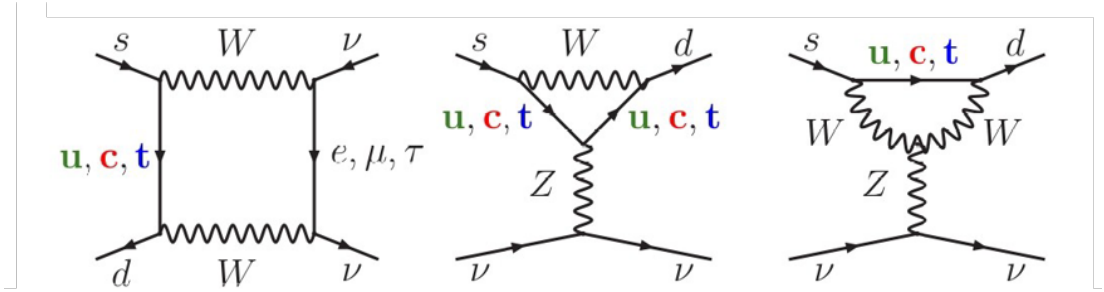
Italo & NA62

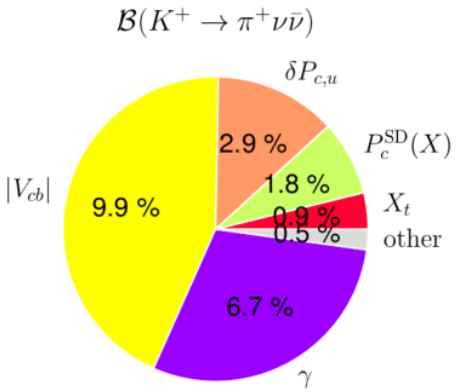
Augusto Ceccucci/CERN

Pisa, 05.10.2018

The FCNC process $K^+ \to \pi^+ \nu\bar{\nu}$

Theoretical error budget
Buras. et. al., JHEP11(2015)033





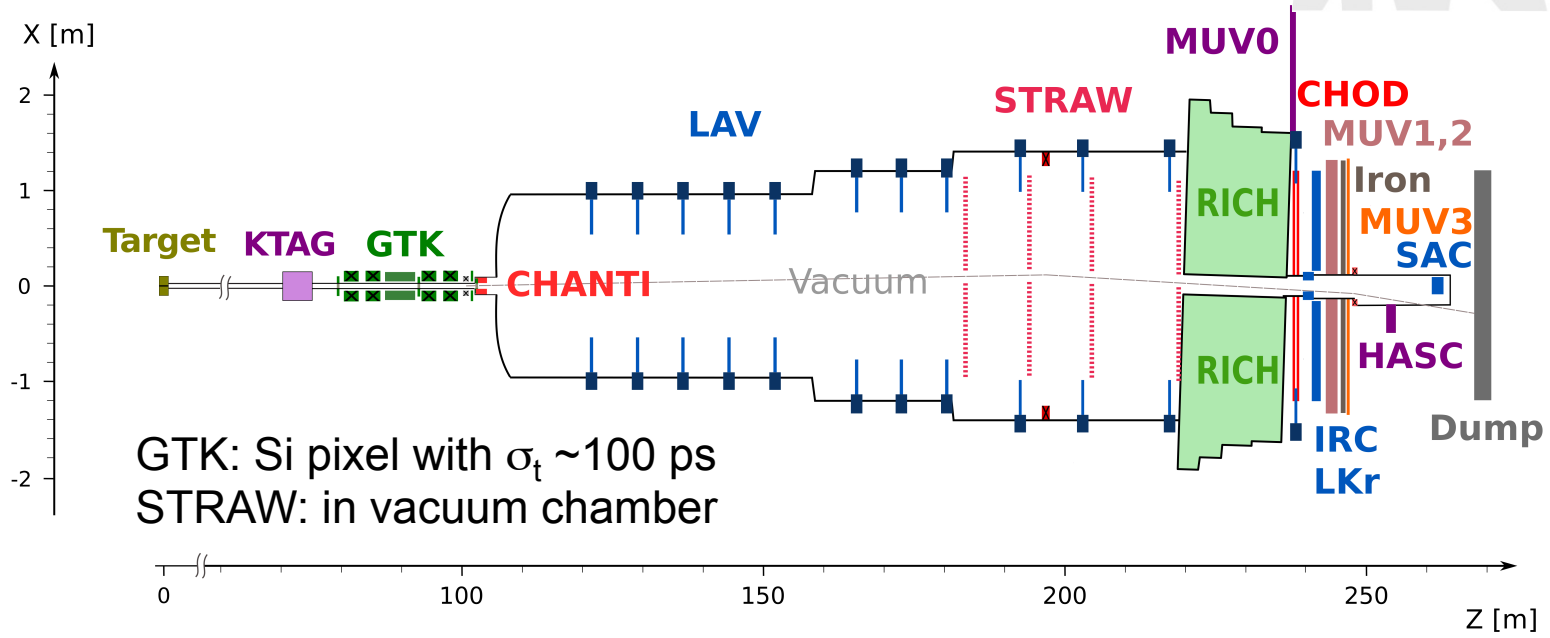
- FCNC loop processes: s → d coupling and highest CKM suppression
- Theoretically clean: Short distance contribution
- Hadronic matrix element measured with K_{l3} decays
- SM predictions:[Brod, Gorbahn, Stamou, Phys. Rev.D 83, 034030 (2011), Buras. et. al., JHEP11(2015)033]:

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (8.39 \pm 0.30) \times 10^{-11} \left(\frac{|V_{cb}|}{0.0407}\right)^{2.8} \left(\frac{\gamma}{73.2^\circ}\right)^{0.74} = (8.4 \pm 1.0) \times 10^{-11}$$

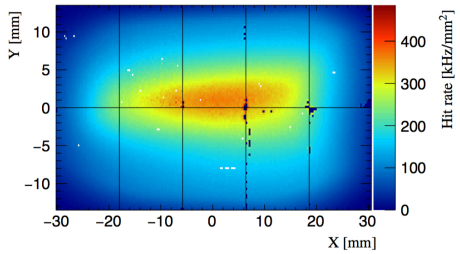
- Experimental result:[Phys. Rev. D 79, 092004 (2009)]

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (17.3^{+11.5}_{-10.5}) \times 10^{-11} \text{ (BNL, "kaon decays at rest")}$$

NA62 beam and detector



- SPS Beam:
  - 400 GeV/c protons
  - 2.10^{12} protons/spill
  - 5s spill [3s eff.] / ~16 s



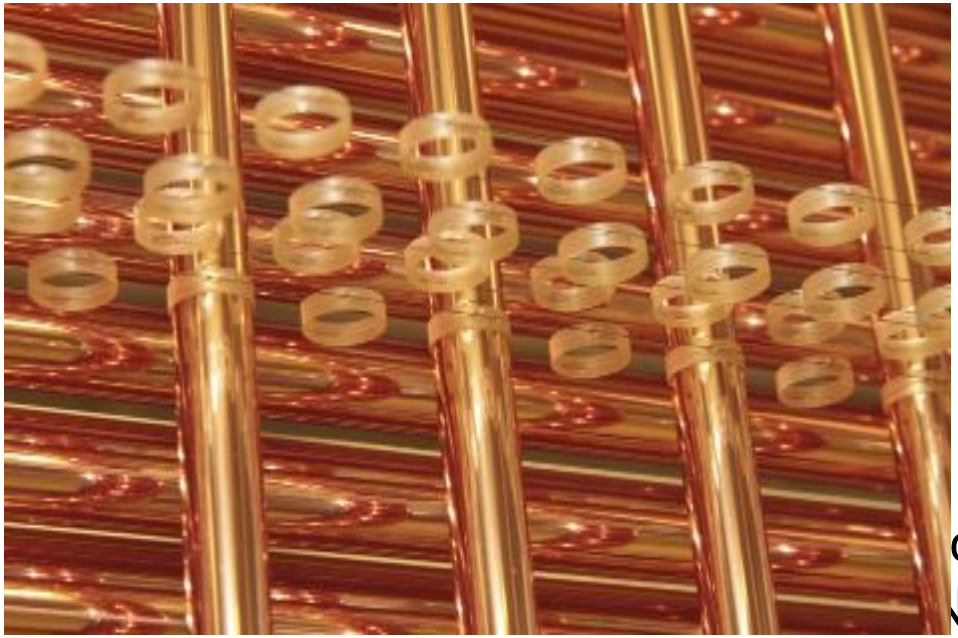
- Secondary positive Beam:
  - 75 GeV/c momentum, 1 % bite
  - 100 μrad divergence (RMS)
  - 60x30 mm^2 transverse size
  - $K^+(6\%)/p^+(70\%)/p(24\%)$
  - For $33x10^{11}$ ppp on T10

