PSD10: 10th International Conference on Position Sensitive Detectors
(7^{th} - 12^{th} September 2014)

The Kaon Identification System in the NA62 experiment at CERN SPS

UNIVERSITY OF LIVERPOOL

On behalf of the NA62 Collaboration
Bozydar Wrona

NA62 Collaboration meeting in Liverpool
(August 2013)

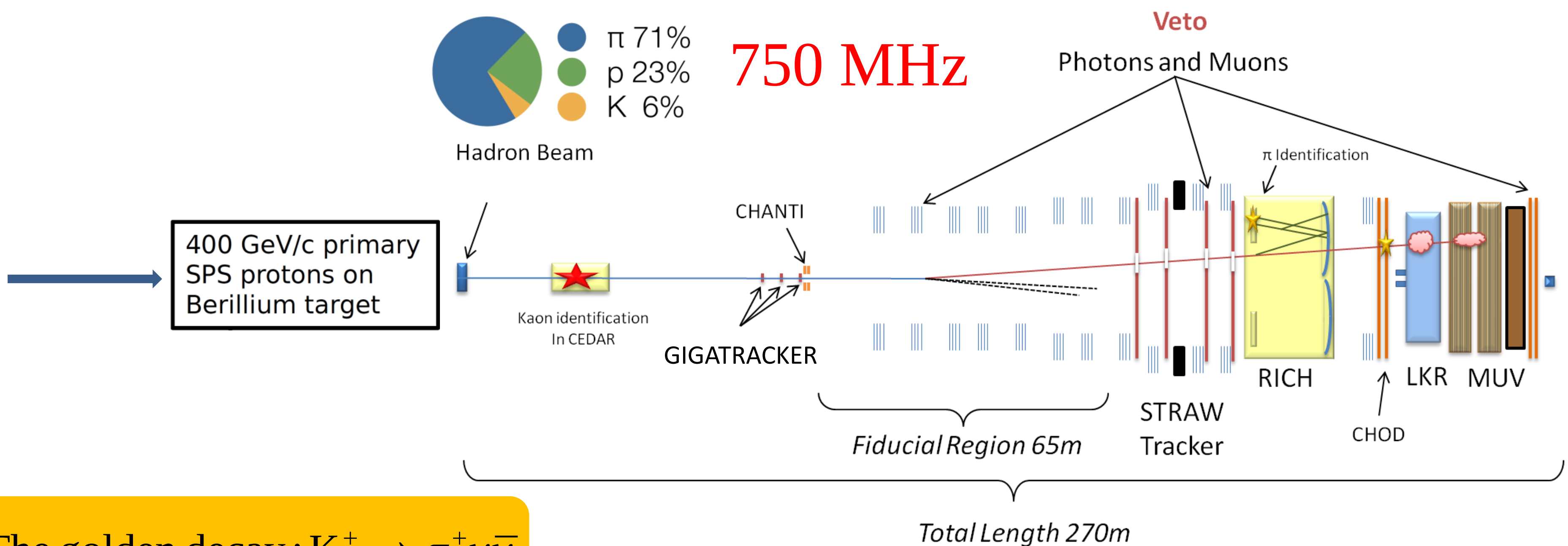
**Photo courtesy of Steve Barrett*

- NA62 today (North Area at CERN SPS)

~ 200 participants 28 institutions >10 countries

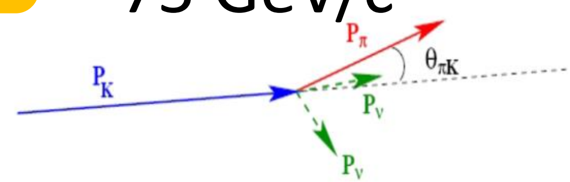
Birmingham, Bratislava, Boston, **Bristol**, Bucharest, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, **Glasgow**, IHEP Protvino, INR Moscow, **Liverpool**, Louvain-la-Neuve, Mainz, Merced, Naples, Perugia, Pisa, Prague, Rome I, Rome II, San Luis Potosí, SLAC, Sofia, Turin

NA62 Detector and Physics Interest



The golden decay : $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

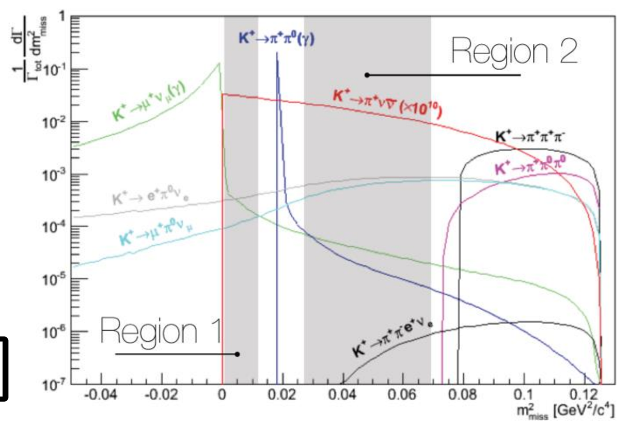
75 GeV/c



BR_{SM} ~7.8 x 10^{-11}

- NA62 goal:

