program flow).
NA62EventDisplay executable has the same syntax (for now it has not been tested with more than few events ... in next releases there will be more control on event processing)

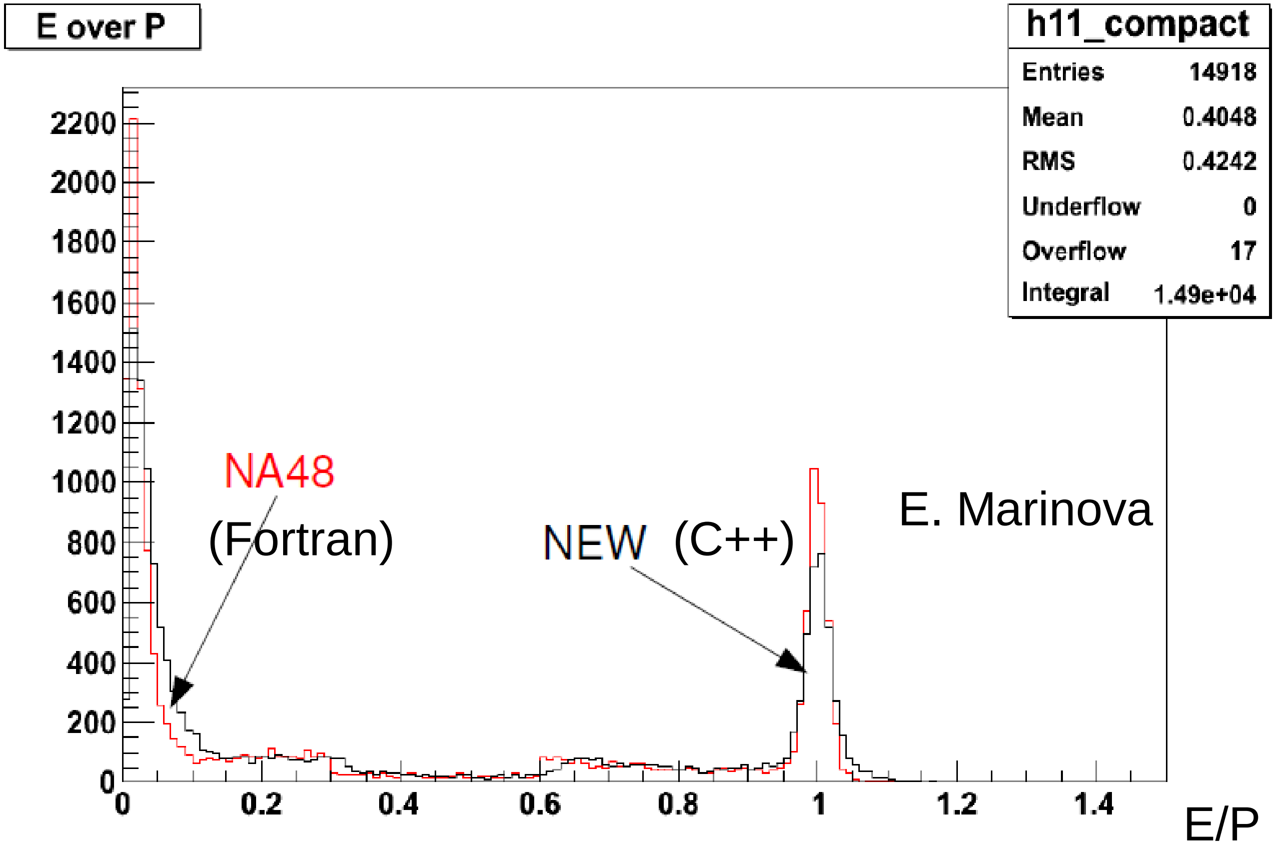
Last updated: 18 Oct 2009
If you have any comments or suggestions send an e-mail to Antonino Sergi

Maintained by Antonino Sergi
Last updated : 18 Oct 2009 1:40:30 CET

Generated on Thu Nov 19 17:02:11 2009 for NA62 Framework by doxygen 1.6.1

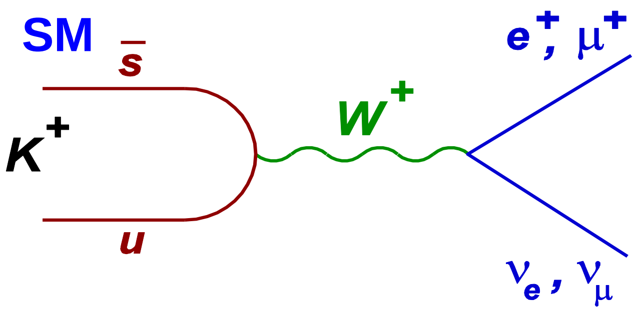
First test of LKR C++ Reconstruction

- List of energy deposition cell by cell extracted from 2007 data and reprocessed using the new algorithm.
- Comparison with the old NA48 reconstruction

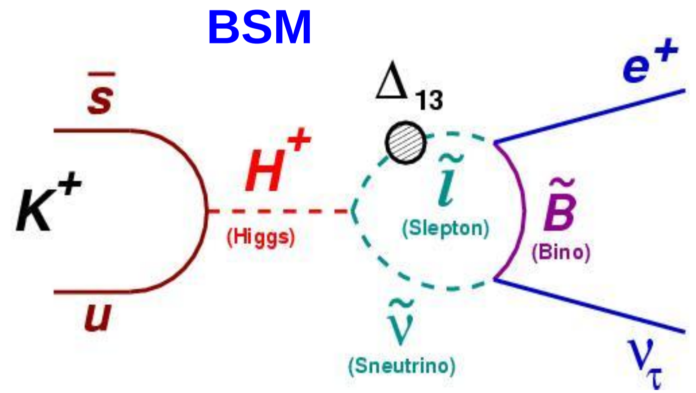


R_K: Lepton Universality Test with $K^+ \to l^+ \nu$ Decays at CERN NA62
First NA62 Result*

New Result presented by Evgueni Goudzovski @ KAON09

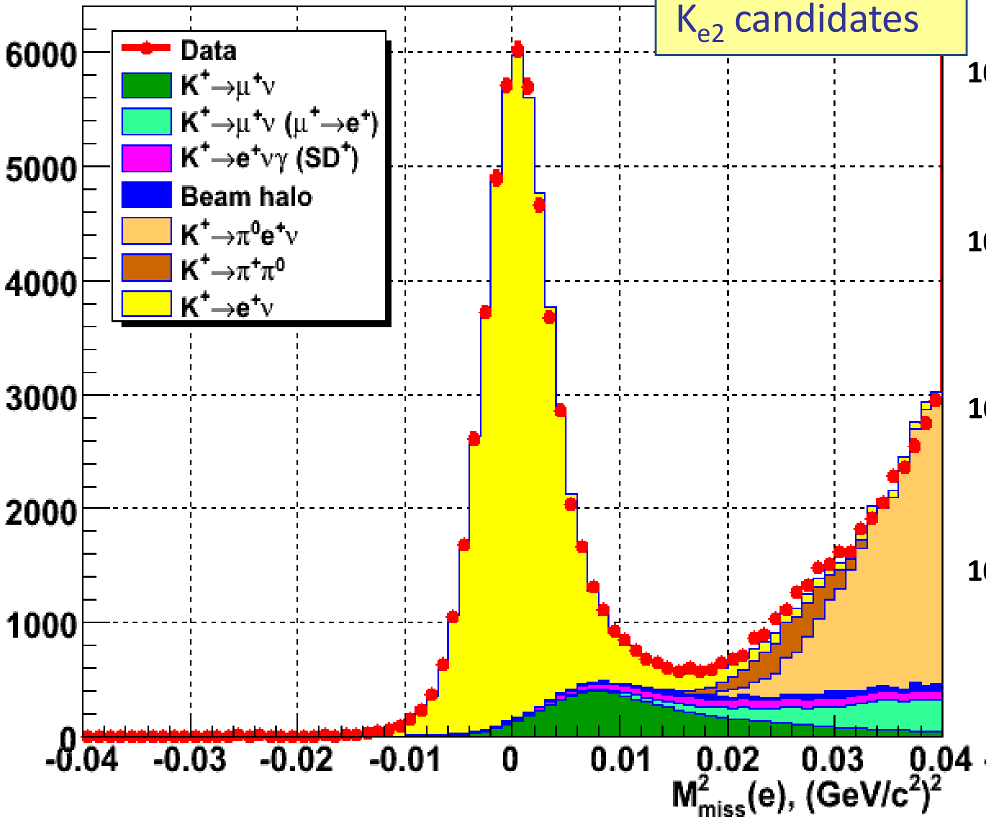


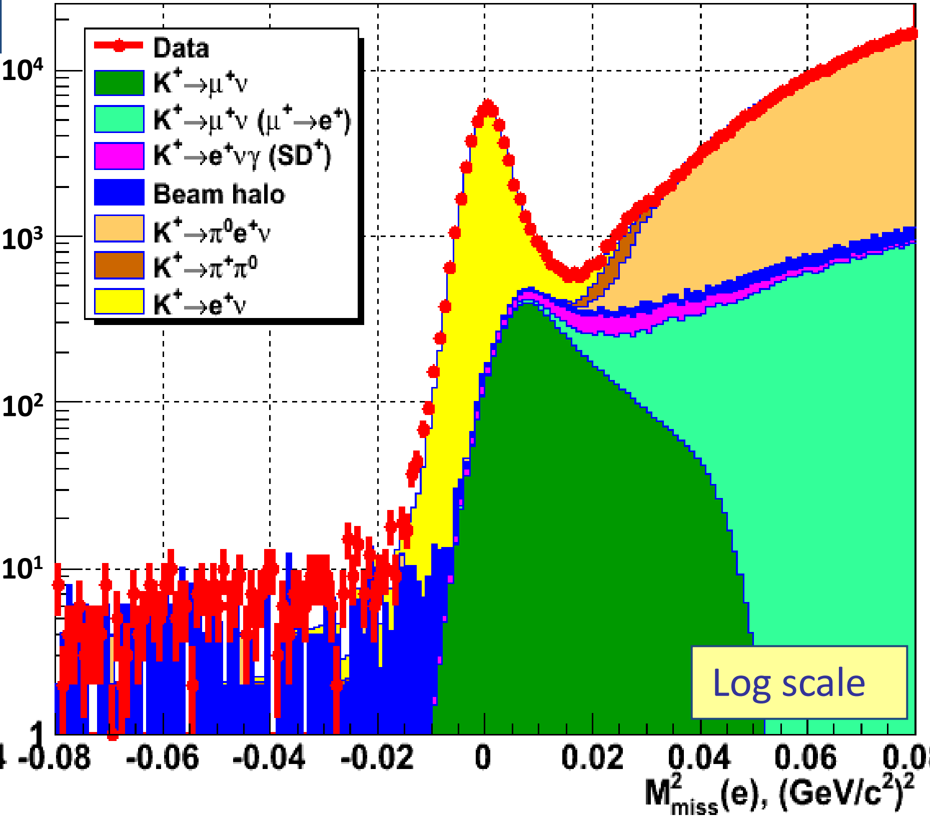
$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \cdot (1 + \delta R_K^{\mathrm{rad.corr.}})$$