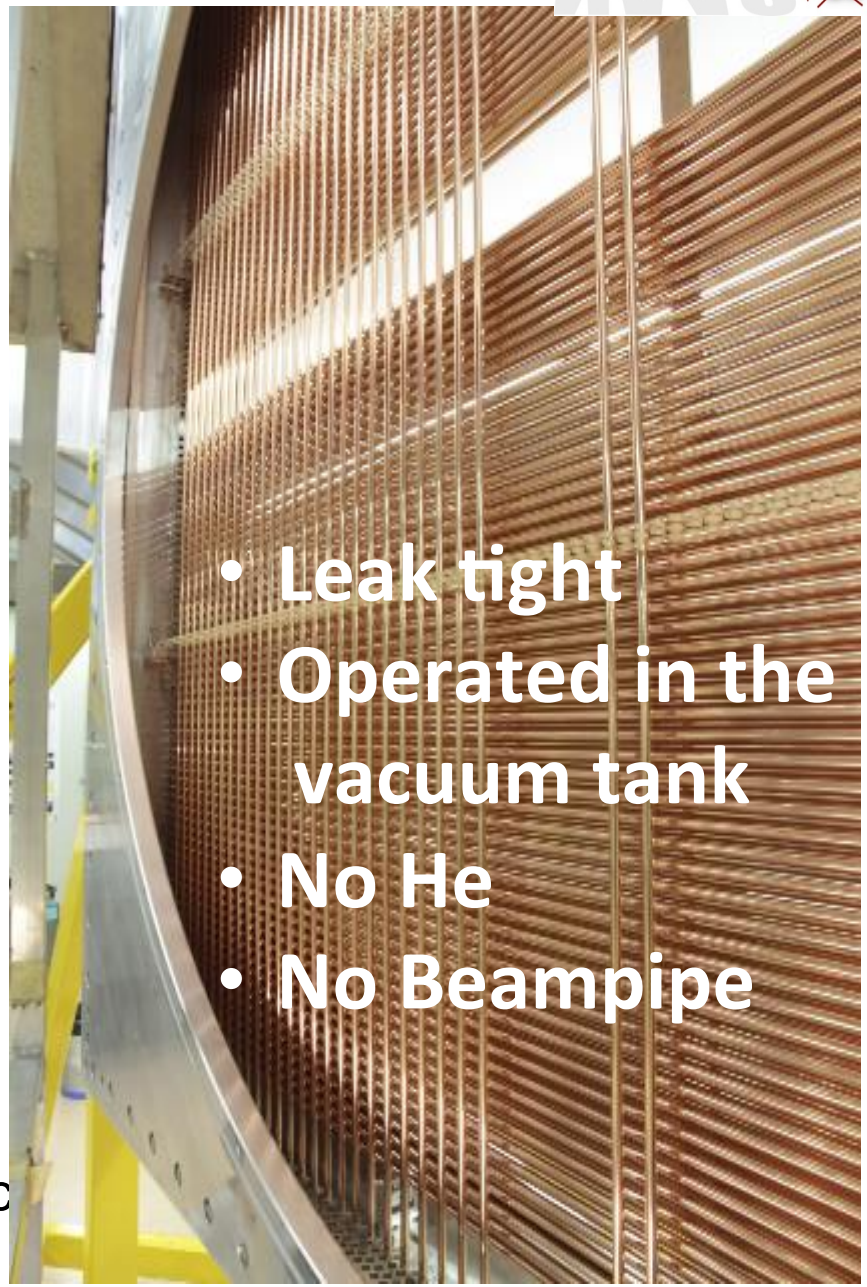
  → 750 MHz at GTK3

- Decay Region:
  - 60 m long fiducial region
  - ~ 5 MHz K^+ decay rate
  - Vacuum ~ $O(10^{-6})$ mbar

Detector and Performances: [arXiv:1703.08501]

NA62 Straws Tracker



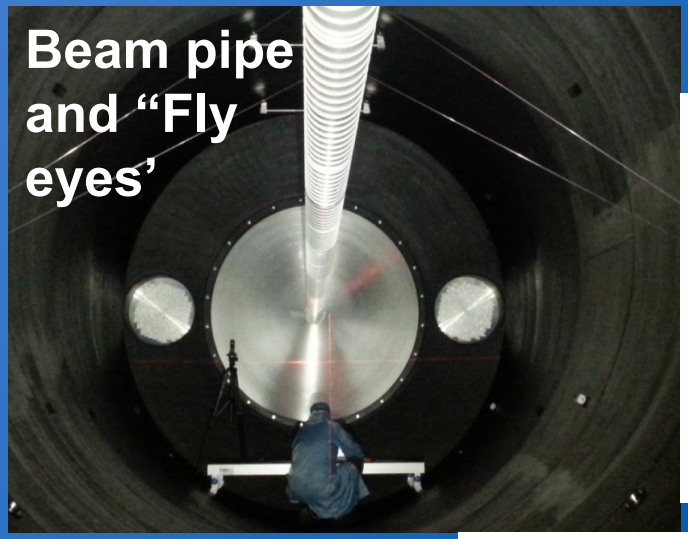


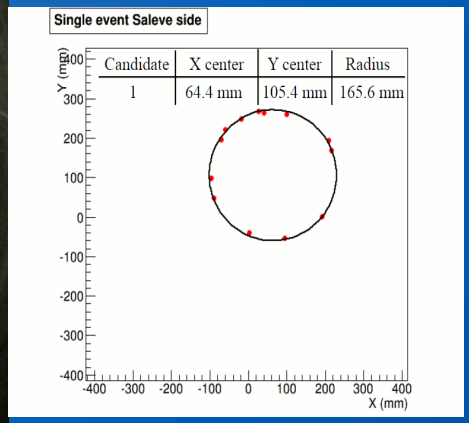
- Leak tight
- Operated in the vacuum tank
- No He
- No Beampipe

C
N

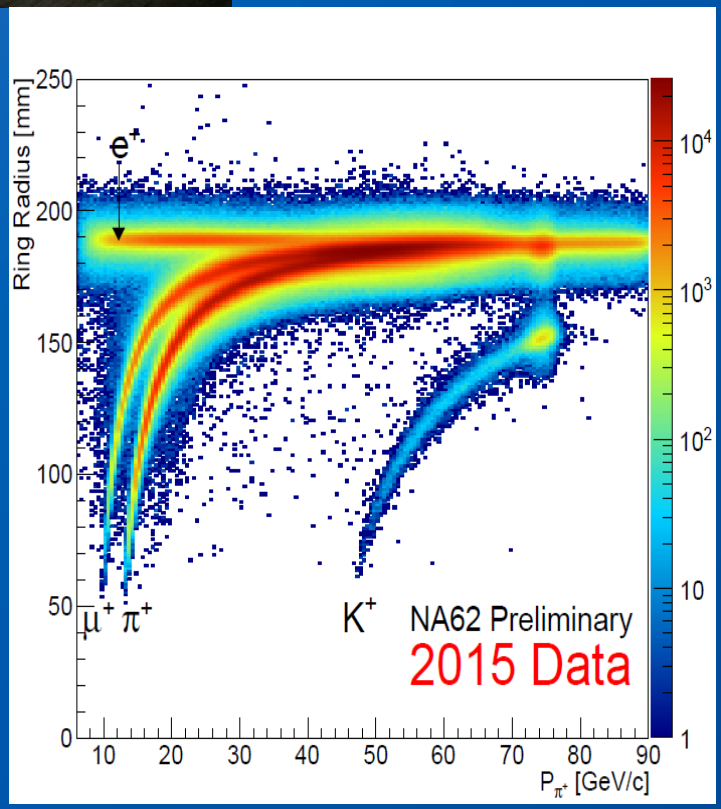
NA62 RICH


Mirror mosaic


Beam pipe
and “Fly
eyes’


Single event Saleve side
Candidate
X center
Y center
Radius
1
64.4 mm
105.4 mm
165.6 mm
Y (mm)
X (mm)