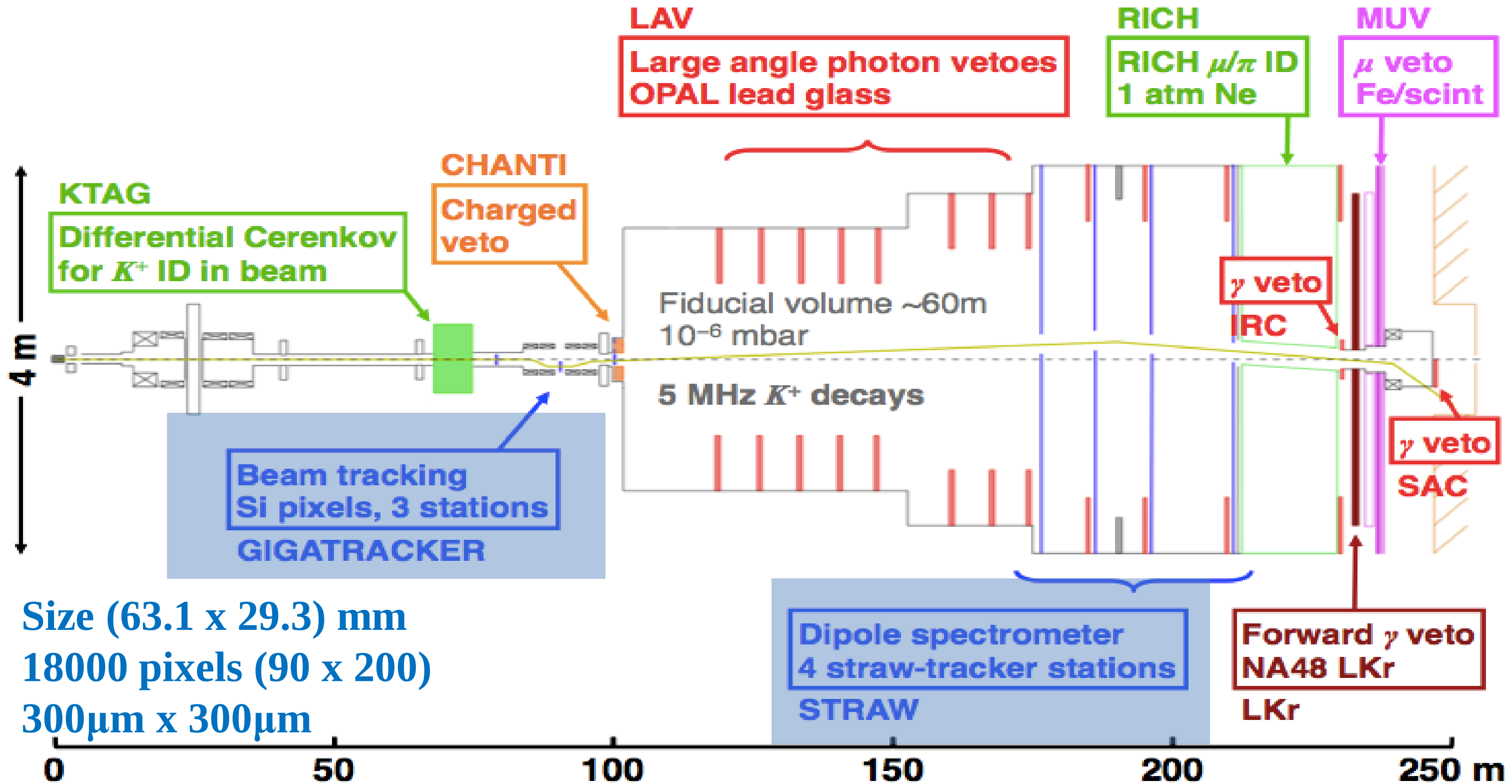
~10^{13} K^+ decays ~ 100 signal events S/B ~10



92% of total **BR(K^+)** rejected kinematically

8% relies on **vetoes, PID**.

NA62 Detector - Trackers



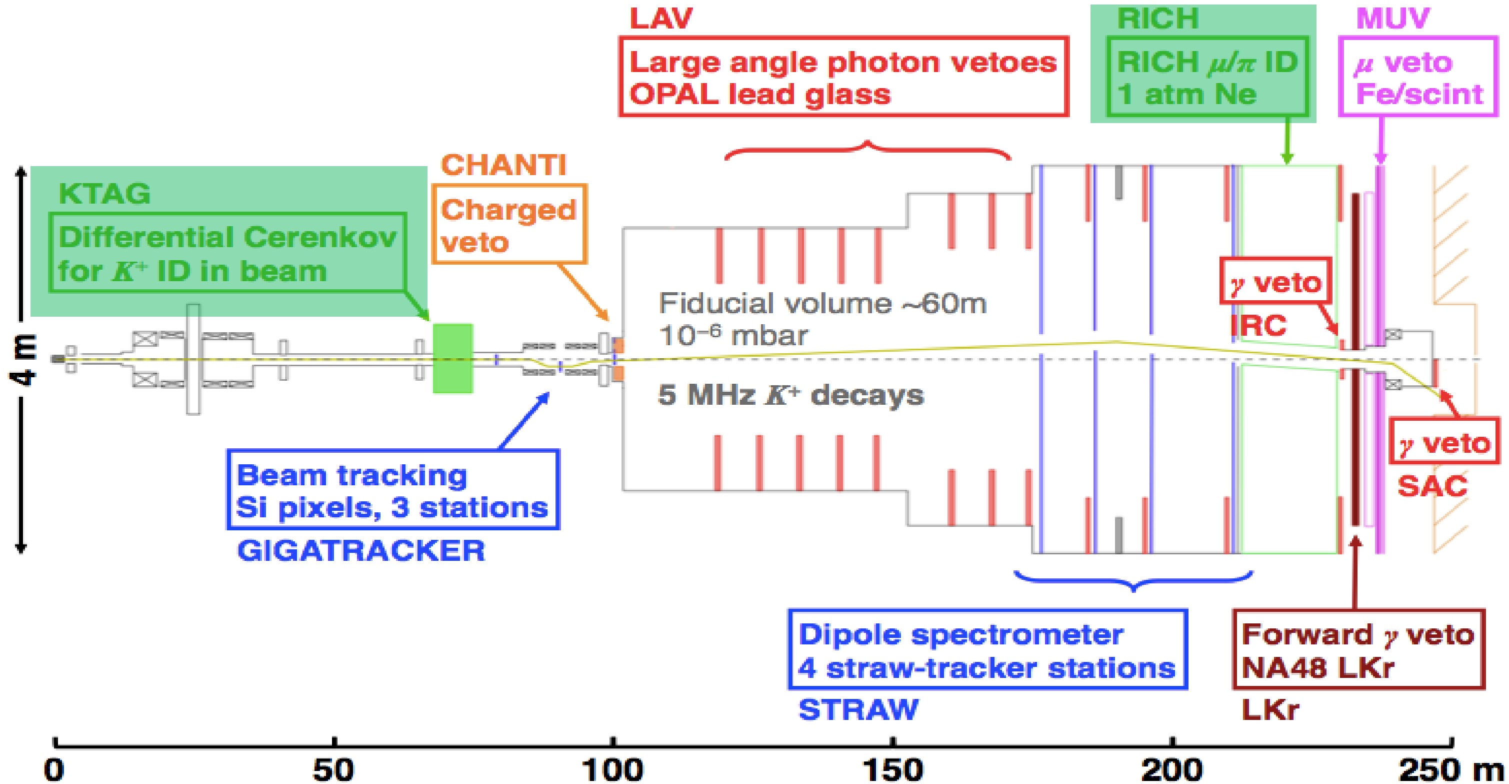
Size (63.1 x 29.3) mm
18000 pixels (90 x 200)
300µm x 300µm