* **New Collaboration practicing with single-track final states with old setup**

K_{e2}: 40% of data set

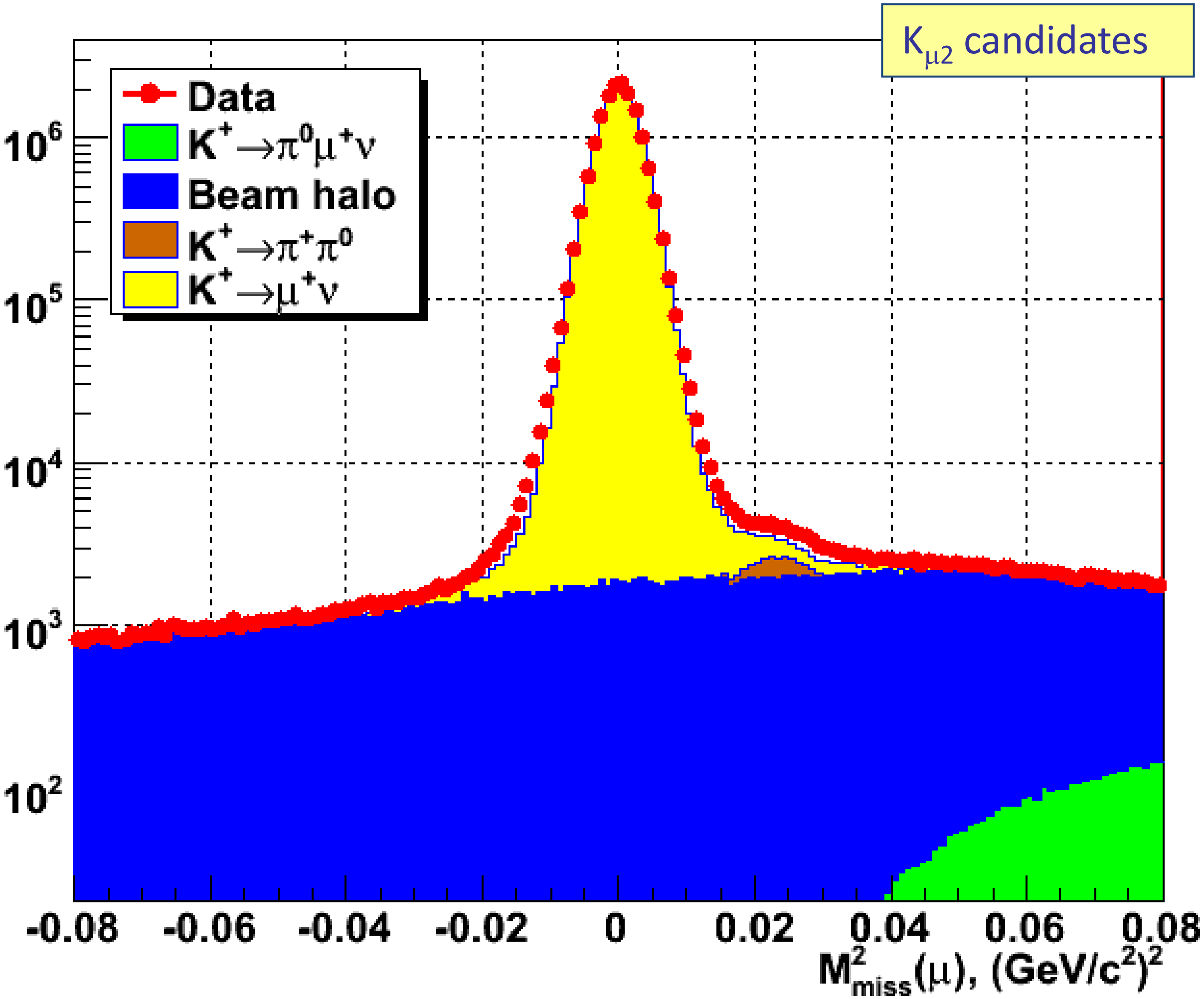




51,089 $K^+ \to e^+\nu$ candidates,
99.2% electron ID efficiency,
$B/(S+B) = (8.0\pm0.2)\%$

NA62 estimated total K_{e2} sample:
~120K K^+ & ~15K K^- candidates.
Proposal (CERN-SPSC-2006-033):
150K candidates

$K_{\mu2}$: 40% of data set



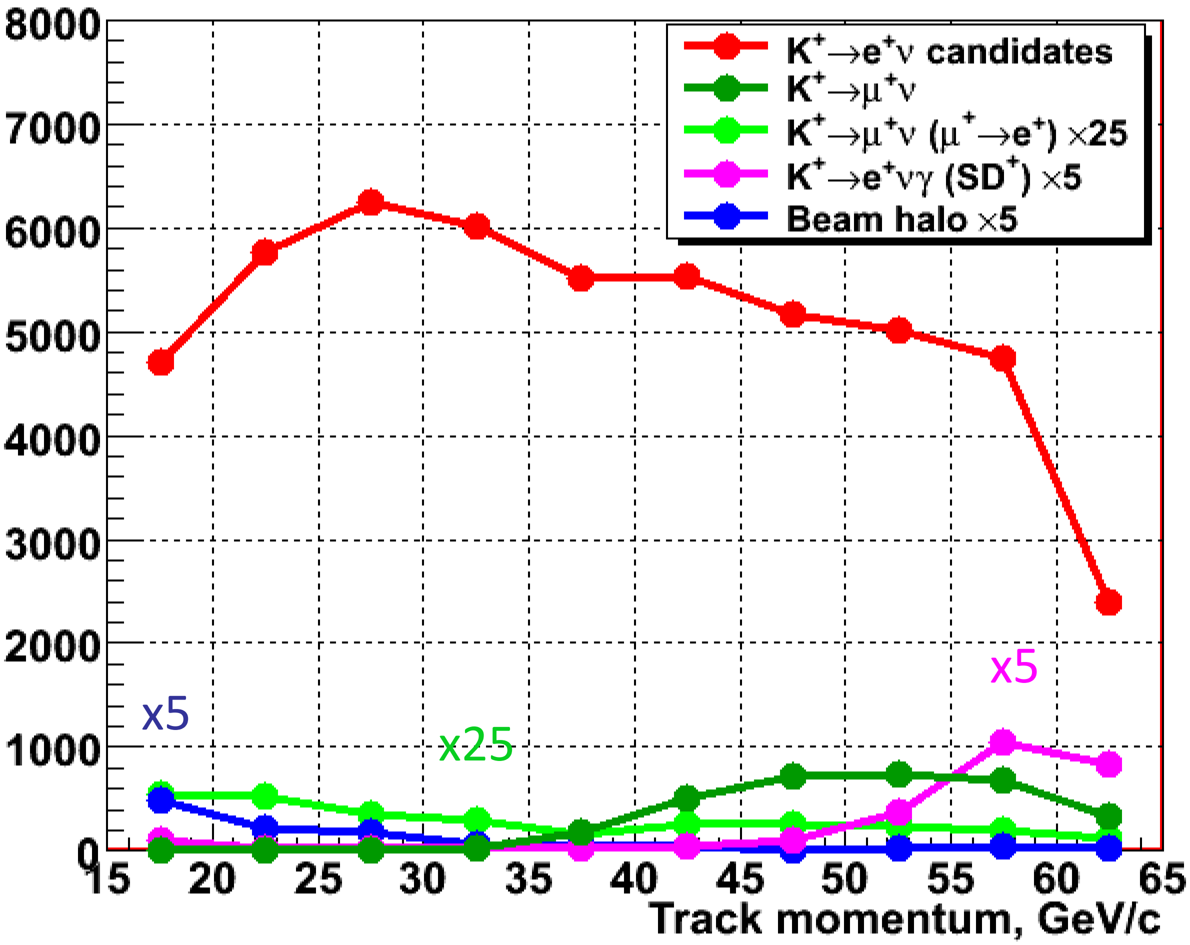
15.56m candidates with low background B/(S+B) = 0.25%

($K_{\mu2}$ trigger is pre-scaled by D=150)

The only significant background source is the beam halo.

Event Counting

Statistics in momentum bins



Background summary

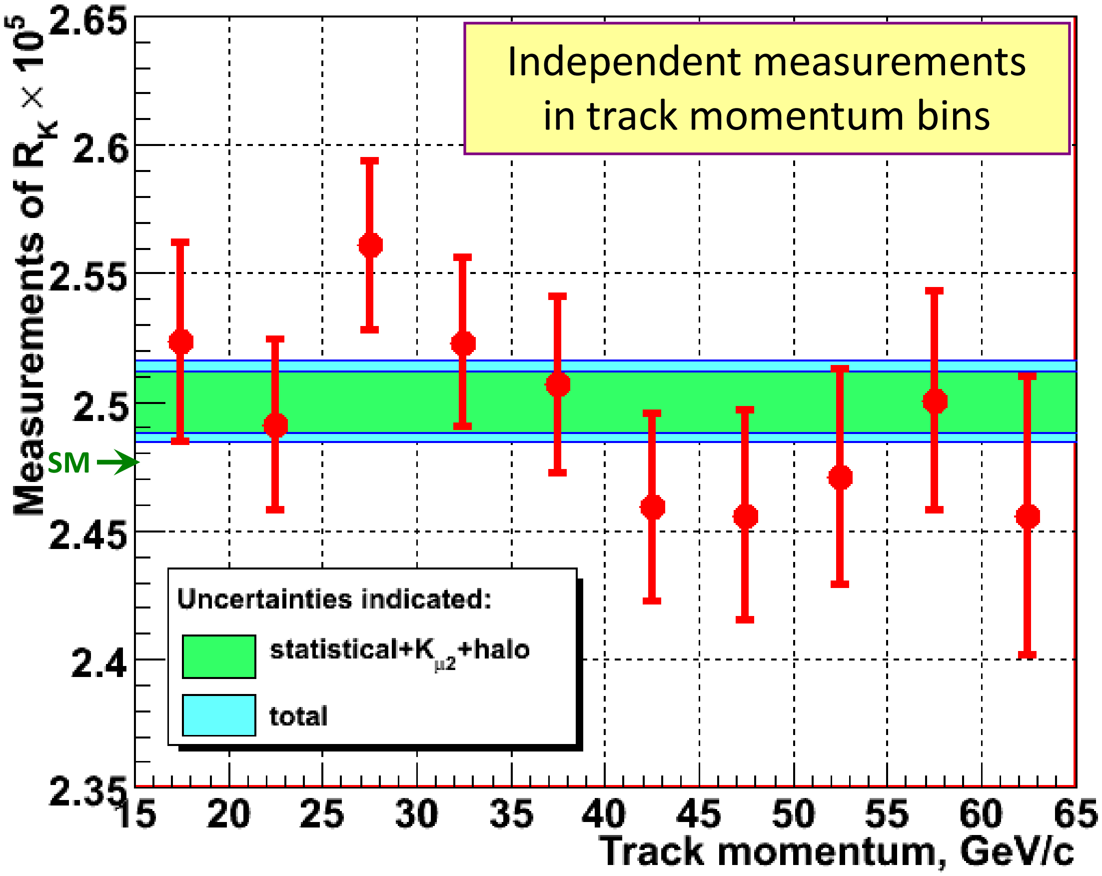
Source	B/(S+B)
$K_{\mu 2}$	$(6.28\pm0.17)\%$
$K_{\mu 2}$ ($\mu\to e$)	$(0.23\pm0.01)\%$
$K_{e2\gamma}$ (SD^+)	$(1.02\pm0.15)\%$
Beam halo	$(0.45\pm0.04)\%$
K_{e3}	0.03%
$K_{2\pi}$	0.03%
Total	$(8.03\pm0.23)\%$

Record K_{e2} sample:
51,089 candidates
with low background
$B/(S+B) = (8.0\pm0.2)\%$

Preliminary result (40% data set)

$R_K = (2.500 \pm 0.012_{stat} \pm 0.011_{syst}) \times 10^{-5}$
$= (2.500 \pm 0.016) \times 10^{-5}$

(New result!)



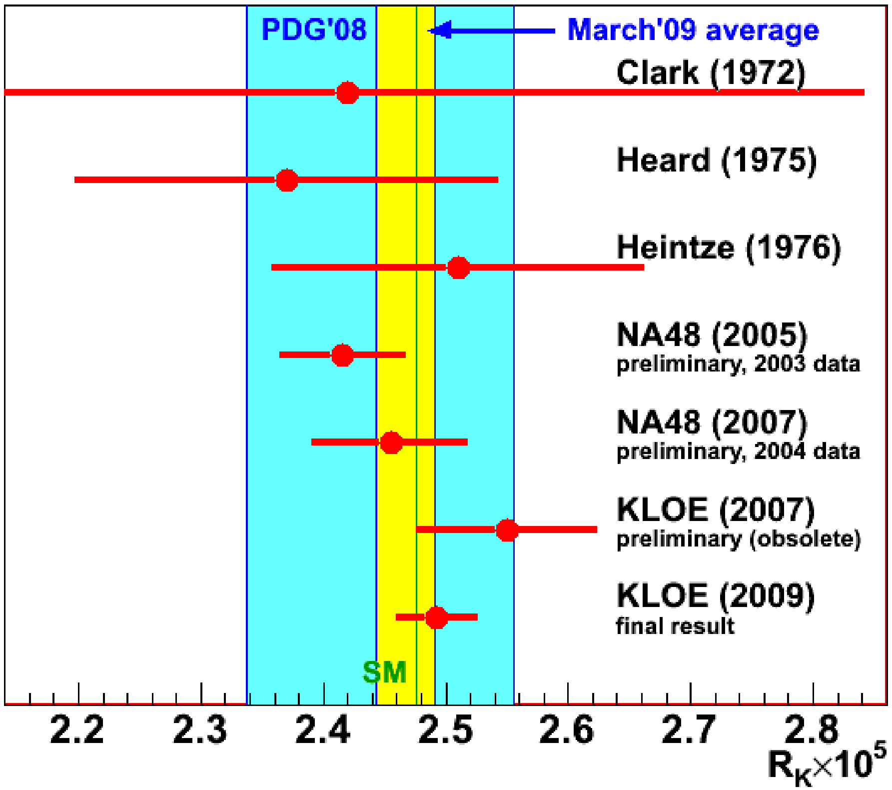
Uncertainties

Source	$\delta R_K \times 10^5$
Statistical	0.012
$K_{\mu2}$	0.004
Beam halo	0.001
$K_{e2\gamma}$ (SD^+)	0.004
Electron ID	0.001
IB simulation	0.007
Acceptance	0.002
Trigger timing	0.007
Total	0.016