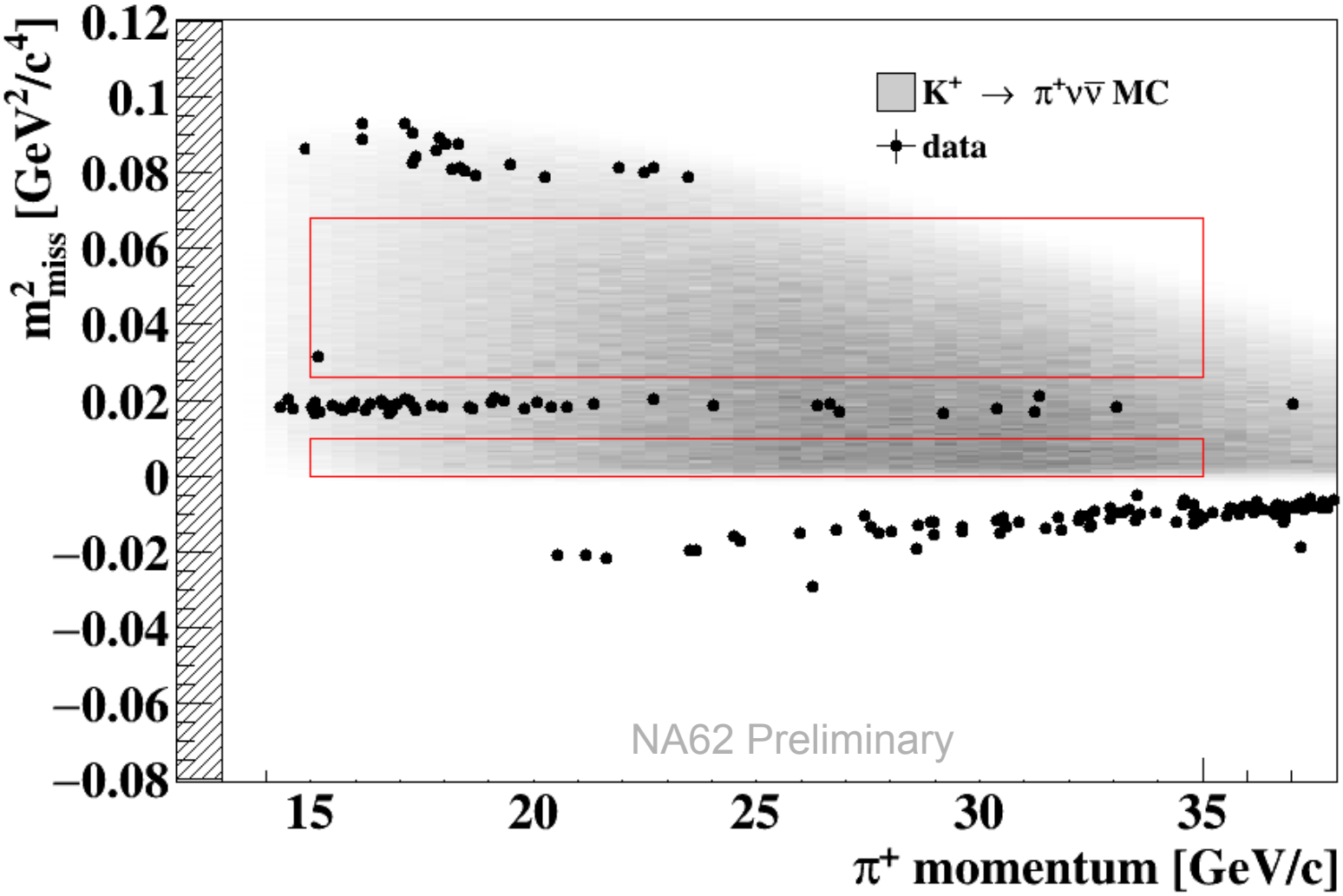

Vessel


Ring Radius [mm]
P_{π^+} [GeV/c]
e^+
μ^+ π^+
K^+
NA62 Preliminary
2015 Data

NA62 Gigatracker

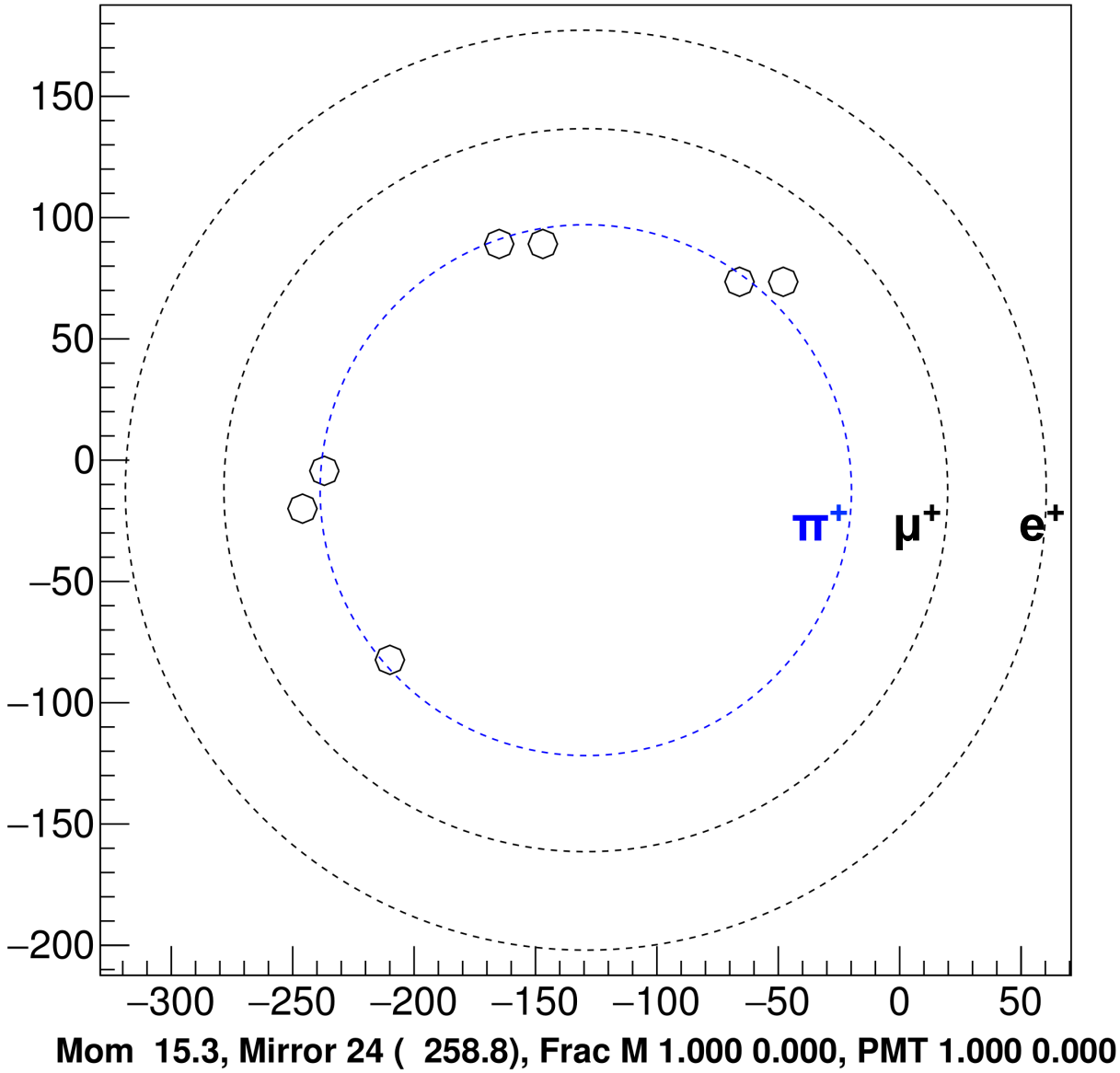
Si pixel
~0.5% X_0
~ 18 cm^2
100 MHz/ cm^2
σ_t ~ 100 ps
$\sigma_{x,y}$ ~ 100 μm
Microchannel cooling

First Results: 2016 data



One candidate observed with 0.27 SM and 0.15 background expected

RICH ring for the candidate



Results

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) < 11 \times 10^{-10} \ @ \ 90\% \ CL$$

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) < 14 \times 10^{-10} \ @ \ 95\% \ CL$$

- One event observed in Region 2, paper in preparation
- The results are compatible with the Standard Model
- For comparison, taking the candidate to be signal:

$$BR(K^+ \to \pi^+ \nu\bar{\nu}) = 28^{+44}_{-23} \times 10^{-11} \ @ \ 68\% \ CL$$

$$BR(K^+ \to \pi^+ \nu\bar{\nu})_{SM} = (8.4 \pm 1.0) \times 10^{-11}$$

$$BR(K^+ \to \pi^+ \nu\bar{\nu})_{exp} = (17.3^{+11.5}_{-10.5}) \times 10^{-11} \ \text{(BNL, "kaon decays at rest")}$$

- **Expect ~ 20 SM events with the 2016-2018 data**
- **The NA62 in-flight technique works: take data after LS2 to complete measurement**

Detectors built by Italo for NA62

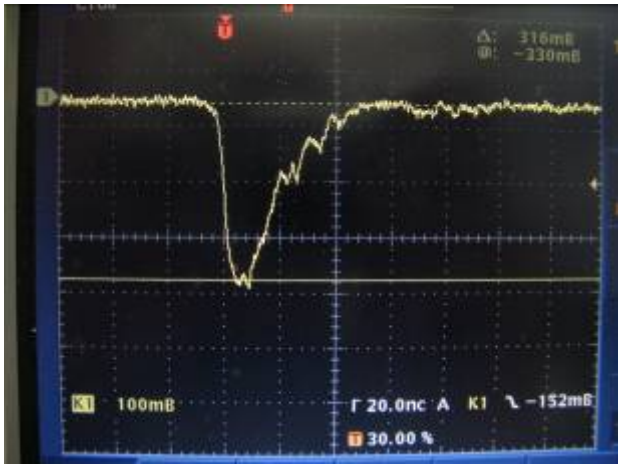
- **LAV** (LNF, Napoli, Pisa, Roma I)
- **MUV3** (Mainz, INR RAS Moscow, Pisa, IHEP Protvino) → See presentation of L. Di Lella
- **CHOD** (Mainz, INR RAS Moscow, Pisa, IHEP Protvino)
- **MUV0** (by-product of CHOD)
- **ANTI-0** (It will be the next to be built)

Large Angle Vetos (LAV)