Track reconstruction :

P_K (GIGATRACKER) $\sigma(P_K)/P_K \sim 0.2\%$, $\sigma_{\theta} = 16\mu rad$

P_π (STRAW) $\sigma(P_\pi)/P_\pi < 0.32\%$, $\sigma_{K\pi} = 20 - 50\mu rad$

NA62 Detector - PID

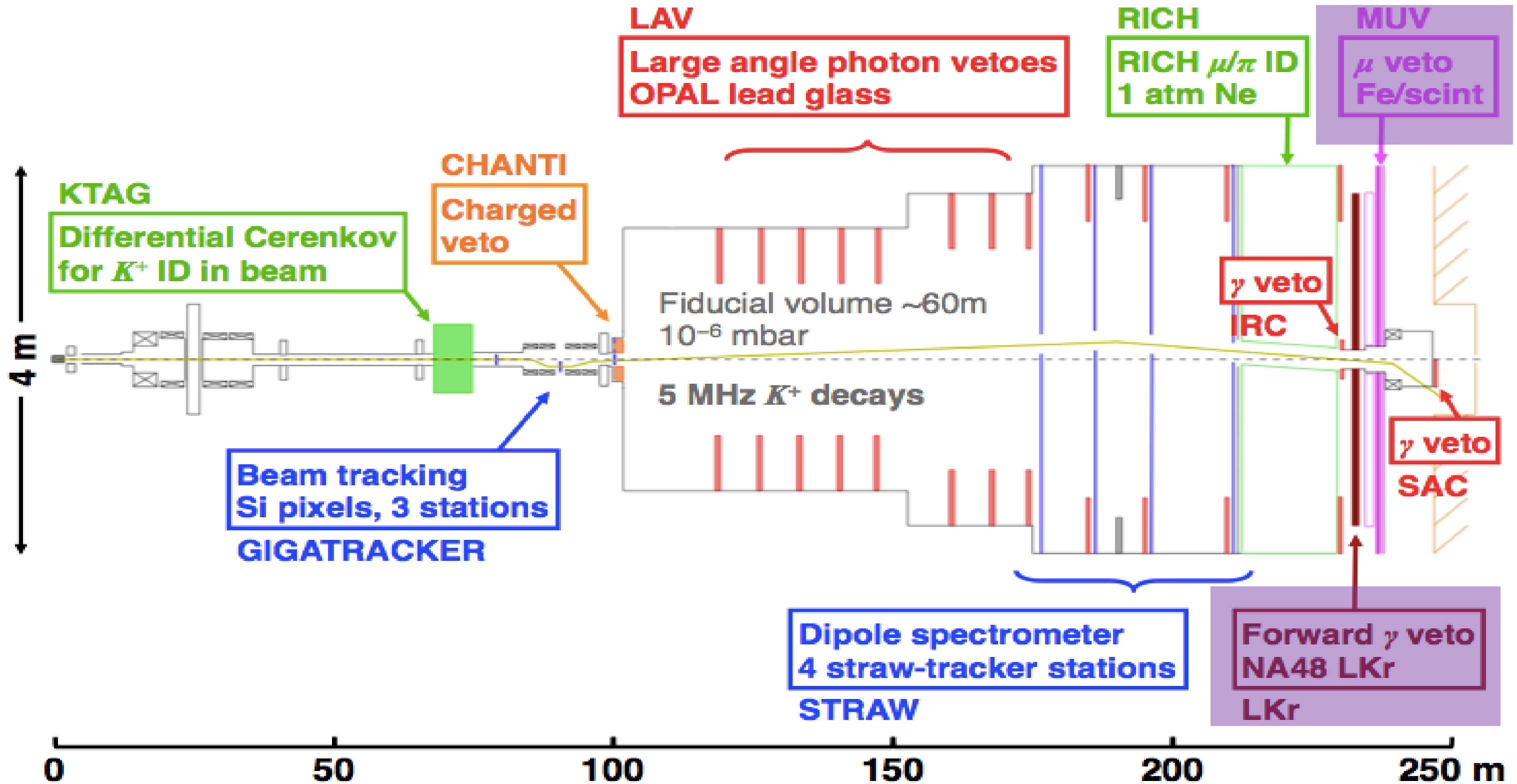


Background suppression :