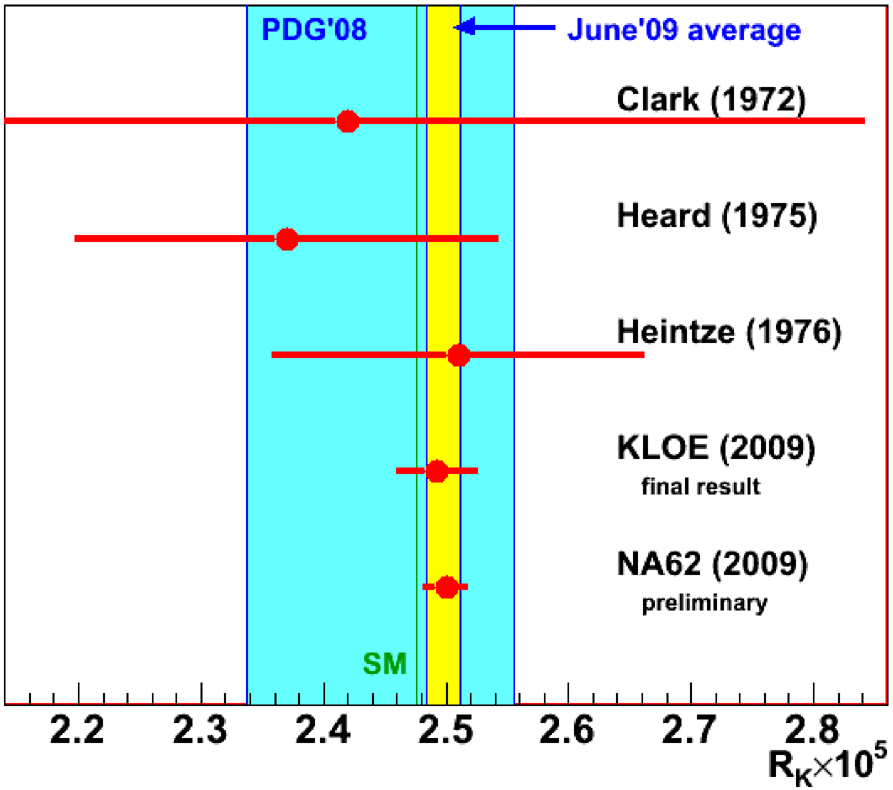
(0.64% precision)

Comparison to world data

March 2009



June 2009



World average	$\delta R_K \times 10^5$	Precision
March 2009	2.467±0.024	0.97%
June 2009	2.498±0.014	0.56%

With the full NA62 data sample of 2007/08, the precision is expected to be improved to better than $\delta K_R/R_K$=0.5%.

Current activities & propects

Analysis focused at decreasing the dominant contributions to systematic uncertainty towards the final result with the partial 40% data set.

- Precision on $K_{\mu2}$ background: $K_{\mu2}$ sample collected with the Pb wall used, in addition to muon runs, to validate the $P(\mu\to e)$ computation.
- Precision on $K_{e2\gamma}$ (SD) background: a recent $K_{e2\gamma}$ measurement by the KLOE collaboration is used. NA62 $K_{e2\gamma}$ (SD) analysis in progress.
- $K_{e2\gamma}$ (IB) simulation: inclusion of the multi-photon process.
- Detailed studies of trigger efficiencies and dead times.
- Significant improvements in electron ID method → higher efficiency.

Practice ground for the future $K\to\pi\nu\nu$ measurement: insight into the properties of single track events.

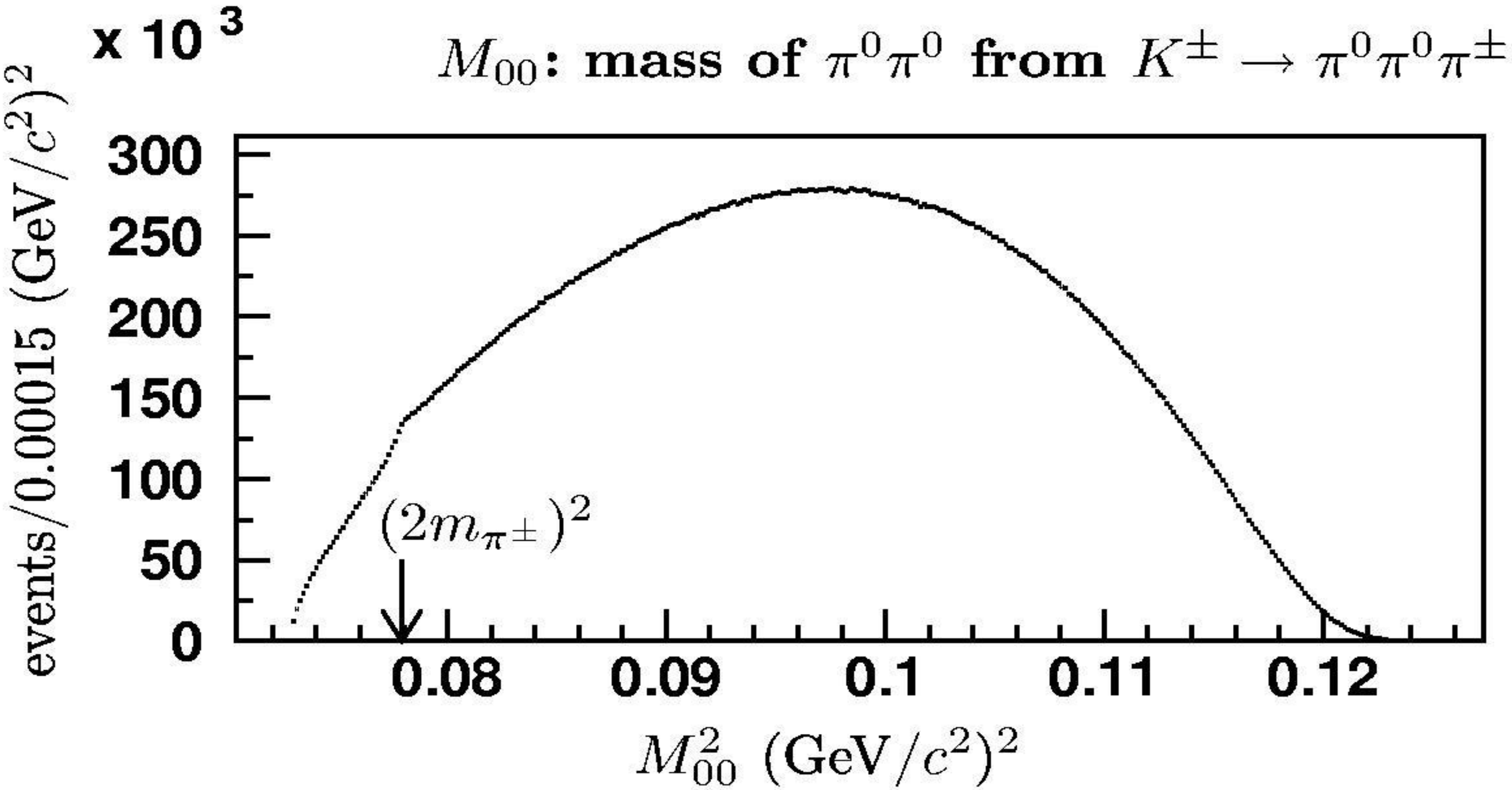
(1) muon beam halo, (2) non-gaussian M_{miss} tails; (3) strategy for the search for heavy neutrinos.

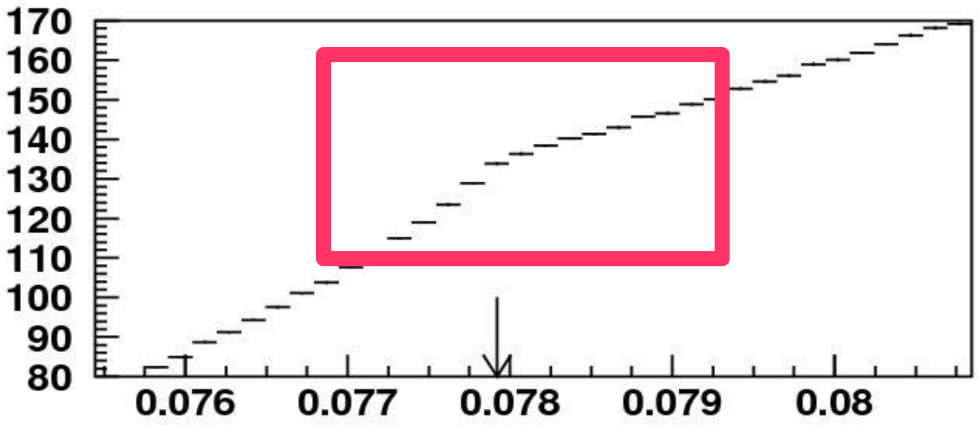
Recent NA48/2 Results

- **NA48/2 data (2003-2004):**
  - Completion of the cusp analyses
  - Form factors and $\pi\pi$ scattering from Ke4 (full sample)
  - Direct Emission from $K^{+/-} \to \pi^{+/-}\pi^{0}\gamma$
  - Measurement of $K^{+/-} \to \pi^{+/-}\gamma\gamma$
  - Measurement of $K^{+/-} \to \pi^{+/-}e^{+}e^{-}$
  - Measurement of $K^{+/-} \to \pi^{+/-}\mu^{+}\mu^{-}$

Slides adapted from presentations by V. Kekelidze and R. Wanke

The “cusp” analysis: Final Result





~ **6 ×10^7** $K^\pm \to \pi^\pm \pi^0 \pi^0$ decays

NA48/2 cusp analysis is completed

Complete analyses are done both for Cabibbo-Isidori and Bern-Bonn theoretical calculations, taking into account electromagnetic correction.
Final result with ChPT link between a0 and a2 :

(a0-a2) = 0.263 ± 0.003(experiment) ± 0.005(theory)

is in good agreement with both Ke4 analysis using ChPT link:

$a_0 m_+ = 0.2206 \pm 0.0052(\text{exp}) \pm 0.0064(\text{theor.})$

and the prediction of **ChPT:**

$(a_0 - a_2) m_+ = 0.265$ +/- 0.004
$a_2\, m_+ = -0.0444$ +/- 0.001

The largest source of experimental error is the uncertainty (PDG)

of $Br(K^\pm \to \pi^\pm\pi^0\pi^0) / Br(K^\pm \to \pi^\pm\pi^0\pi^0)$ *can be reduced using the huge N48/2 statistics*

.

Recent "Cusp" papers:

1. ***"Determination of the S-wave $\pi\pi$ scattering lengths from a study of $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ decays"***

published in The European Physical Journal C (2009)

http://www.springerlink.com/openurl.asp?genre=article&id=doi:10.1140/epjc/s10052-009-1171-3

DOI 10.1140/epjc/s10052-009-1171-3

2. ***"Empirical parameterization of the $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ decay Dalitz plot"***

(to be submitted)

ππ Scattering Lengths from Ke4 Decays

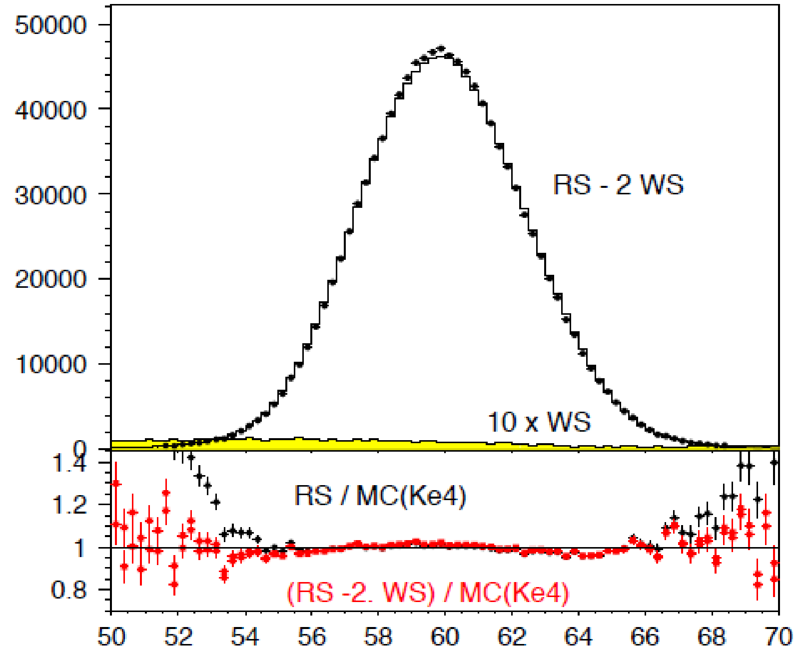
$K^{\pm} \to \pi^{+}\pi^{-}e\nu$ (K_{e4}) Decays:

Publication of 2003 data (SS123) last year.