- Different options were evaluated to build the large angle vetos (LAVs) when we bumped accidentally into **the OPAL (LEP) lead glass** (barrel) which was still available at CERN, buried somewhere in the BA5 building (the surface building of UA1)
- As soon as he got convinced that the use of the lead glass was a plausible solution, **Italo worked out a layout to use the blocks and their PMTs in NA62** and he addressed the technical issues, e.g. how to operate the PMTs under vacuum. **As you all know, Italo has the passion to combine elegant geometry to the laws of mechanics (He could have been a great architect!)**
- Then a big flood happened in BA5 , the lead glass got touched by dirty water, **Italo played an important role to convince the CERN insurance to pay for the recovery of the lead glass and the LAV project was set in motion**

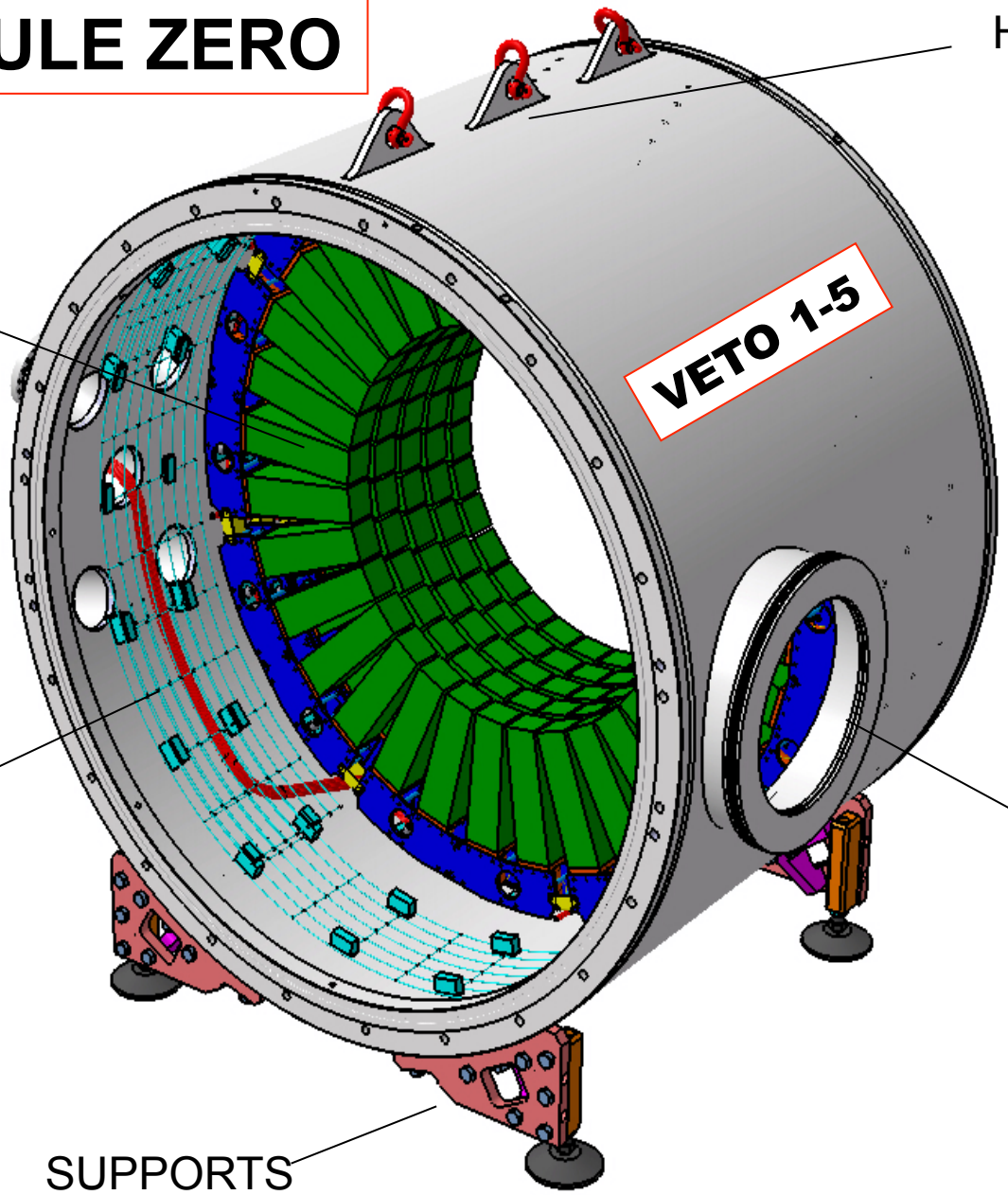
Large Angle Photon Vetoes

Italo and Luigi Di Lella ("junior post doc" carefully inspecting light pulses



Italo and Riccardo Fantechi (the Go-to Wizard)