PID K/π/p for bkg coming from accidental tracks (KTAG)

PID π/μ for main bkg (BR~64%) K→μν (RICH)

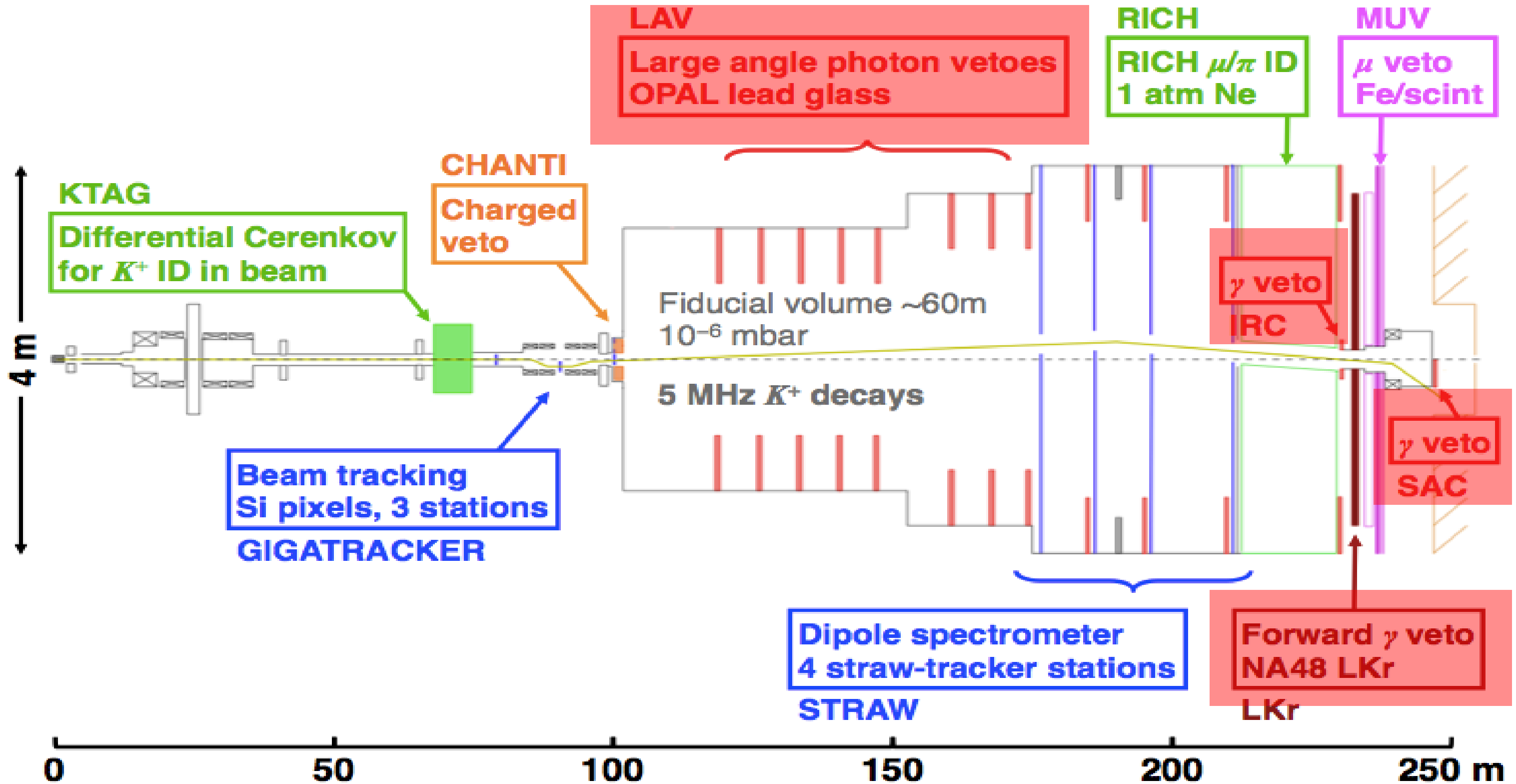
NA62 Detector - Veto



Background suppression :