Now: Analysis of full NA48/2 dataset

→ **more than 1 million Ke4 decays**

- **Background: ~ 0.5%** (e.g. $\pi \to e\nu$ decays)
- estimated from wrong-sign decays

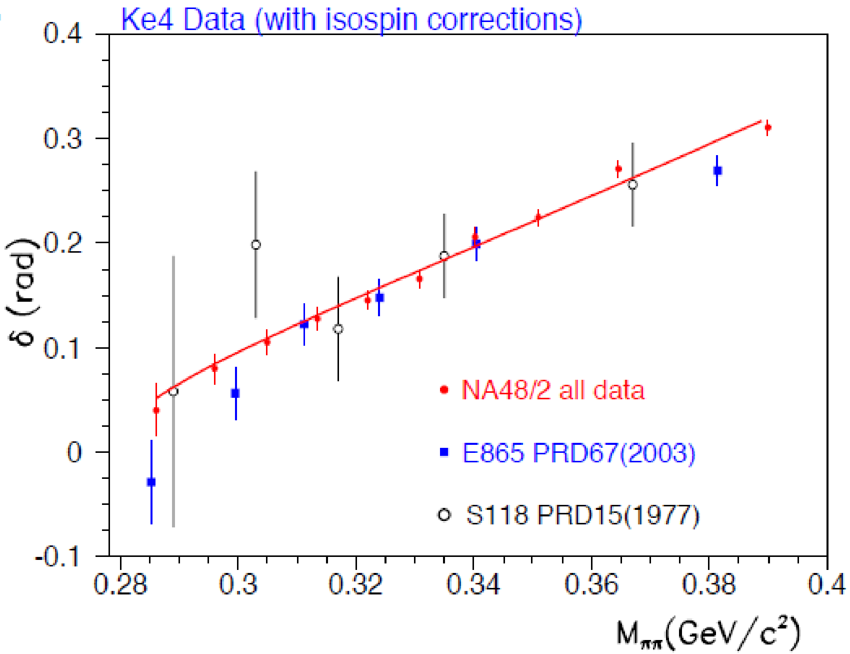


ππ Scattering Lengths from Ke4 Decays

From phase shifts to scattering lengths:

- Phase shifts fitted together with form factors
- Several corrections necessary:
  - **Radiative effects**
    (Coulomb attraction, PHOTOS)
  - **Isospin corrections**
    (close collaboration with theory)

  → non-negligible effect!



Ke4 results NA48/2:

a_0 = 0.2220 (128) (50) (37)
a_2 = -0.0432 (86) (34) (28)
stat. syst. theo.

With ChPT constraint:

a_0 = 0.2206 (49) (18) (64)

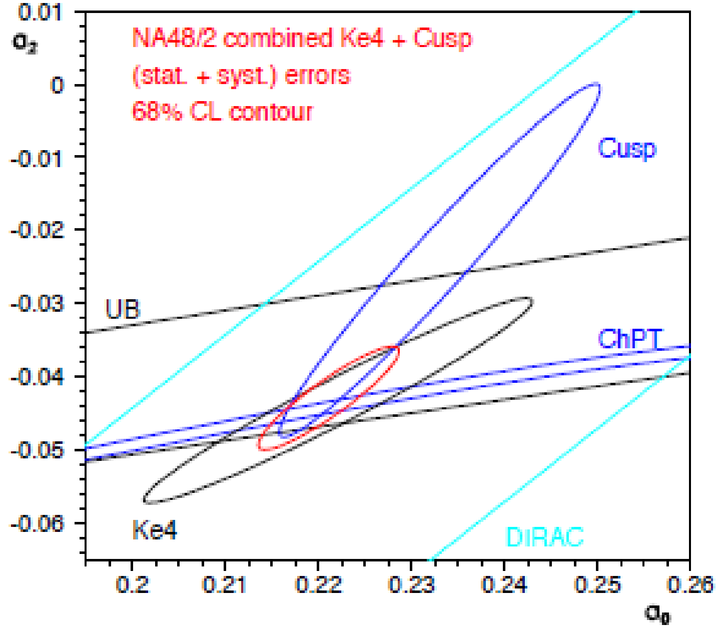
ChPT prediction:

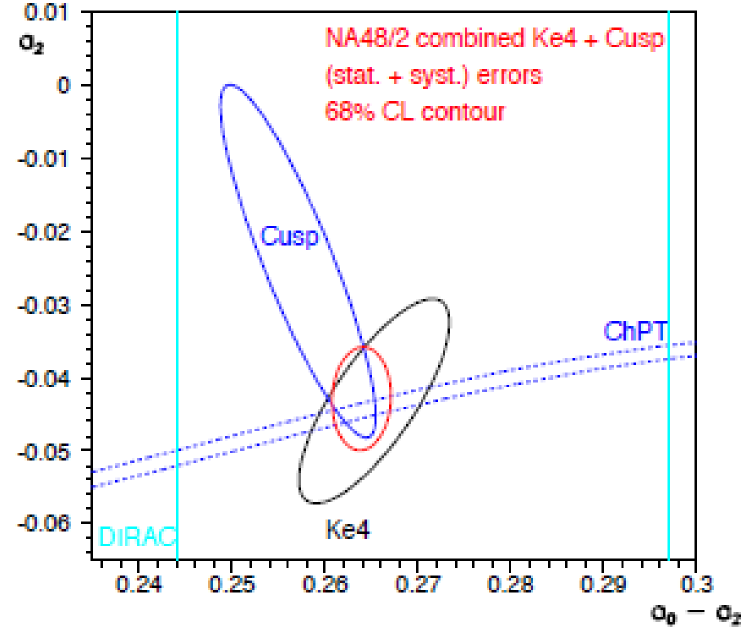
$a_0 = 0.220 \pm 0.005$

$a_2 = -0.0444 \pm 0.0010$

ππ Scattering Lengths from Ke4 Decays

Combination of Ke4 and cusp measurements:





$a_0 = 0.2210\ (47)\ (15)$
$a_2 = -0.0429\ (44)\ (16)$
stat. syst.

$a_0 - a_2 = 0.2639\ (20)\ (4)$
$a_2 = -0.0429\ (44)\ (16)$
stat. syst.

With ChPT constraint:

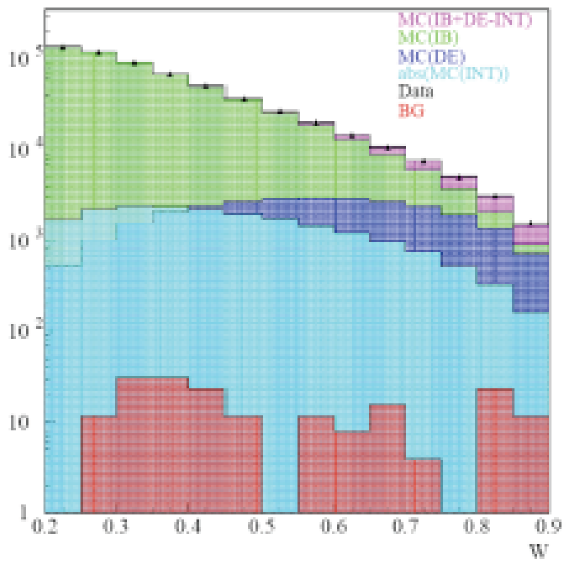
$a_0 = 0.2196\ (27)\ (21)$
$a_2 = -0.0444\ (7)\ (5)$

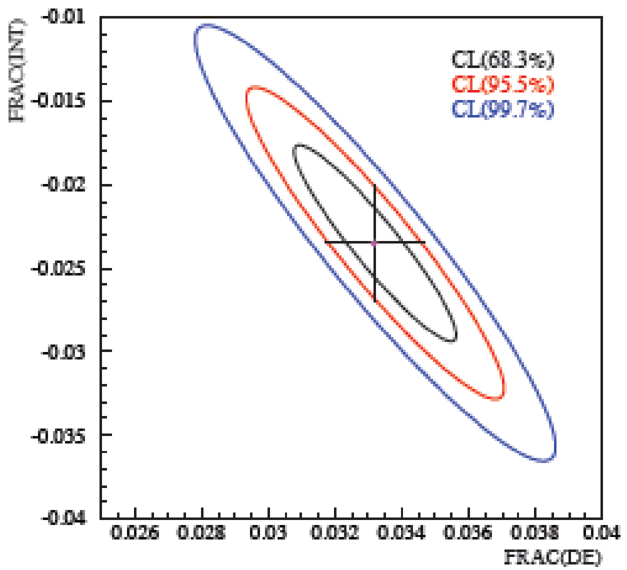
ChPT prediction:

$a_0 = 0.220 \pm 0.005$
$a_2 = -0.0444 \pm 0.0010$

Direct Emission in $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$

Fit to the W distribution:





Final NA48/2 results on $K^{\pm}\to\pi^{\pm}\pi^{0}\gamma$ fractions:

$$\text{Frac(DE)}_{0<T_\pi^*<80\text{ MeV}} = (\ \ 3.32 \pm 0.15_{\text{stat}} \pm 0.14_{\text{syst}}) \times 10^{-2}$$

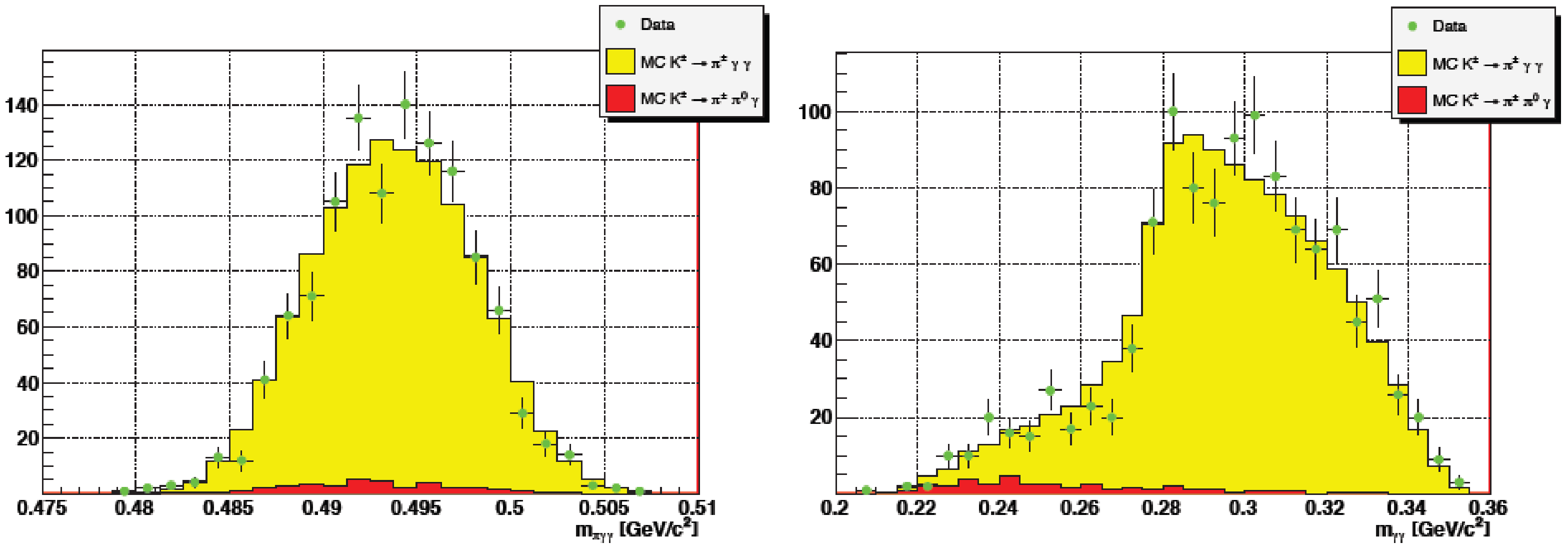
$$\text{Frac(INT)}_{0<T_\pi^*<80\text{ MeV}} = (-2.35 \pm 0.35_{\text{stat}} \pm 0.39_{\text{syst}}) \times 10^{-2}$$

Correlation: $\rho = -0.93$

First observation of the interference term!

Paper draft ready, will be submitted end of the month.

Measurement of $K^{\pm}\rightarrow\pi^{\pm}\gamma\gamma$



- **1164 $K^{\pm} \rightarrow \pi^{\pm}\gamma\gamma$ candidates** in 40% of NA48/2 data.
  (About 40 times more than previous world sample!)
- **Background:** **3.3%,** mainly from $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$.
- **Systematics:** Mainly from trigger efficiency determination.