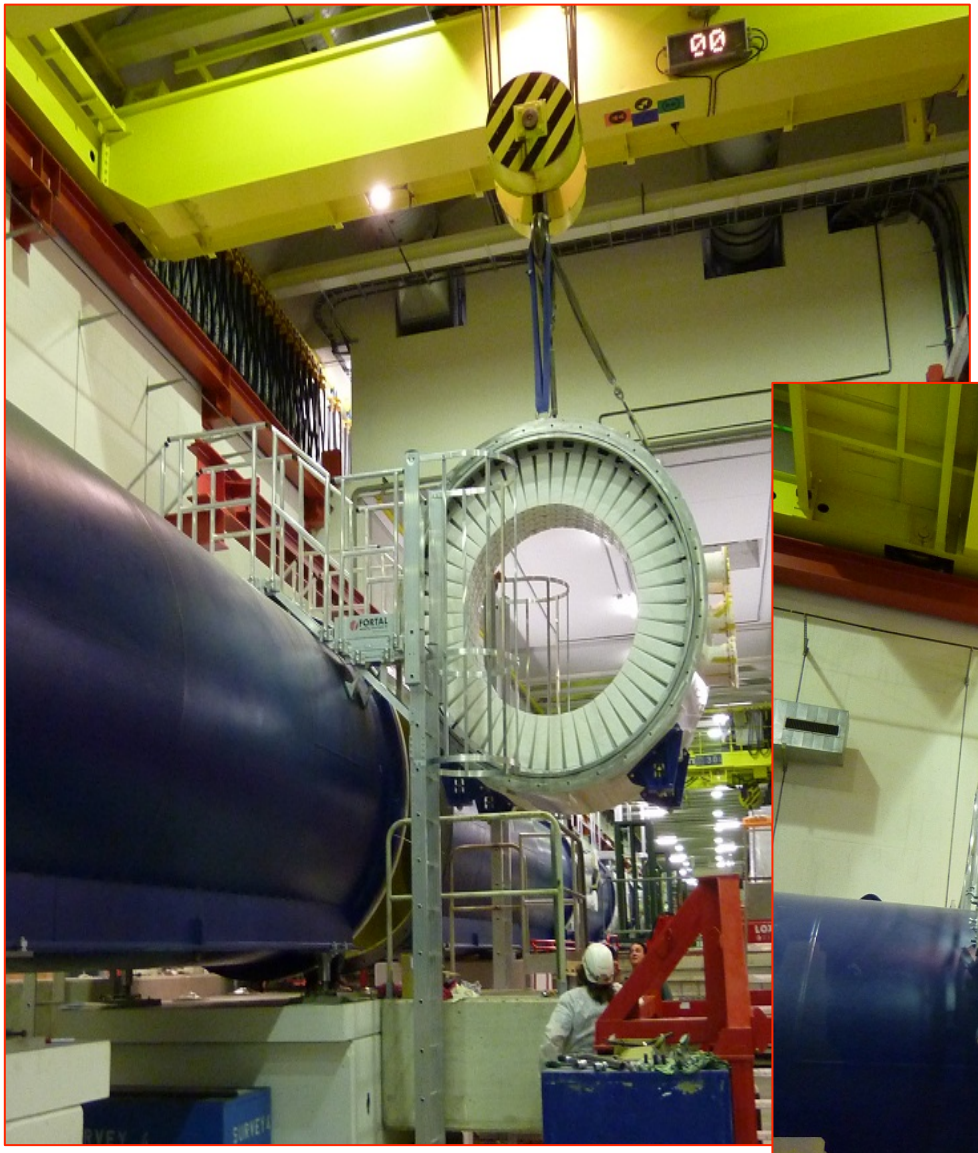
P326 MODULE ZERO

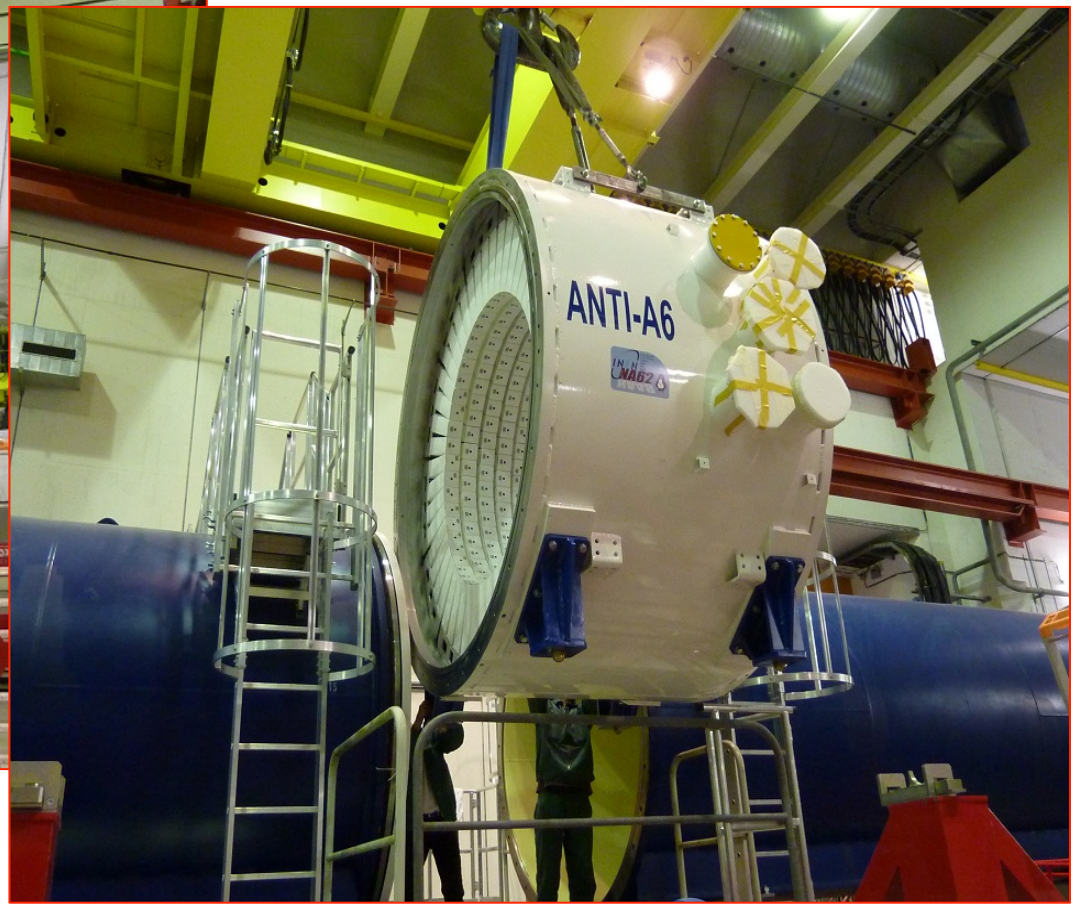


LNF-SPAS
C.Capoccia

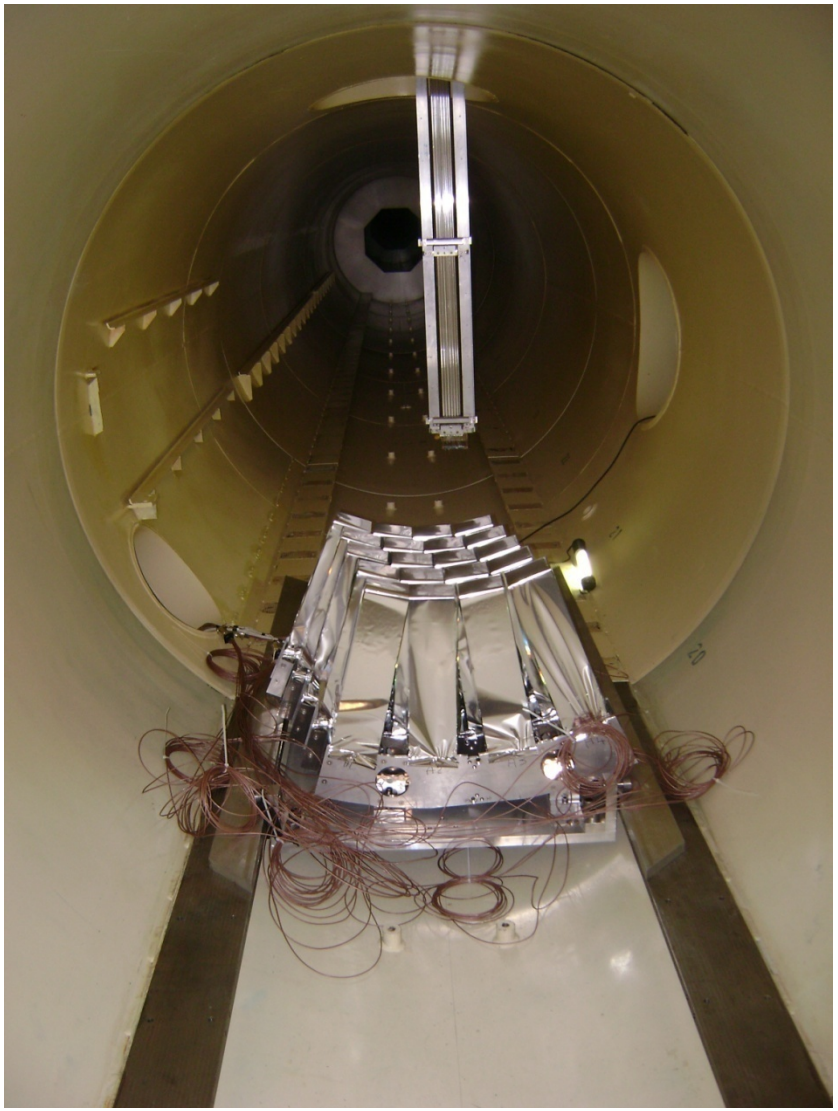
8/29/18

LAVs





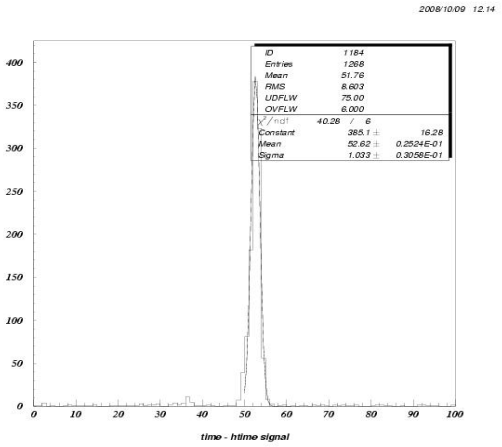
A LAV prototype tested at CERN



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

NA62: MUV3 Proposal

PROPOSAL FOR A MUON VETO SYSTEM BEHIND THE HADRONIC CALORIMETER (MUV-3)

I. Mannelli, C. Biino, L. DiLella, N. Doble, R. Fantechi, F. Marchetto, V. Obraztsov
HAC-MUV Working Group
23 March 2010

Italo's textbook example of how to make use of an old detector To make a new one

Problems and requirements:

- Expected total rate for 9.25 < R < 120 cm: 12.1 MHz:
  - 3.9 MHz from decays before GTK3
  - 5.7 MHz from K^+ decay
  (see presentation by S. Gallorini, TDAQ meeting, 3 February 2010)
- Level 0 trigger rate must not exceed 1 MHz
  ➡ veto all triggers associated with muons crossing MUV-3
- Random vetoing of good events must be kept as low as possible:
  ➡ MUV-3 time resolution must be as good as possible
  (random veto probability at 12.1 MHz = 1.2 % for 1 ns)
- 1 ns time resolution excludes light collection and readout using wave-length shifting fibers

Italo's magic word: "suitably"

Proposal (Italo Mannelli):

Counters consisting of a 2.5 cm thick scintillator plate facing a 2" PMT

Air light guide

Scintillator plate dimensions 15.8 x 15.8 cm^2

Distance between scintillator and PMT window 16 cm

Only direct light is collected by the PMT

Reuse as much as possible NA48 AKL hardware:

- PMTs with housing and magnetic shielding
- Constant Fraction Discriminators
- High Voltage Power Supplies and (possibly) associated slow control
- Cables (?)
- Scintillator (suitably reshaped and reassembled)

Liquid Krypton Calorimeter

- …We all know that Italo played a fundamental role building the NA48 liquid krypton calorimeter…**but in addition he still is its ultimate expert**…
- …In October 2016 during the NA62 data taking, once finally everything else worked…the LKr started sparking apparently without reason…
- We had no idea…after a sleepless night we asked Italo. He suggested the unthinkable: what about a leak so that the level of the liquid in the cryostat is so low that the top of the electrodes are left un HV in Kr gas?
- **As always….he was right!**
- Some Lkr was still available to top-up and more LKr has been bought since

New CHOD

- The issue of provide a uniform time reference at the Level 0 trigger was solved by Italo devising and building a tile plastic scintillator hodoscope.
- Contrary to MUV3, PMTs could not stay in the acceptance because they would disturb the photon rejection….
- ….So he worked out a new detector with wave length shifting fibres bringing the light outside of the acceptance where it is amplified by SiPMs

- **When Italo proposes "Preliminary Construction Ideas", it means that he has already worked out every detail from A to Z, including the dimensions of each element, how many elements should be built and how should they be built, the precise geometry, how to install the detector and which electronics to use**
- **All the necessary simulations are done by Italo himself and/or his "team"**
- **The detector will satisfy all the specifications. In fact the specifications will be defined by Italo himself because they are most likely missing**…

NEWCHOD

Preliminary construction ideas

I.M.