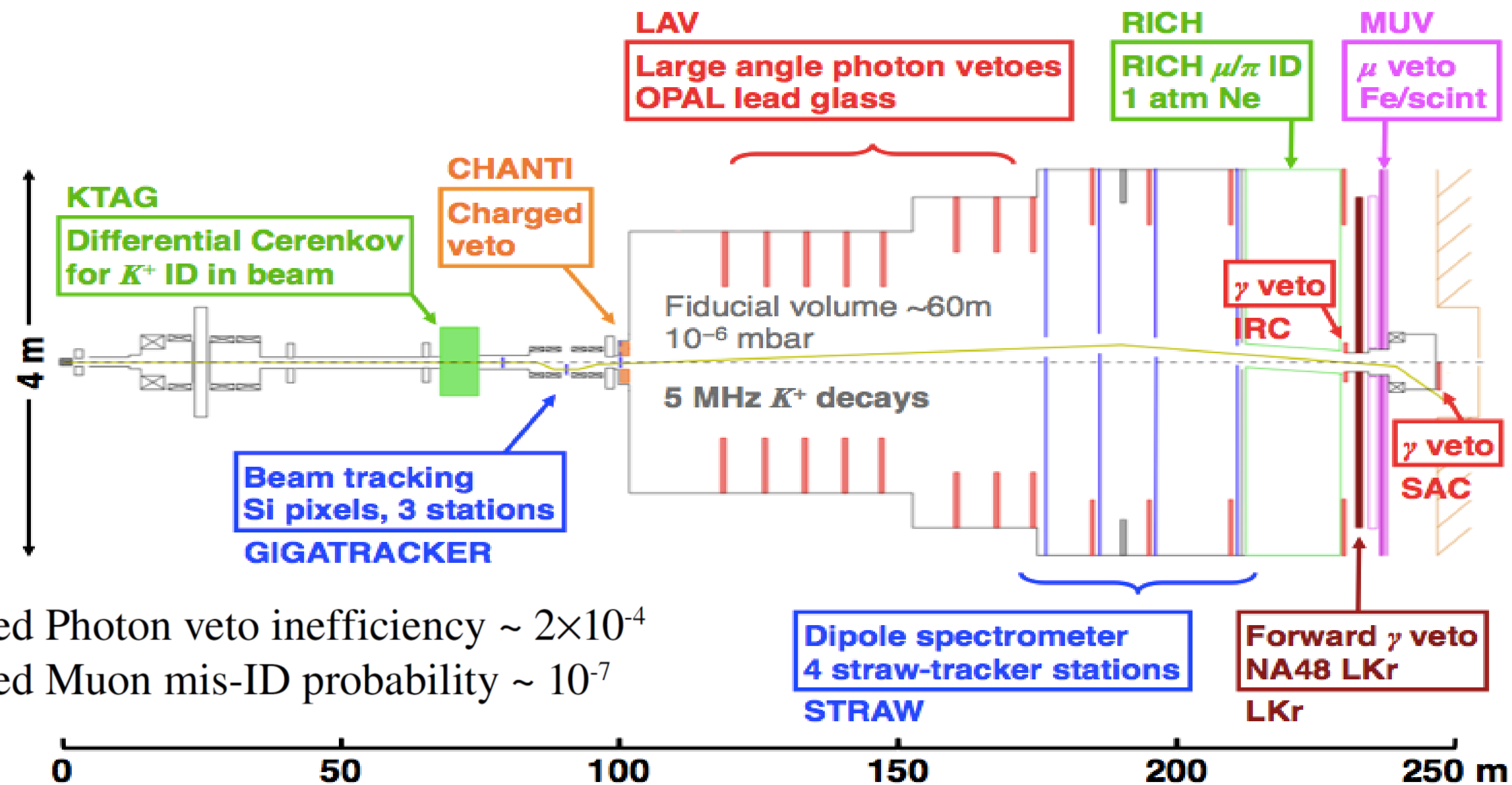
μ/e separation for bkg with leptons in final state (LKr, MUV)

NA62 Detector- Veto



Background suppression :
Photon rejection for bkg with γs in final state (LAV, IRC, SAC, LKr)

K→πνν Selection



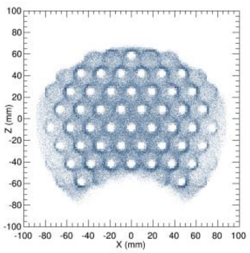
Required Photon veto inefficiency ~ 2×10^{-4}

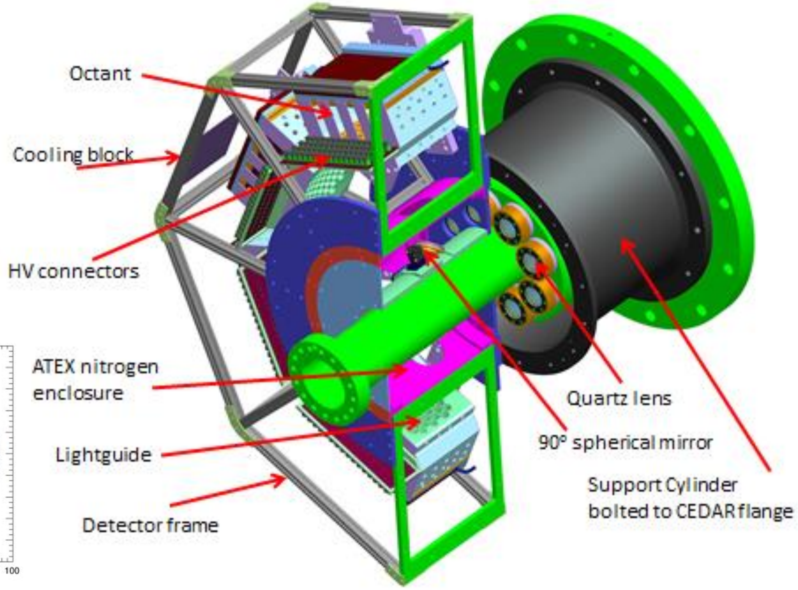
Required Muon mis-ID probability ~ 10^{-7}