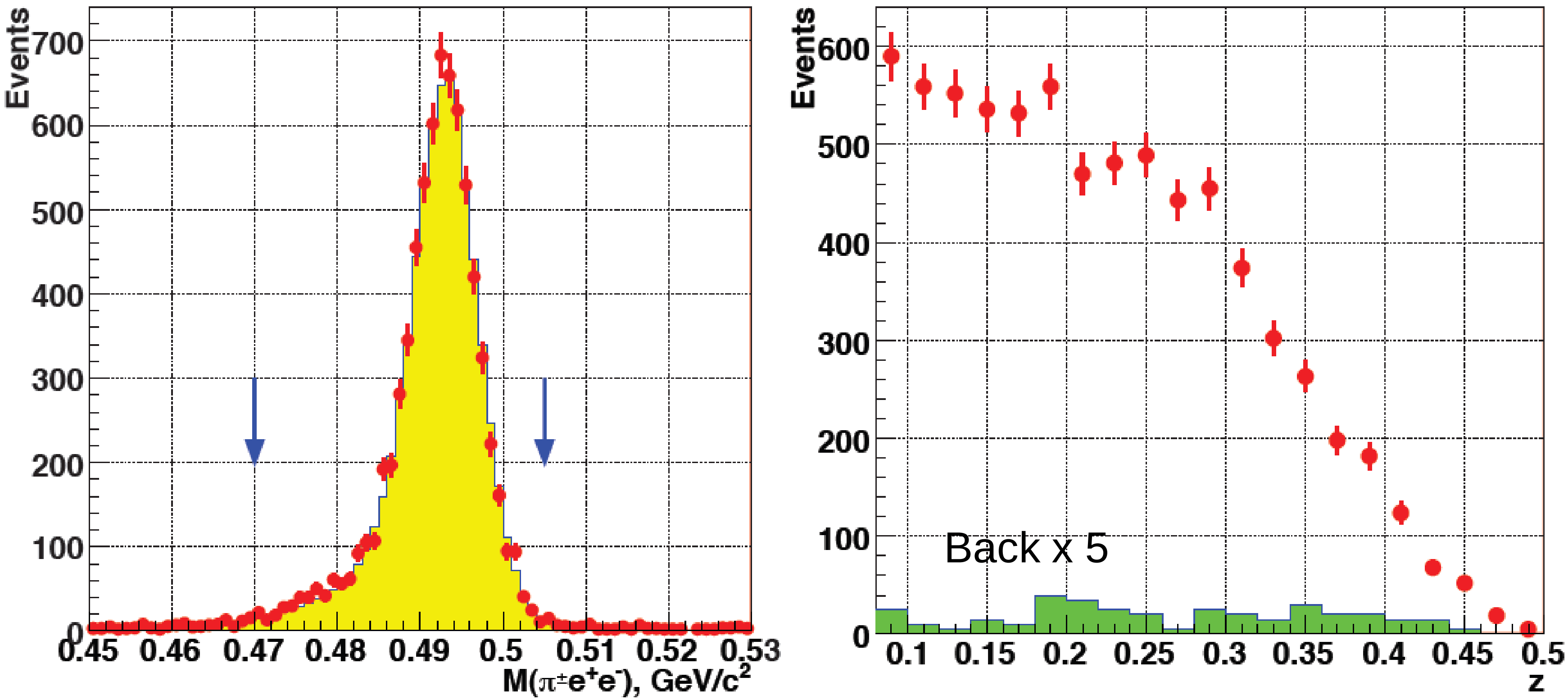
Assume ChPT $\mathcal{O}(p^6)$ and $\hat{c} = 2$:

(NA48/2 preliminary)

$$\text{Br}(K^{\pm} \rightarrow \pi^{\pm}\gamma\gamma)_{\hat{c}=2,\mathcal{O}(p^6)} = (1.07 \pm 0.04_{\text{stat}} \pm 0.08_{\text{syst}}) \cdot 10^{-6}$$

Model-independent measurement and ĉ extraction on whole data set in preparation

Precise Measurement of $K^{\pm} \rightarrow \pi^{\pm} e^{+} e^{-}$

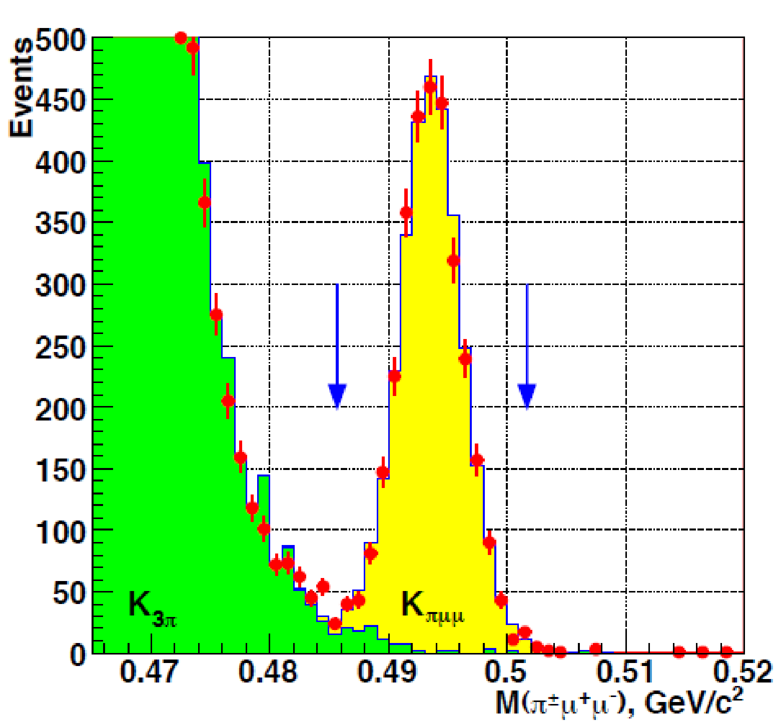


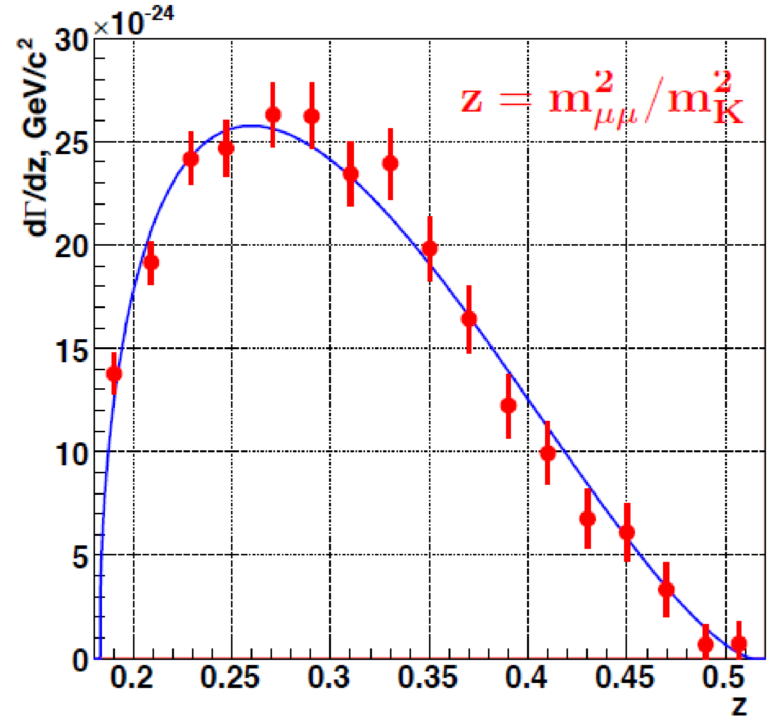
(PLB 677 (2009) 246)

$$\text{Br}(K^{\pm} \rightarrow \pi^{\pm} e^{+} e^{-}) = 3.11\,(4)_{\text{stat}}\,(5)_{\text{syst}}\,(8)_{\text{ext}}\,(7)_{\text{model}} \times 10^{-7}$$

Also limit on direct CP violation: $\frac{\text{Br}^{+} - \text{Br}^{-}}{\text{Br}^{+} + \text{Br}^{-}} = (-2.1 \pm 1.5 \pm 0.6)\%$

Measurement of $K^{\pm}\rightarrow\pi^{\pm}\mu^{+}\mu^{-}$





<u>Whole NA48/2 data set:</u>

3120 $K^{\pm}\rightarrow\pi^{\pm}\mu^{+}\mu^{-}$ candidates

(World largest data sample)

Background/Signal: ~3.8%

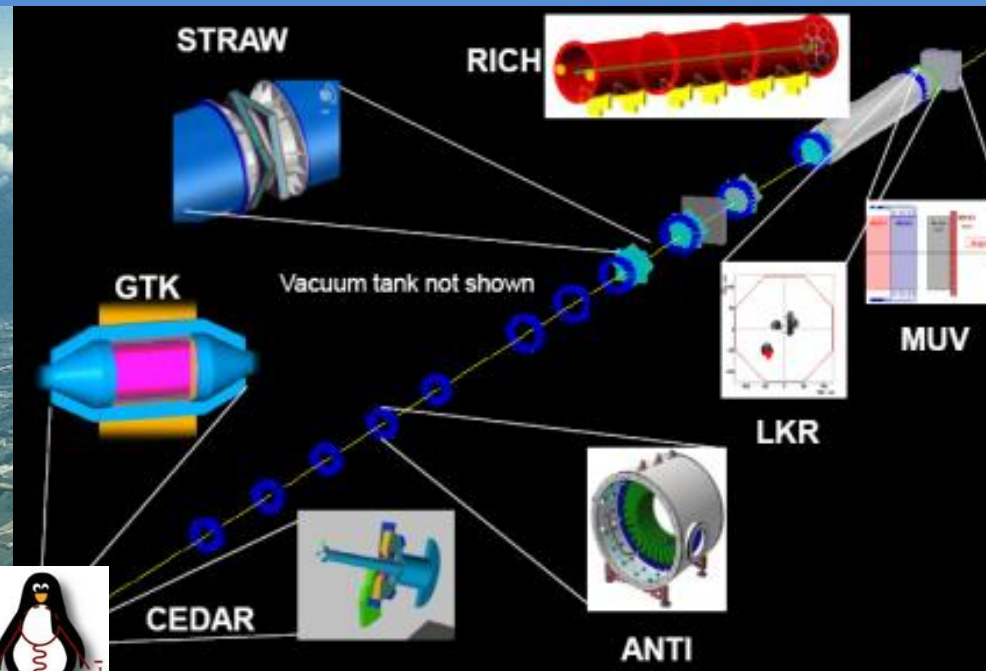
$Br(K^{\pm}\rightarrow\pi^{\pm}\mu^{+}\mu^{-}) = (9.6 \pm 0.2 \pm 0.1) \times 10^{-8}$

NA62 Physics Handbook

CERN, December 10-11, 2009

Advisory Committee:

Gerhard Buchalla
Andrzej Buras
Nicola Cabibbo
Vincenzo Cirigliano
Gerhard Ecker
Jonathan R. Ellis
Jean-Marc Gérard
Gino Isidori
Marc Knecht
Heinrich Leutwyler
Bill Marciano
Helmut Neufeld
Antonio Pich
Jorge Portoles
Eduardo de Rafael
Chris Sachrajda
Lalit Sehgal



Kaons @ CERN SPS, Topics:

- Rare Decays
- Radiative Decays
- Forbidden Decays & LFV tests
- (Semi)-Leptonic Decays
- Hadronic decays, $\pi\pi$ phases

Program Committee:

Johan Bijnens
Augusto Ceccucci
Patrizia Cenci
Gilberto Colangelo
Giancarlo D'Ambrosio
Martin Gorbahn
Ulrich Haisch
Federico Mescia
Matthew Moulson
Paride Paradisi
Christopher Smith

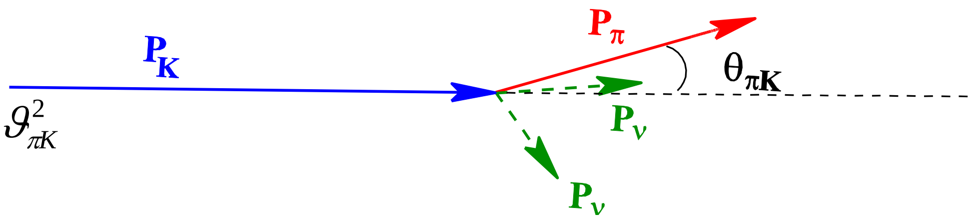
Secretariat: veronique.wedlake@cern.ch

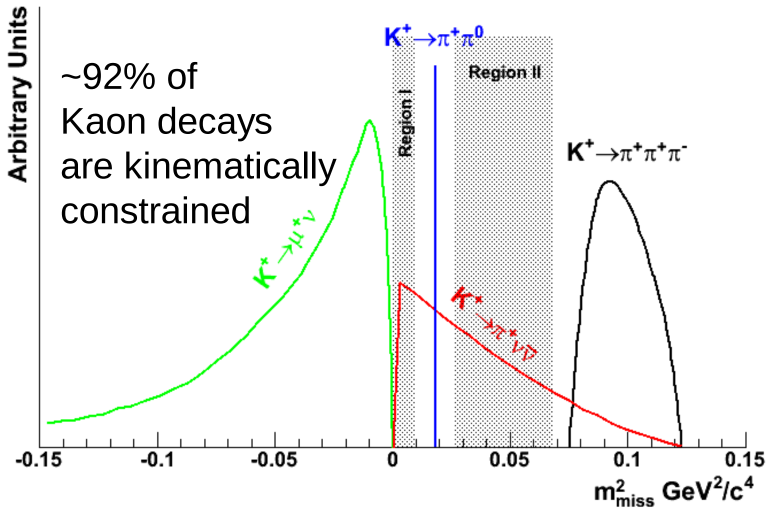
http://na62pb.ph.tum.de/

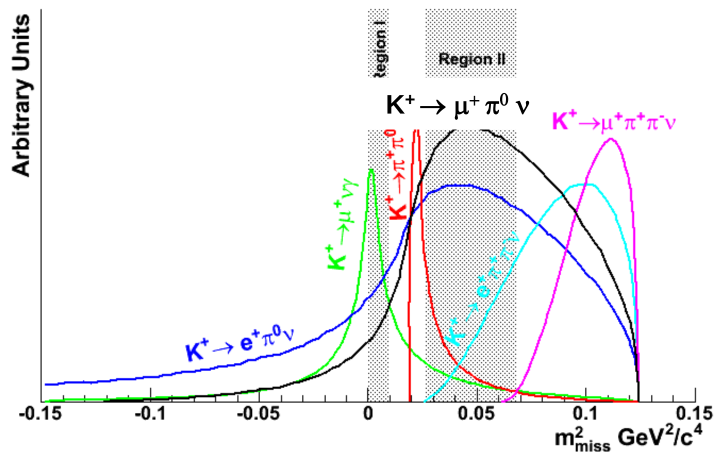
SPARE

NA62 Experimental Method

$$m_{miss}^2 \approx m_K^2\left(1-\frac{|P_\pi|}{|P_K|}\right)+m_\pi^2\left(1-\frac{|P_K|}{|P_\pi|}\right)-|P_K||P_\pi|\vartheta_{\pi K}^2$$