03/06/2013

Basic considerations:

- Ideally the NEWCHOD should be “ thin ” and be contained in a light tight box, occupying a limited longitudinal space.

  It should be built with plastic scintillator TILES of dimensions, dependent on the position relative to the beam, such that the maximum rate of particle crossing is < 500KHz in any tile with time resolution better than 1ns

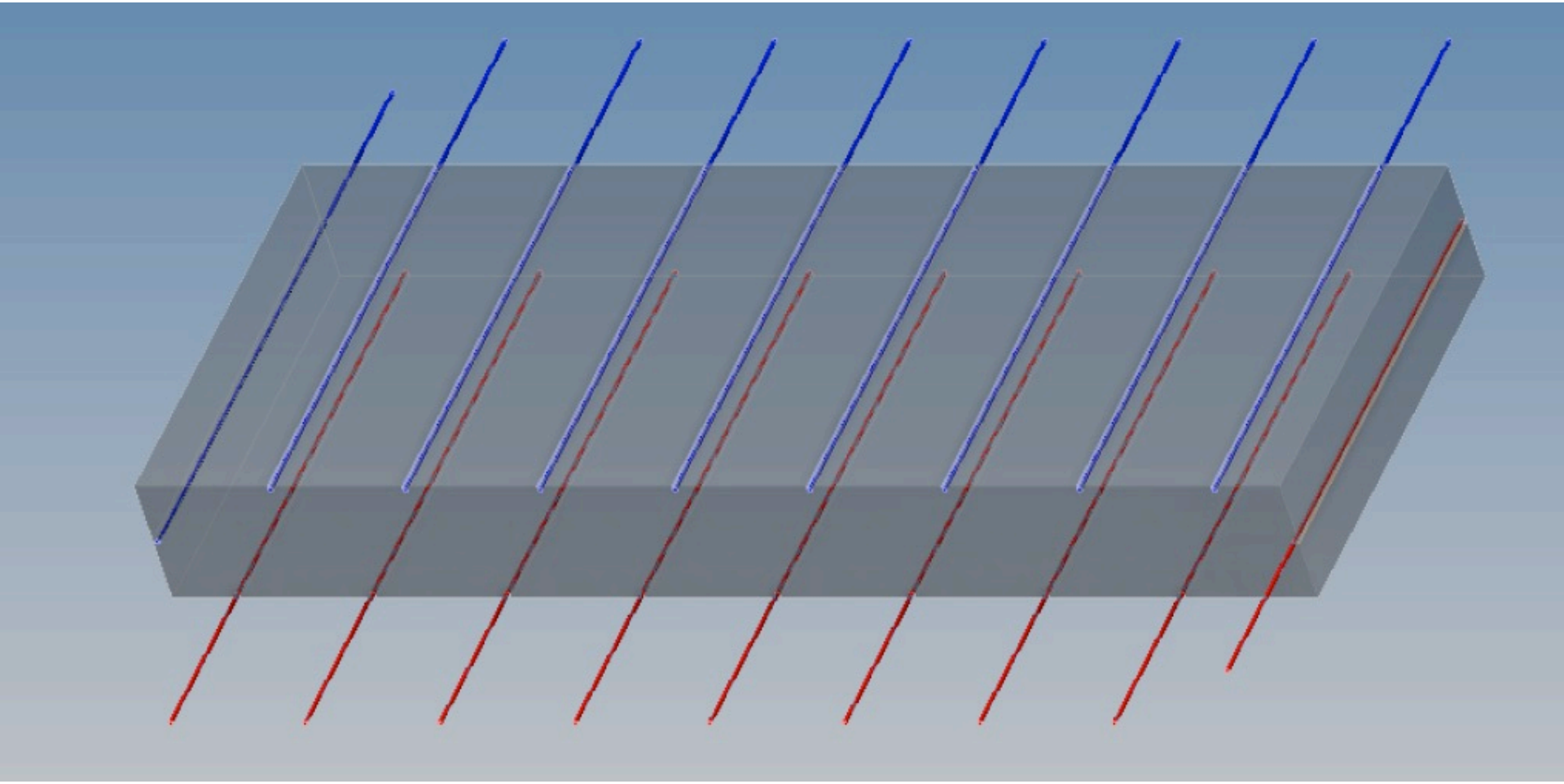
Thw size of each element is defined with millimetric precision

- As an example I have chosen the basic TILE with dimensions:

  Height = 1070/10 = 107mm

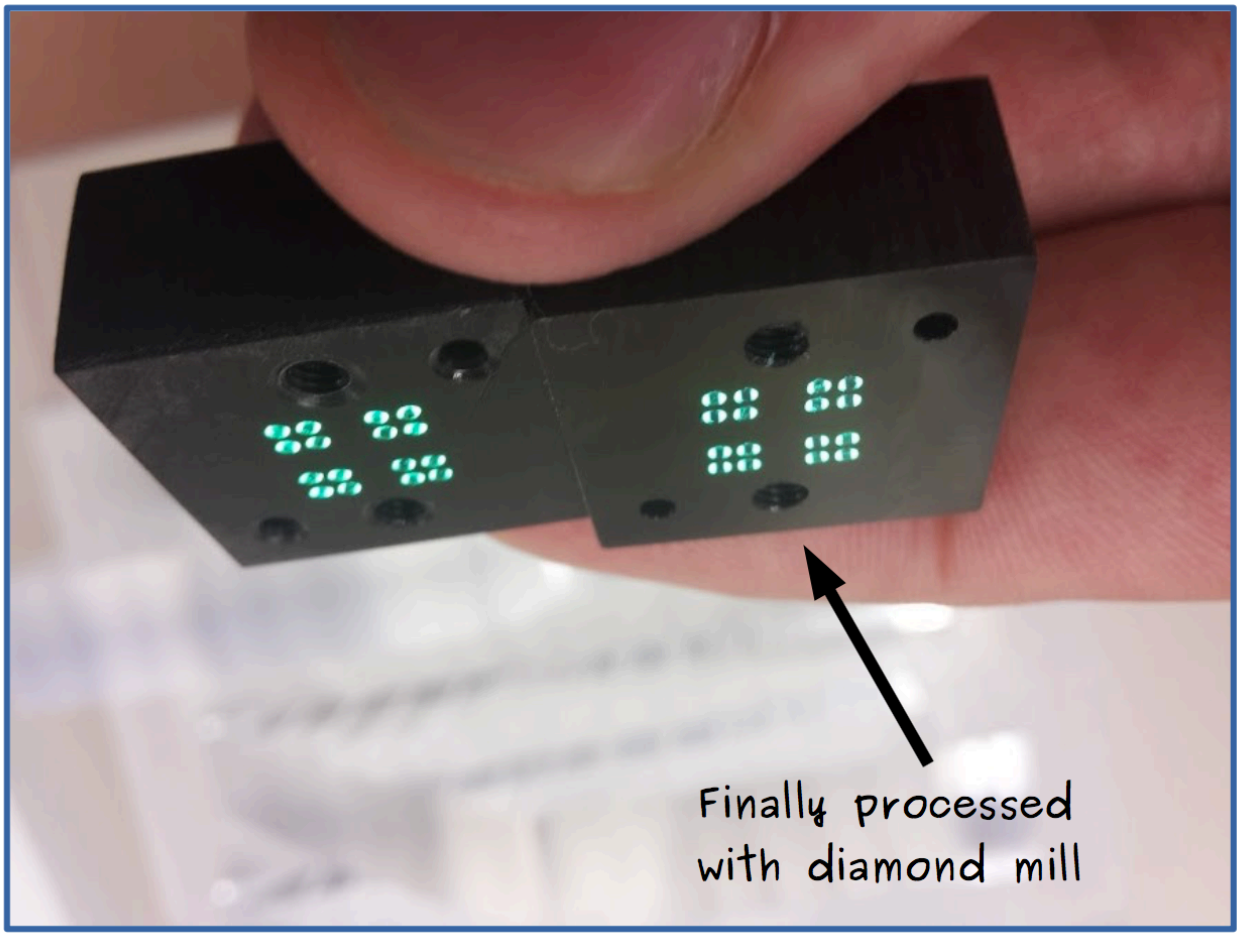
  Width = 1070/4 = 265mm

- With this choice 37x4 = 148 tiles are needed (with 2 SiPM or PM each, 296 electronic channels) of which 40 of half size