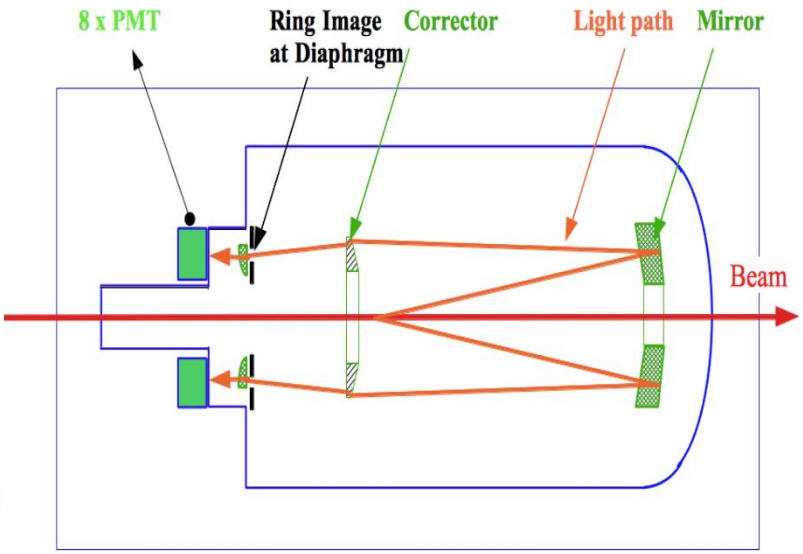
Event Reconstruction :

- ✓ **single π^+ in final state (RICH, LKr, MUV),**
- ✓ **K^+ - π^+ time association (KTAG, GTK, STRAW, RICH),**
- ✓ **No γs (LAV, IRC, SAC), z_{vtx} in 60m fiducial volume**
- ✓ **m^2_{miss} reconstruction for signal definition, Region1 + Region2**

KTAG upgrade for CEренkov Differential counter with Achromatic Ring focus







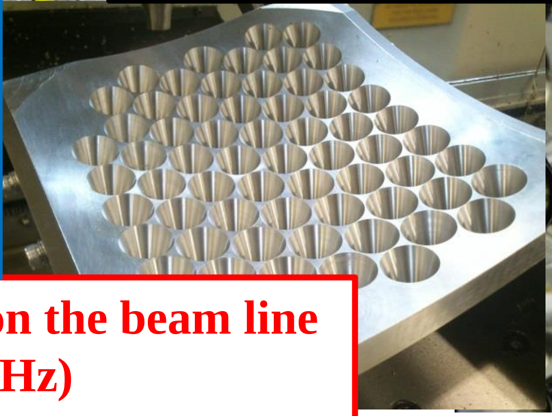
- NA62 is re-using the West CEDAR filled with H_2 or N_2 (used before for SPS secondary beam diagnostics)
- High beam flux 750 MHz requires original 8 PMTs to be replaced with 384 faster photo-detectors i.e. 48 PMTs /octant for 2014
- New external optics, front end and readout
- A high-intensity muon halo, accompanied by low-energy neutrons, surrounds the beam, a radius of 20 – 50 cm minimises background.
- Design locates the photo-detectors at a radius of 35 cm and associated electronics within an envelope of radius 50 cm.

KTAG Characteristics

KTAG working conditions
- Kaon Rate (average) **~ 45 MHz**
- Light Yield (@ Quartz Windows) ~ 200 photons/Kaon
- Rate of detected photon on single PMT ~ 4 MHz

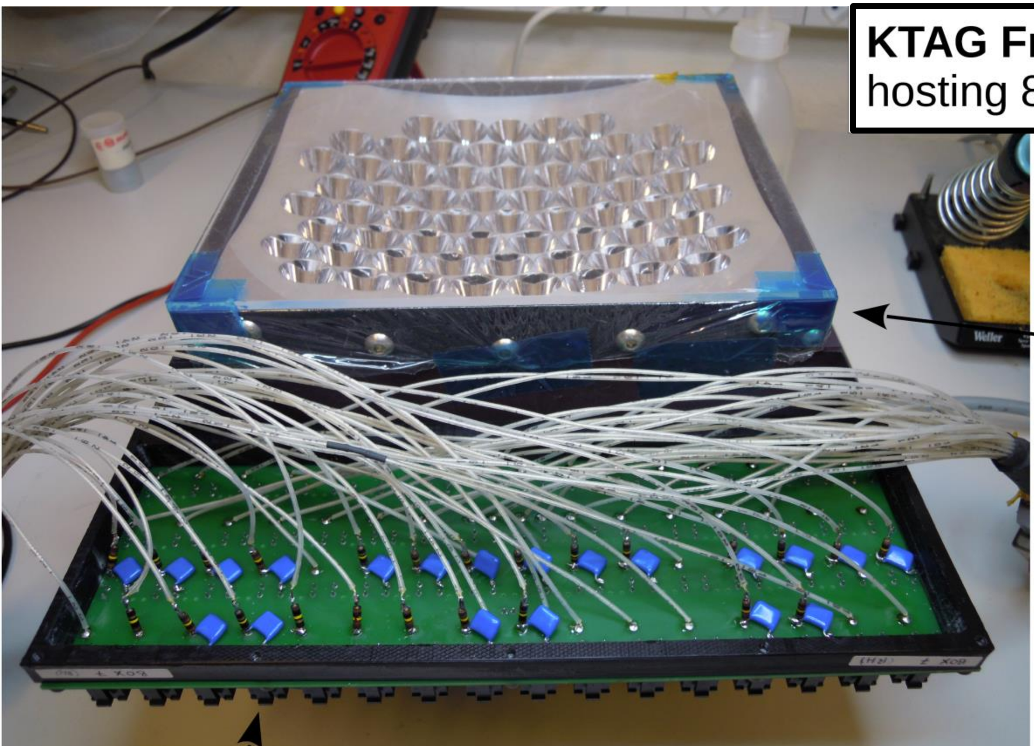
KTAG characteristics:
- 8 light boxes with **48 R9880-110** PMTs each
- KTAG enclosure flushed with dry Nitrogen gas
- Water-cooling system for electronics