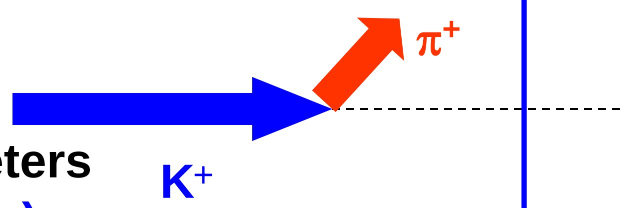






Signature:

- **Incoming high momentum (75 GeV/c) K^+**
- **Outgoing low momentum (< 35 GeV/c) π^+**
- **For $K_{\pi 2}$ $P(\pi^0)$ > 40 GeV/c deposited in calorimeters**
- **PID: CEDAR (π/K), RICH (π/μ), MUV (μ), E/P (e/π)**



NA62 Sensitivity

Decay Mode	Events
Signal: $K^+ \to \pi^+ \nu \bar{\nu}$ *[flux = 4.8×10[12] decay/year]*	55 *evt/year*
$K^+ \to \pi^+ \pi^0$ $[\eta_{\pi 0} = 2 \times 10^{-8}$ (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: ~100 days/year; 60% overall efficiency

Isidori's FCNC Matrix

	$b \to s\ (\sim\lambda^2)$	$b \to d\ (\sim\lambda^3)$	$s \to d\ (\sim\lambda^5)$
$\Delta F=2$ Box	$\Lambda > 100$ TeV from ΔM_{Bs} $A_{CP}(B_{ds} \to \psi\phi)$	$\Lambda > 2\text{x}10^3$ TeV from $A_{CP}(B_d \to \psi K)$	$\Lambda > 2\text{x}10^4$ TeV from ε_K
$\Delta F=1$ 4-quark Box			
Gluon Penguin	$\Lambda > 80$ TeV from $B(B \to X_s\gamma)$		$\Lambda > 10^3$ TeV from $\varepsilon'/\varepsilon_K$
γ Penguin	$\Lambda > 150$ TeV from $B(B \to X_s\gamma)$		
Z^0 Penguin	$\Lambda > 20$ TeV From $B(B \to X_s \ell^+\ell^-)$		$B(K \to \pi\nu\nu)$ $B(K_L \to \pi \ell^+\ell^-)$
H^0 Penguin	$B(B_s \to \mu\mu)$	$B(B_d \to \mu\mu)$	

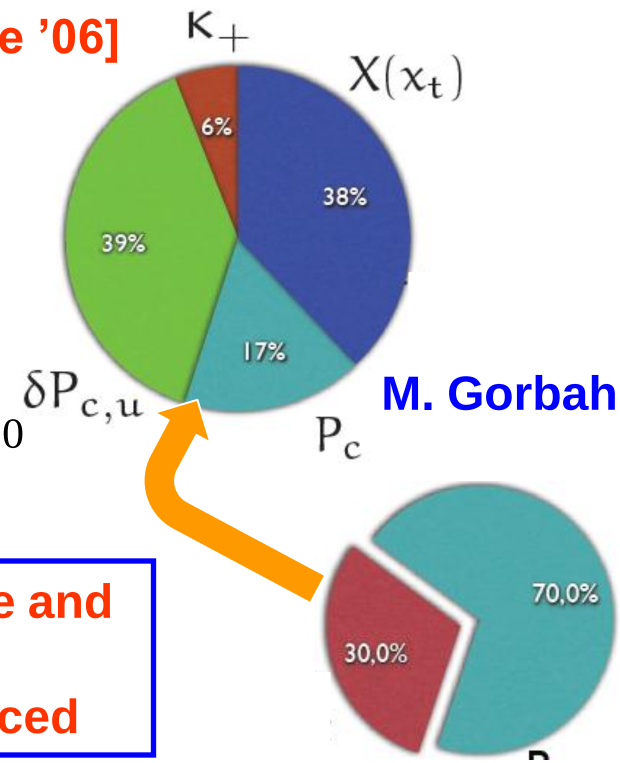
Present Bounds on Λ assuming O(1) Flavor-changing couplings

Corners where Sizable Non-standard Effects could hide

SM Prediction: $K^+ \to \pi^+ \nu \bar{\nu}$

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

- **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]**



M. Gorbahn

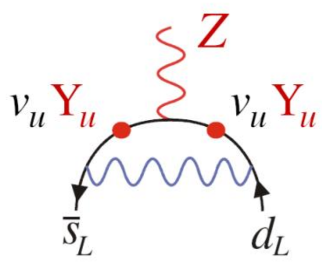
$$Br(K^+ \to \pi^+ \nu\bar{\nu}(\gamma)) = (0.85 \pm 0.07) \times 10^{-10}$$

•The SM Branching Ratio prediction is precise and the intrinsic theory error is small
•The parametric error (70%) will be further reduced

Kaon Rare Decays and NP

(courtesy of Christopher Smith)

C. The Z penguin (and its associated W box)

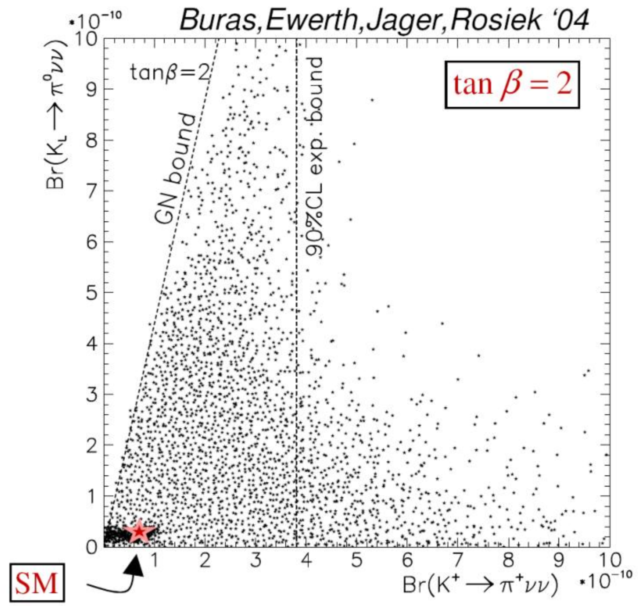


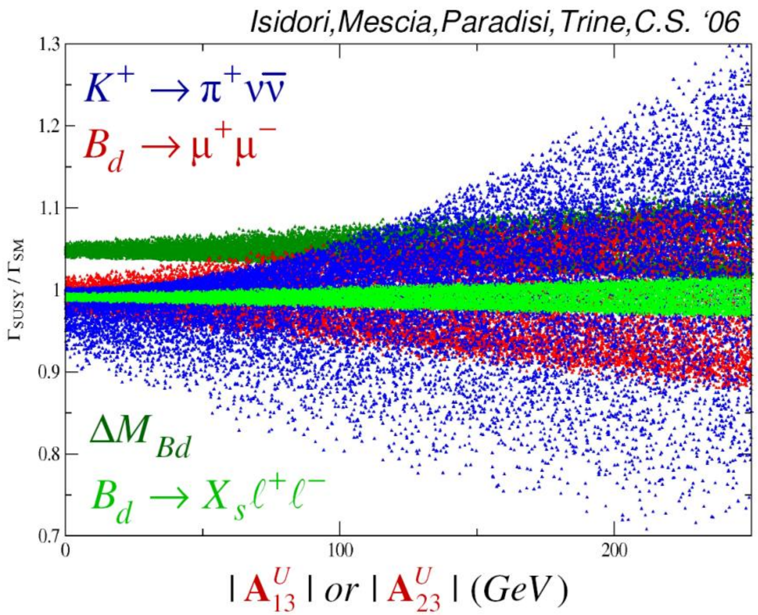
- $SU(2)_L$ breaking: $SM: v_u^2 \mathrm{Y}_u^{*32} \mathrm{Y}_u^{31} \sim m_t^2 V_{ts}^* V_{td}$

$$MSSM: v_u^2 \mathrm{A}_{\tilde{u}}^{*32} \mathrm{A}_{\tilde{u}}^{31} \sim m_t^2 \times O(1)\,?$$

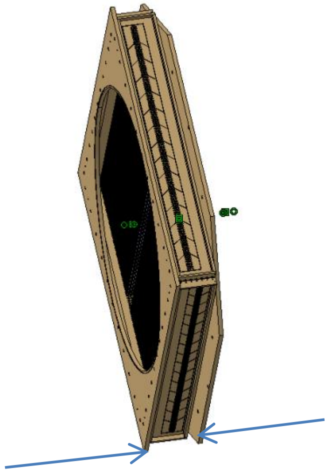
$$MFV: v_u^2 \mathrm{A}_{\tilde{u}}^{*32} \mathrm{A}_{\tilde{u}}^{31} \sim m_t^2 V_{ts}^* V_{td} \left|A_0 a_2^* - \cot\beta\mu\right|^2.$$

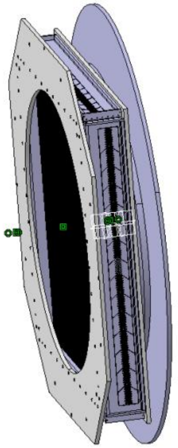
- Relatively slow decoupling (w.r.t. boxes or tree).