CHOD: Tiles & WLS Fibres

CHOD: fibres connectors

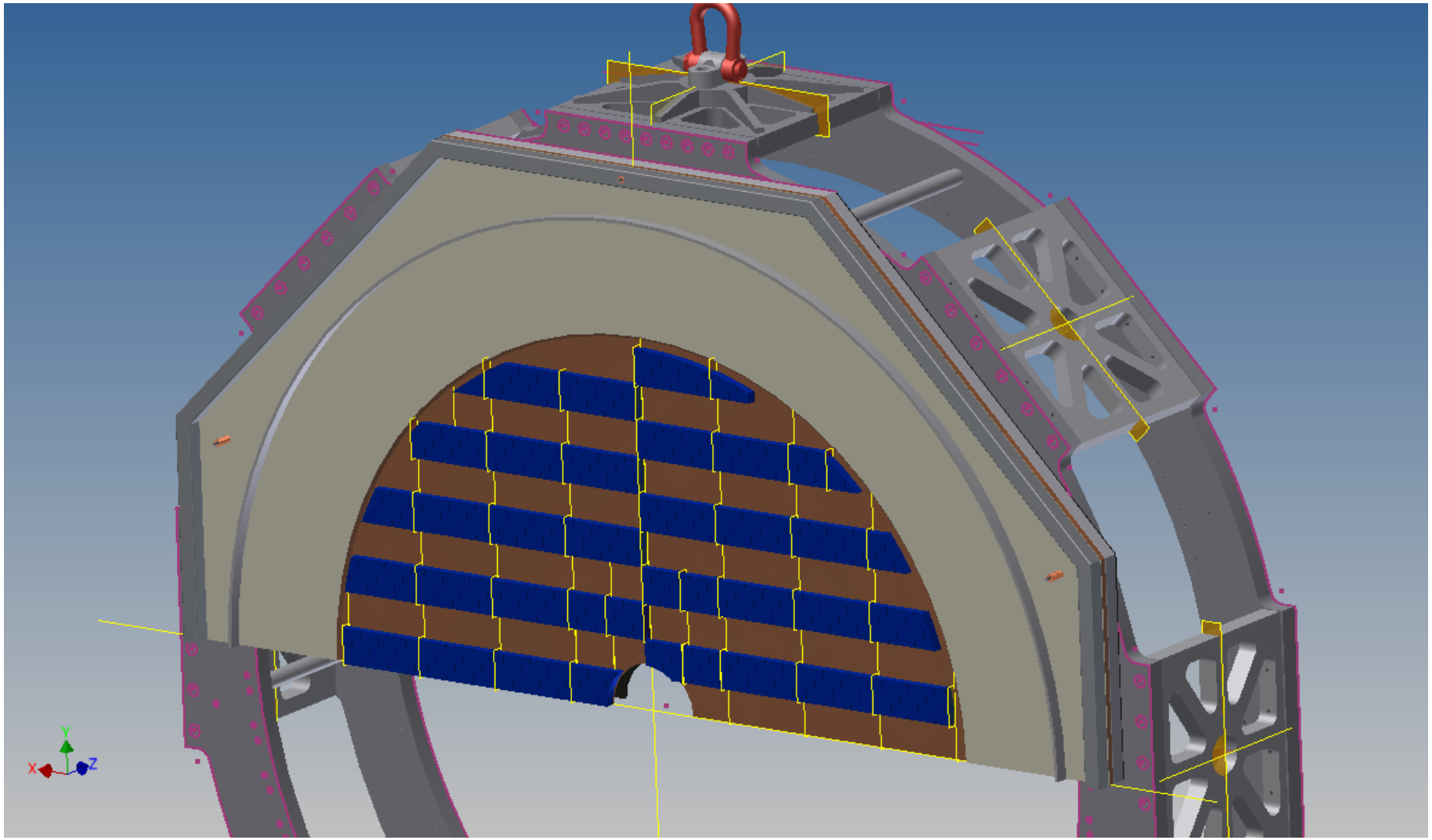


How to install CHOD in Italo's words

- The NEWCHOD should be divided in two halves horizonthally, which could be placed in position by sliding them from the JURA side and then fixed to the front of LAV12 .

  The structure supporting the tiles will be attached to a 50x50mm2 Al frame on both front and back side.

You can recognize Italo's trademark octagonal shape



All Details worked out…

- The maximum rate in the small tiles is 404 KHz EXCEPT for 8 tiles sorrounding the beam with rates up to 537 KHz.
  If necessary, these 8 tiles could be split vertically in two, thus halving the rate.
  The total number of electronic channels would be 296 +16 = 312.

NA62 CHOD: Rates

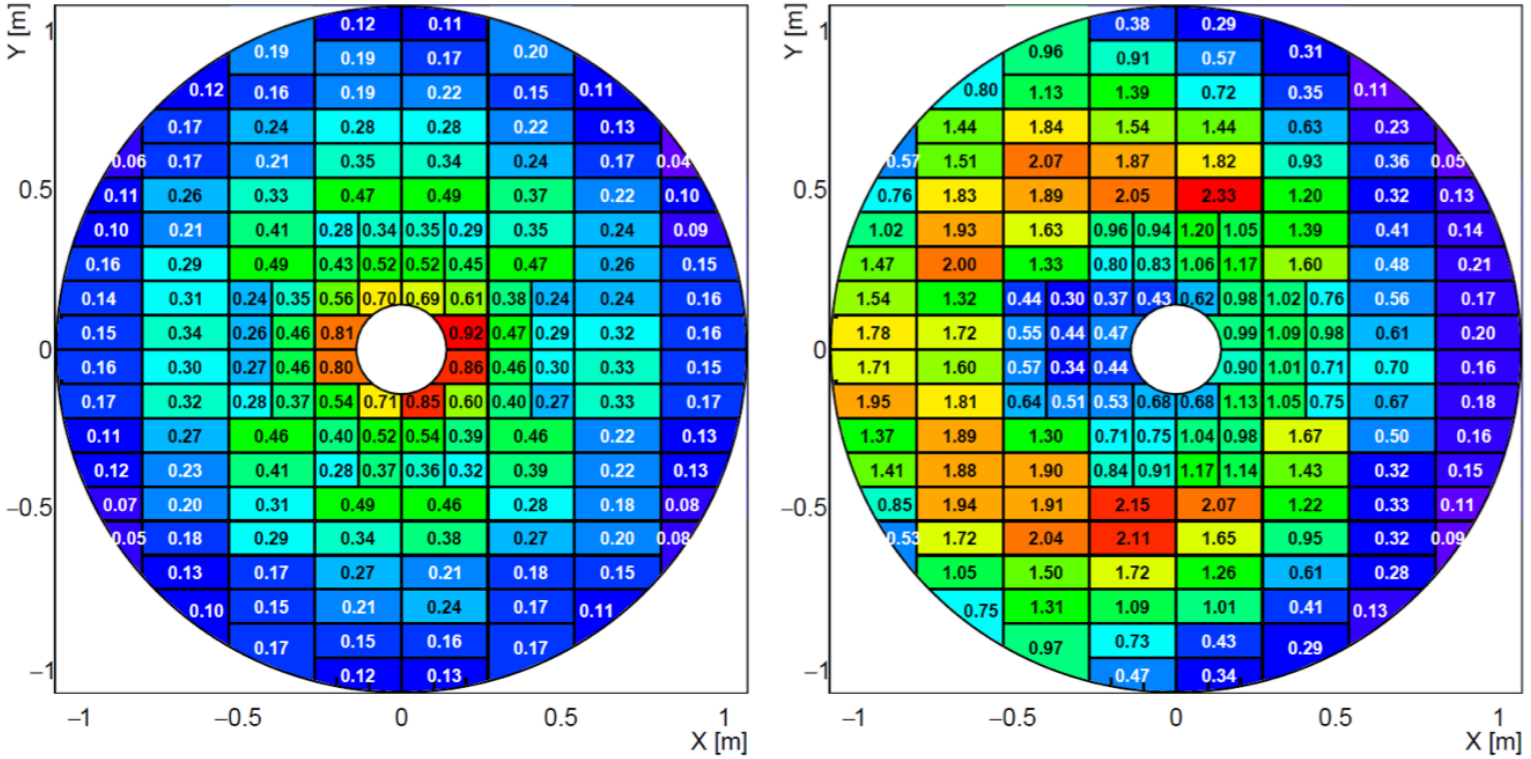


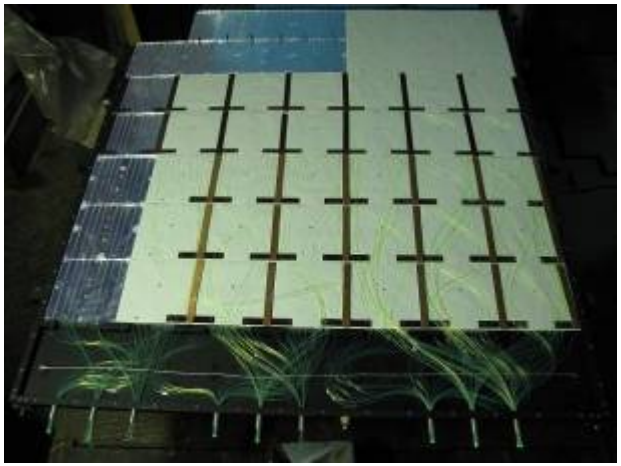
Figure 49. Left: expected rates in CHOD tiles at nominal beam intensity (in MHz). Right: probability of detecting a signal in each CHOD tile for $K^+ \to \pi^+ \nu\bar{\nu}$ decays satisfying the signal selection conditions 105 m $< Z_{\text{vertex}} <$ 165 m and 15 GeV/c $< p_\pi <$ 35 GeV/c in each tile (in percent). Both are calculated with MC simulations.