KTAG design Objectives
- Kaon Tagging resolution $\sigma_t \sim 100$ps
- Kaon Tagging efficiency > 95%
- Pion Mis-ID probability < 0.001



K ID to suppress the bkg from accidentals on the beam line
Essential to time match P_K (GTK @~750 MHz)
with π (RICH) and P_π (STRAW) @~10MHz

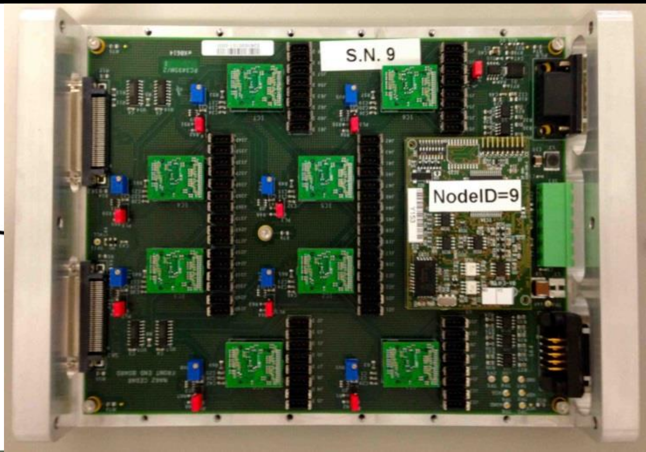
KTAG Electronics



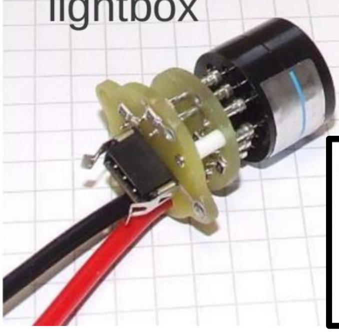
KTAG Front End Board: 64 channels mother board hosting 8 NINO ultra-fast amplifiers/discriminators