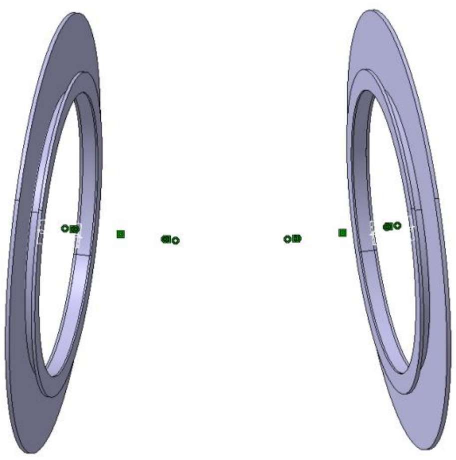


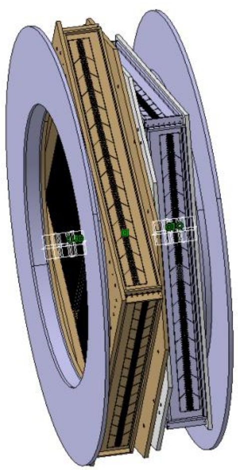


Straw frame and chamber design

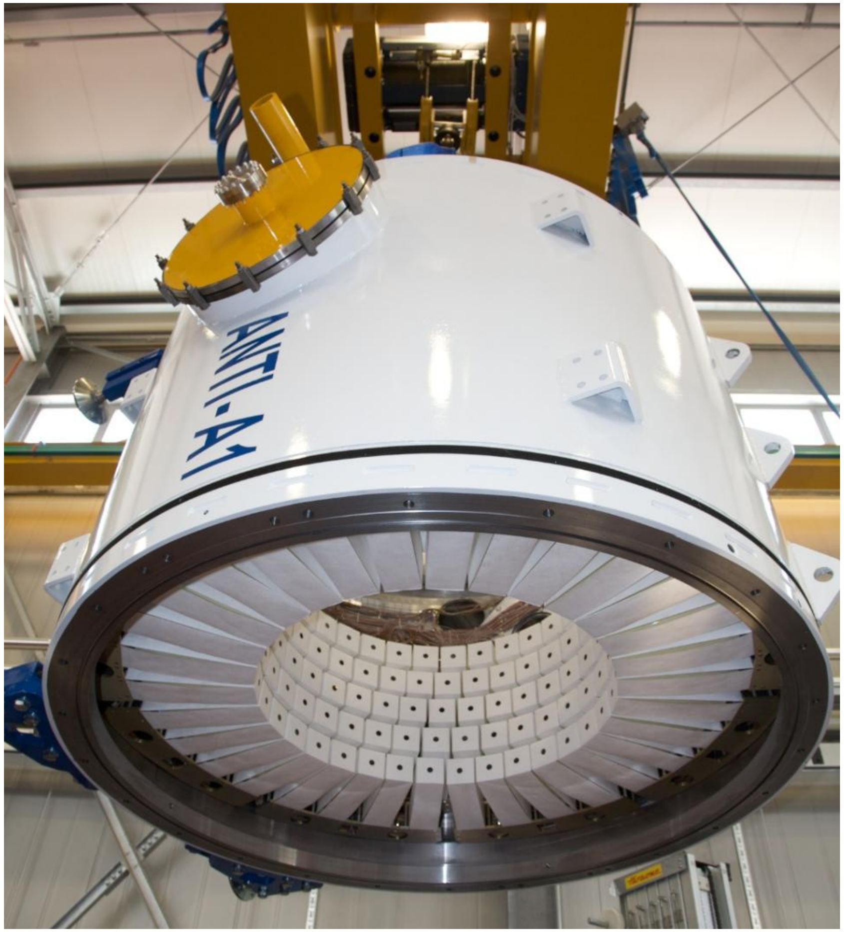








Installation of First LAV Station



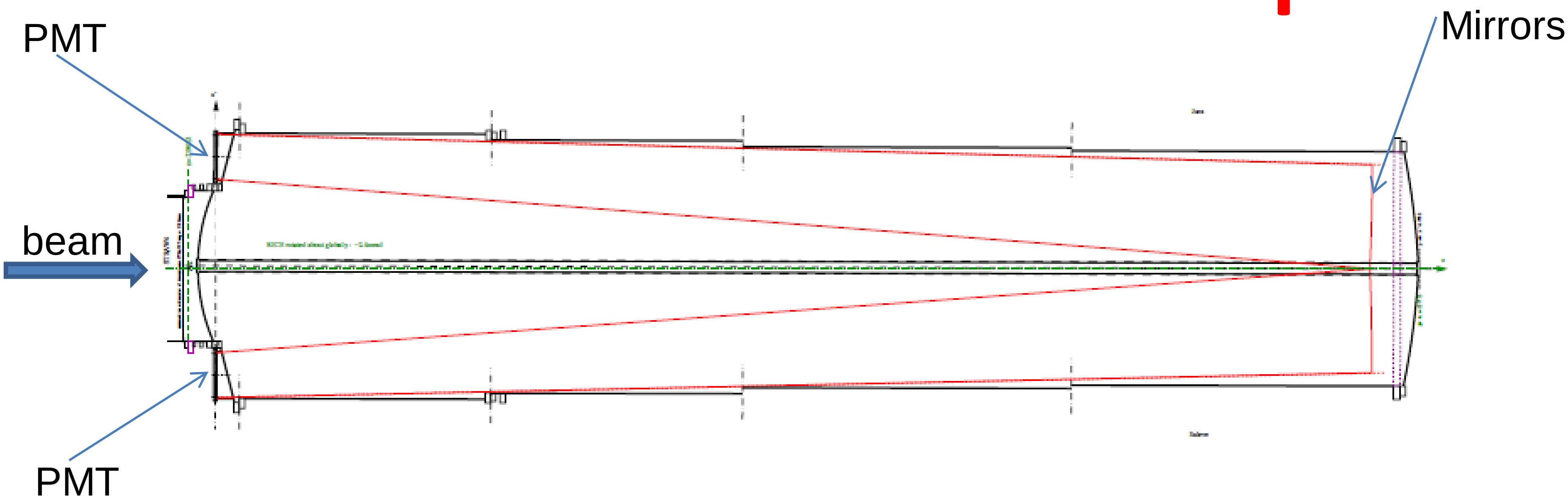
- The first of the twelve Large Angle Vetoes was installed on August 6, 2009
- These lead-glass blocks were formerly used in the OPAL Experiment at LEP

LAV Front-End requirements

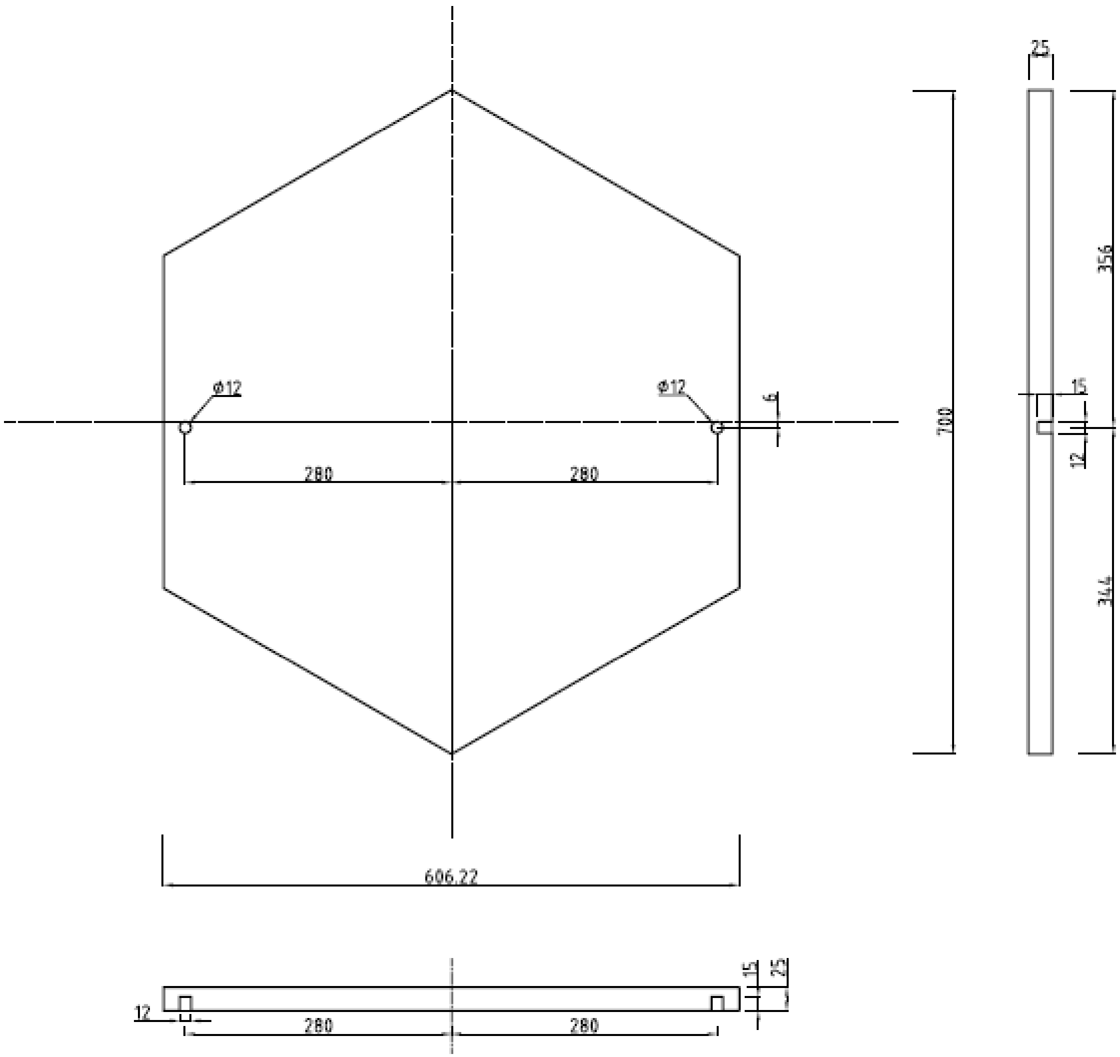
- FEE time resolution (~500 ps)
- Energy resolution ≈ 10%/√E
- Max rate ≈ MHz/ch (real rate/block < 100 KHz)
- Able to manage very large signals ≈10V
- Measure energy 20 MeV – 20 GeV in a single block

- Measure Time Over Threshold to evaluate charge
- Use custom TDC cards for the readout (HPTDC)
- Use Tell1 as TDC motherboard

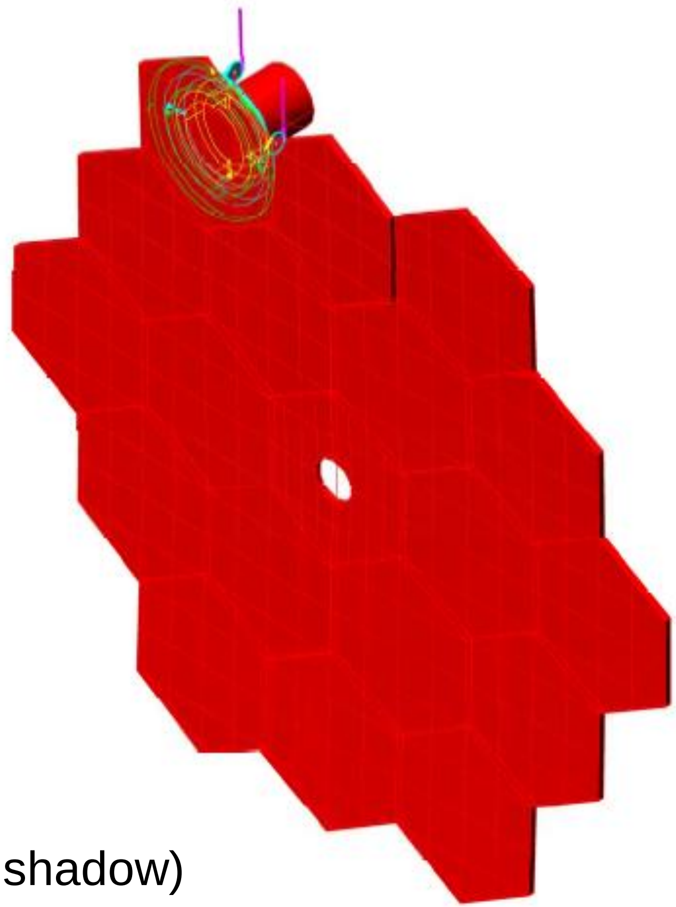
Vessel: view from the top



- Limited from access shaft to the experimental area
- 4 sections of increasing diameter (about 4 m in the upstream part)
- Sections length: 3.7m, 3.7m, 4.8m, 4.8m
- beam pipe passing through
- vessel axis tilted by 2.4 mrad to follow beam path



Mirrors



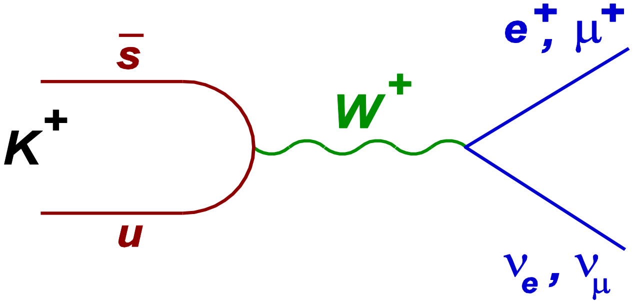
- 18 hexagonal mirrors, 2 semihexagonal
- 17 m focal length, 700 mm wide, 25 mm thick
- half pointing to the left, half to the right (beam pipe shadow)
- All mirrors in order

K_{l2} and π_{l2} decays in the SM

Standard Model:

• excellent sub-permille accuracy of R_P due to cancellation of hadronic uncertainties in the ratio;

• strong helicity suppression of the electronic channel enhances sensitivity to non-SM effects.



$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \cdot \left(1 + \delta R_K^{\mathrm{rad.corr.}}\right)$$

Helicity suppression (V–A couplings):
enhances sensitivity to non-SM effects

Radiative correction (few %) due to the IB part of the radiative $K \to e\nu\gamma$ process, by definition included into R_K

SM uncertainties well below 10^{-3}

$R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$

$R_\pi^{SM} = (12.352 \pm 0.001) \times 10^{-5}$

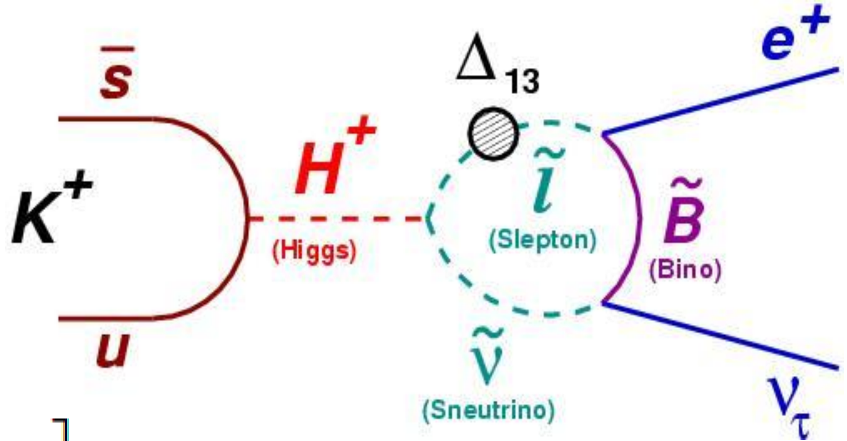
V. Cirigliano and I. Rosell, Phys. Lett. 99 (2007) 231801

R_K beyond the SM

<u>Possible scenario in MSSM:</u>

charged Higgs mediated SUSY LVF contribution with emission of τ neutrino can be strongly enhanced.