NA62 CHOD (a.k.a. NewCHOD)

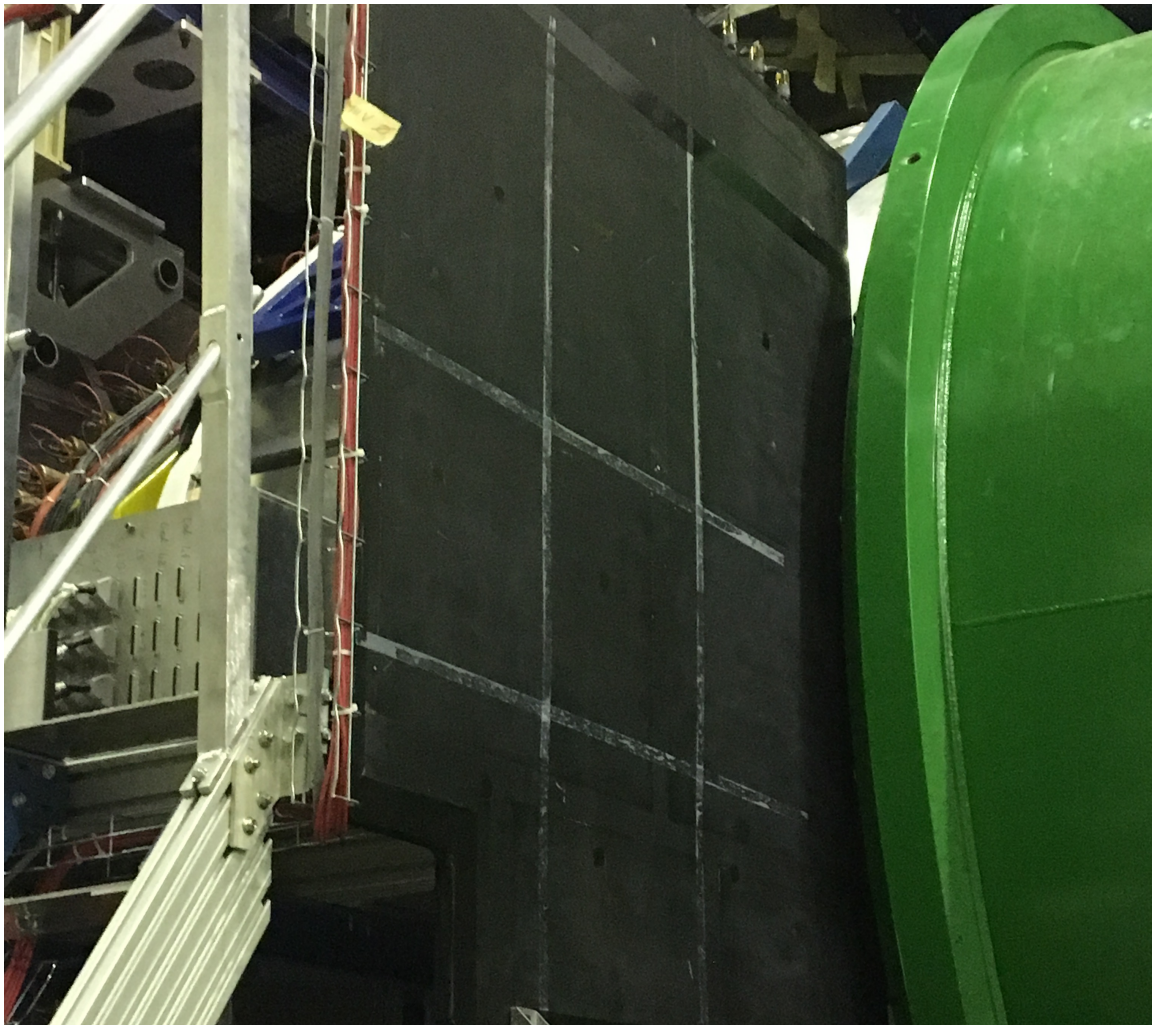
MUV0: CHOD By-product

- To catch some tricky pion decays going outside the acceptance, Giuseppe Ruggiero proposed a Muon Veto extension (MUV0)
- …But we had no detector to install
- So, to make Giuseppe happy, Italo took an old CHOD prototype built in Protvino, retrofitted it and installed at the experiment as MUV0

The first CHOD Prototype from INR/Protvino carefully inspected by Italo

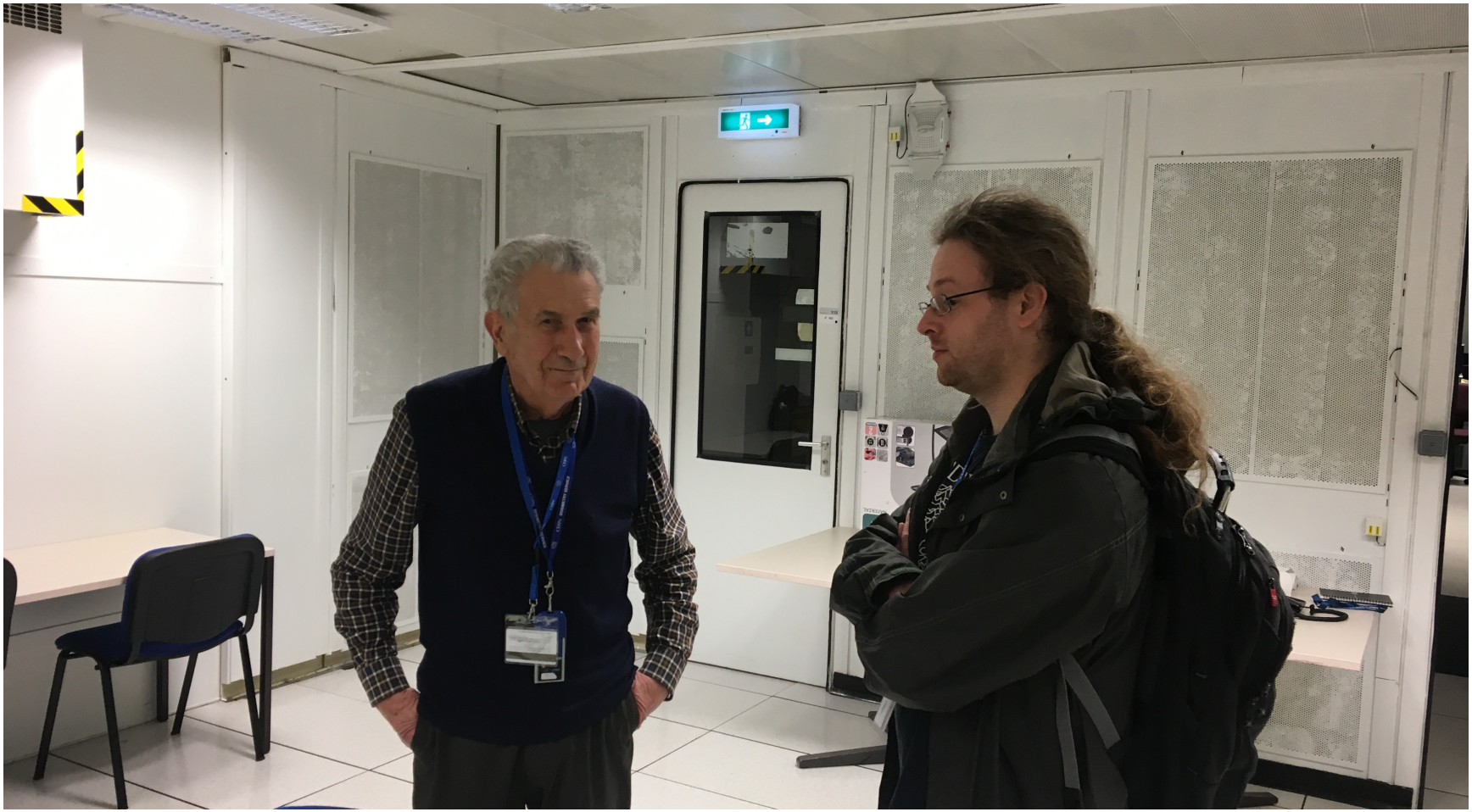


MUV0



Italo advising the NA62 Technical Co-ordinator Hans Danielsson

Italo discussing Lattice QCD with Antonin Portelli



Outlook

- **In 2003 we gathered here in Pisa to celebrate Italo's 70th birthday**
- We had preliminary ideas on how to measure $K^+ \rightarrow \pi^+\nu\nu$ at the SPS (NA48/3)
- Italo believed in the project, he made fundamental contributions, left no stone uncovered looking for potential bugs (I mention the beam pipe geometry just to make an example)
- He designed and built essential detectors
- **We are back in Pisa to celebrate Italo's 85th anniversary: NA48/3 became NA62 and it is steadily taking data**…
- Italo will remain as busy as always making essential contribution to the analysis of the plenty NA62 data and to the design and construction of future detectors/experiments…
- **Congratulations Italo: we all look forward to 2033!**