A. Masiero, P. Paradisi and R. Petronzio, PRD74 (2006) 011701 and JHEP 0811 (2008) 042

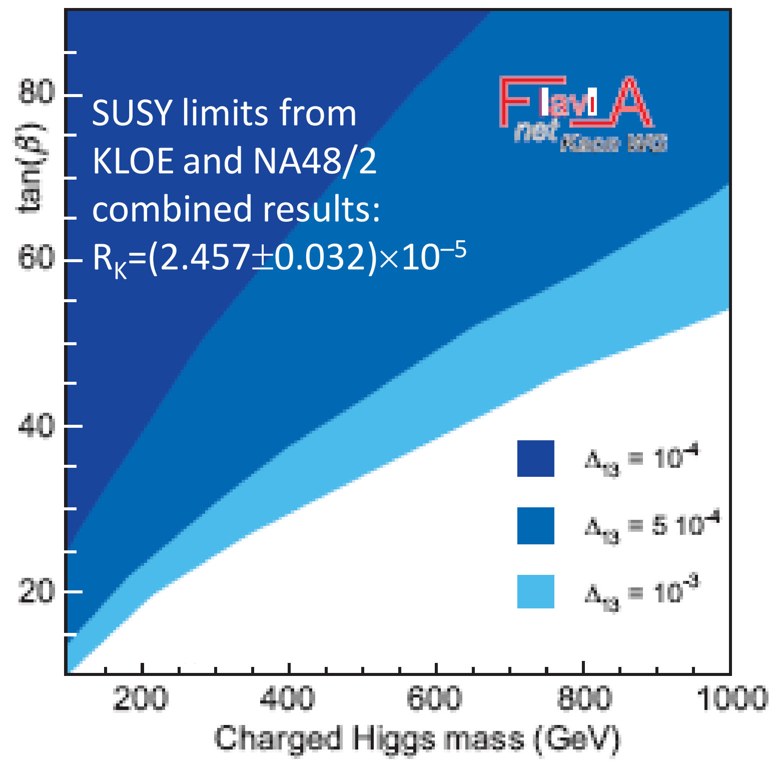


$$R_K^{LFV} \approx R_K^{SM}\left[1+\left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{M_e^2}\right)|\Delta_{13}|^2 \tan^6\beta\right]$$

A few percent effect in large (not extreme) $\tan\beta$ regime with massive charged Higgs.

<u>Example:</u>

($\Delta_{13}=5\times10^{-4}$, $\tan\beta=40$, $M_H=500$ GeV/c^2) lead to $R_K^{LVF} = R_K^{SM}(1+0.013)$.



NB: analogous SUSY effect in pion decay is suppressed by a factor $(m_\pi/M_K)^4 \approx 6\times10^{-3}$

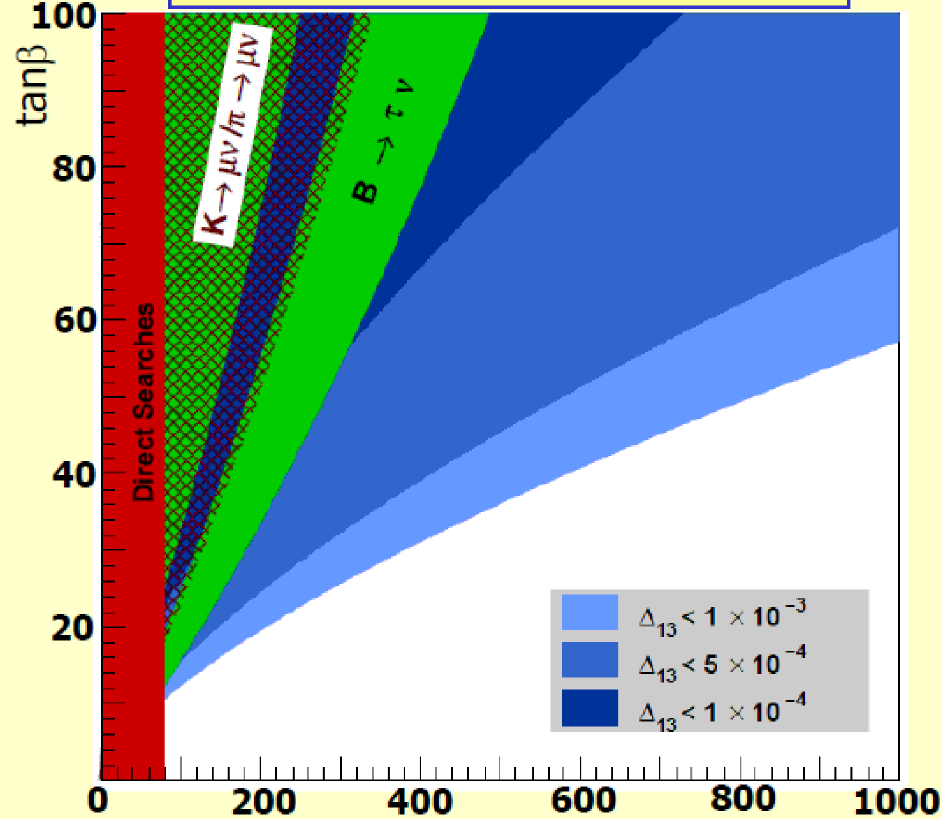
R_K: sensitivity to new physics

R_K measurements are currently in agreement with the SM expectation at $\sim 1.5\sigma$.
Any significant enhancement with respect to the SM value would be an evidence of new physics.

Exclusion limits at 95% CL derived from the new R_K world average are presented.

For non-tiny values of the LFV effective mixing Δ_{13}, sensitivity to $H^{\pm}$ in $R_K = K_{e2}/K_{\mu 2}$ is better than in $B \to \tau\nu$

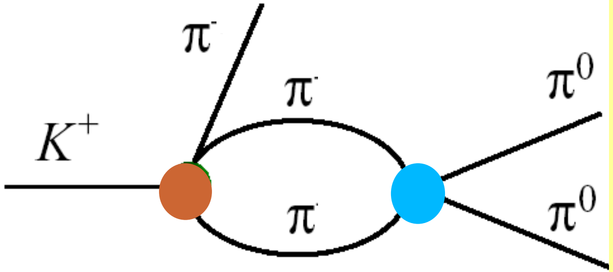
(M_H, $\tan\beta$) 95% exclusion limits



N. Cabibbo and G. Isidori ("CI"), JHEP 503 (2005) 21

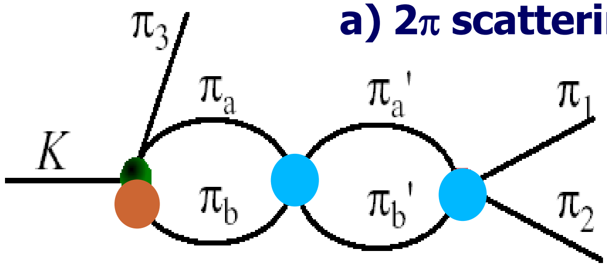
- S-wave scattering lengths **(a_x, a_{++}, a_{+-}, a_{+0}, a_{00})** expressed as linear combinations of a_0 and a_2
- isospin symmetry breaking - following J. Gasser
- for example, $a_x = (1+\varepsilon/3)(a_0-a_2)/3$, where $\varepsilon=(m_+^2-m_0^2)/m_+^2=0.065$ - isospin breaking parameter
- all rescattering processes at one- & two-loop level
- radiative corrections missing: **($a_0 - a_2$)** precision ~5%

One-loop diagrams:

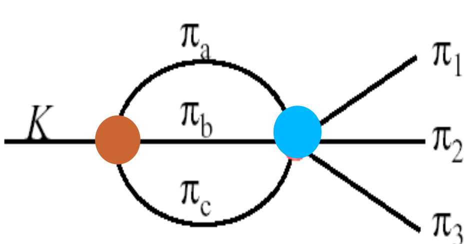


Two-loop diagrams:

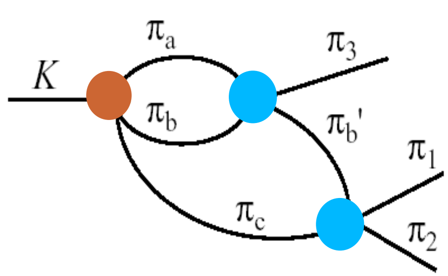
a) 2π scattering

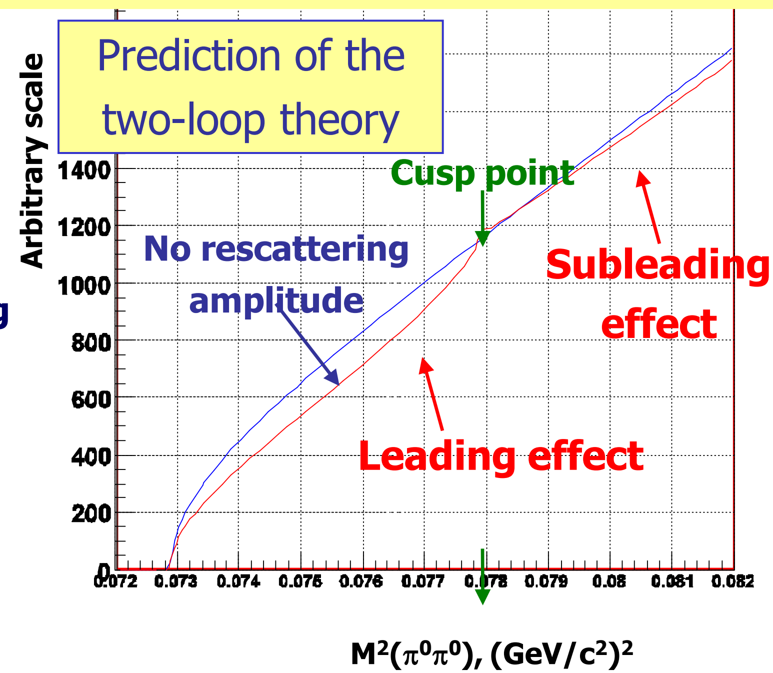


b) irreducible 3π scattering



c) reducible 3π scattering

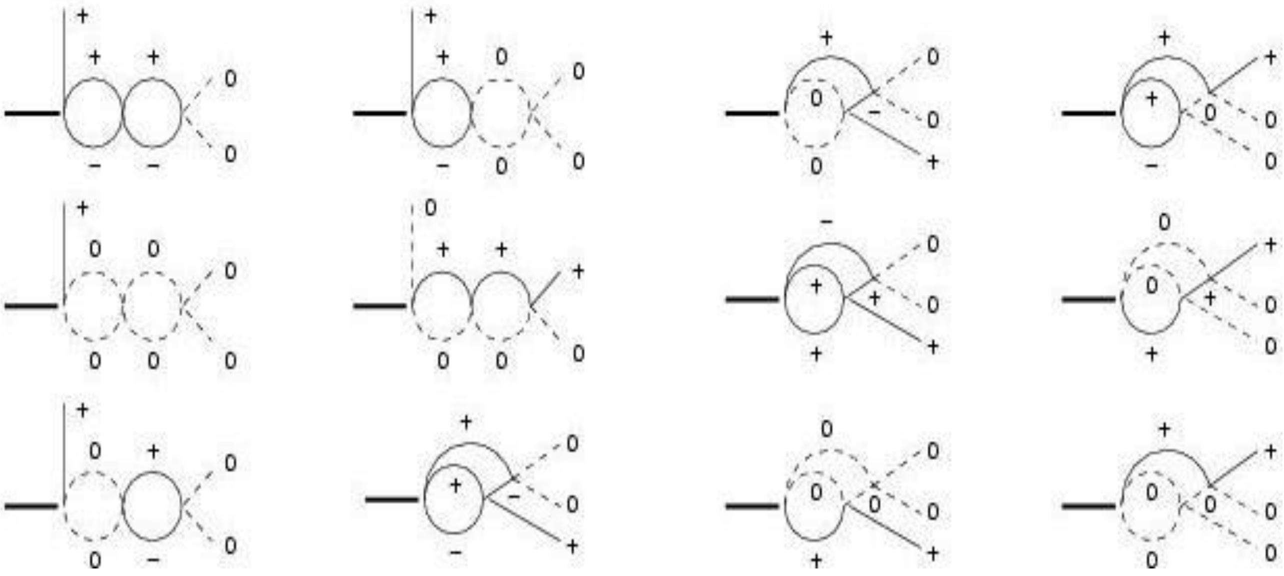




Theory: effective fields

G. Colangelo, J. Gasser, B. Kubis, A. Rusetsky (Bern-Bonn group: “BB”)
Phys.Lett. B638 (2006) 187-194

- Non-relativistic Lagrangian for effective fields; expanding in another small parameters.
- Valid in the whole decay region.
- Another (in comparison with CI) part of amplitude is absorbed in the polinomial terms (so another correlations).
- At two loops, algebraically different formulae for amplitude
- FORTRAN code written by authors



a_0, a_2, measured in NA48/2 experiment:

- from the fits of cusp in three-pion decay of charged kaon
- from form-factors of K_{e4} (see “rare decays”)

final results from NA48/2 both for independent (a_0, a_2) & using ChPT link