1 board inside

each lightbox



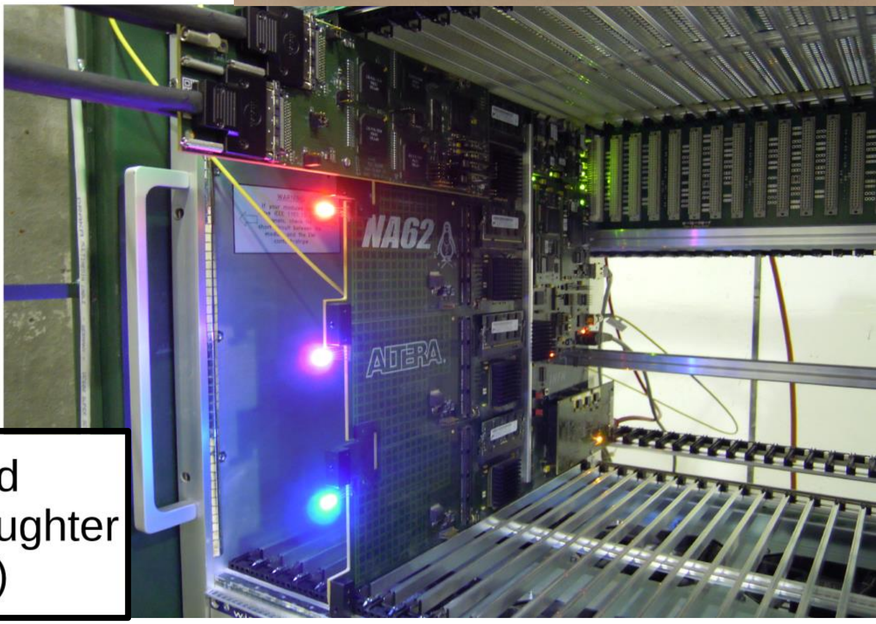
48 PMTs in each lightbox



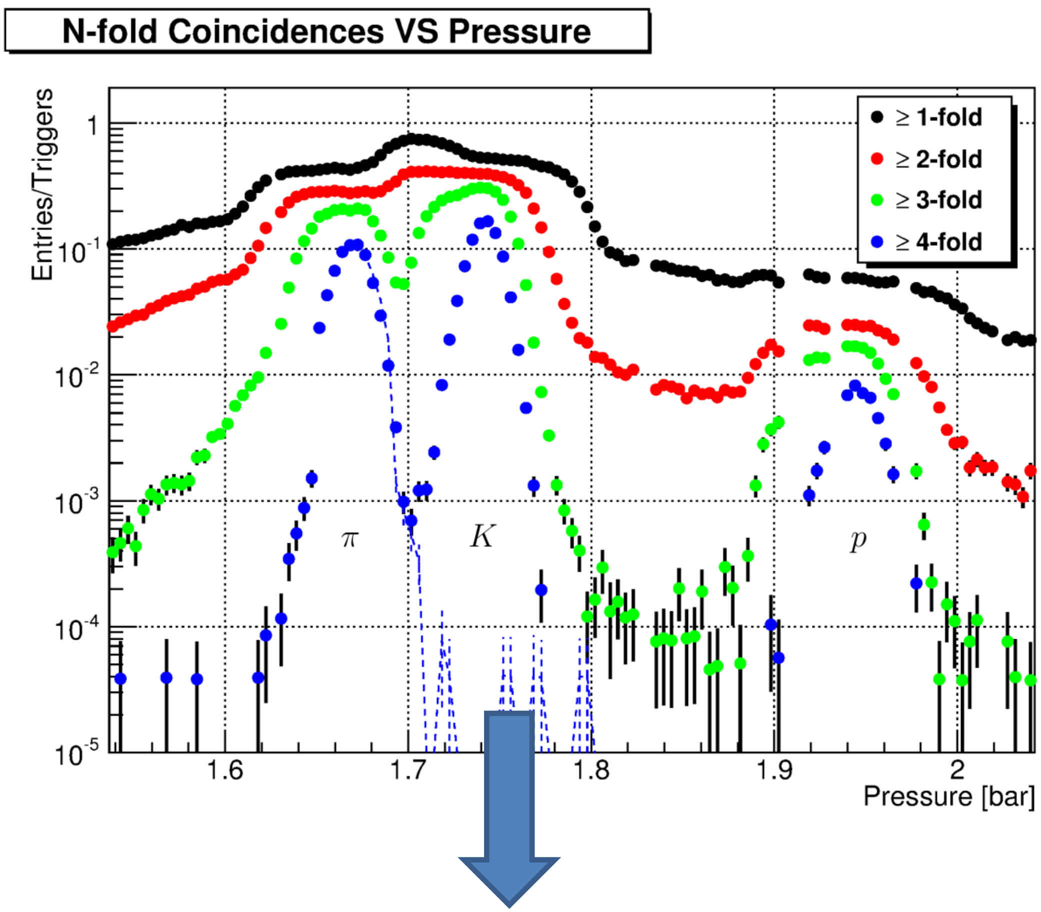
PMT (Hamamatsu R9880-110) with customised socket:

- Differential Output
- Lower power dissipation

TEL62 Board: Integrated trigger and data acquisition board, hosting 4 daughter HPTDC boards (128 channels each)



KTAG ID Results (TR2012)



Technical Run 2012 setup
CEDAR: vessel radiator Nitrogen (instead of H_2)
KTAG: 32 PMTs/4 Octants (instead of 48/8) i.e less than half of the detector instrumented

Pressure scan performed in order to tune CEDAR pressure to the value maximising Kaon ID efficiency.
Beam components **π/K/p** resolved, evaluated for 1,2,3 and above 4-fold coincidences
Kaon pressure from Gaussian fit to 4-fold spectrum 1.742 [bar]

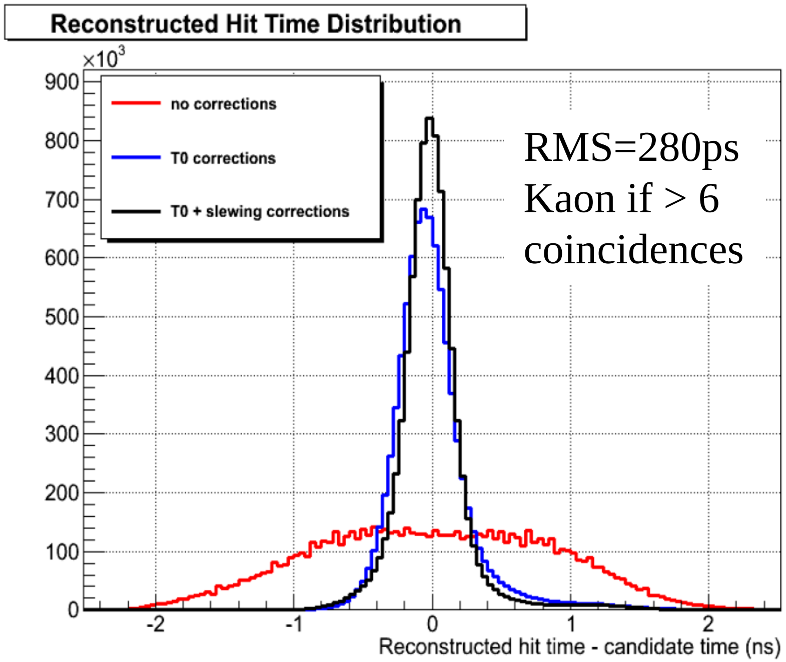
Pion Mis-ID probability estimated from the extrapolated contamination of **π** in **K** **~10^{-4} meet the NA62 requirement despite ~30% detector PMTs**

KTAG Time Resolution (TR2012)

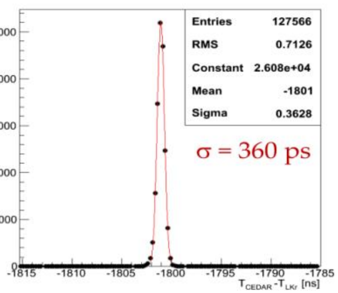
Single PMT time resolution
RMS = ~280ps measured w.r.t. averaged Kaon time (T0)

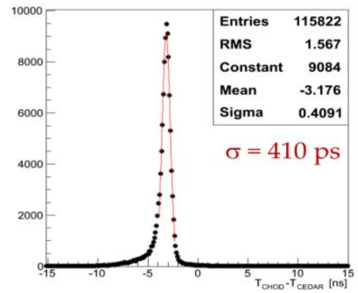
Full KTAG t.r. is RMS/$\sqrt{7}$ assuming 7 PMTs/Kaon on average firing, leads to **σ_t~100 ps** for the KTAG time resolution

Timing correlation between **KTAG and downstream detectors** measured w.r.t. the trigger (jitter the same for all the detectors)



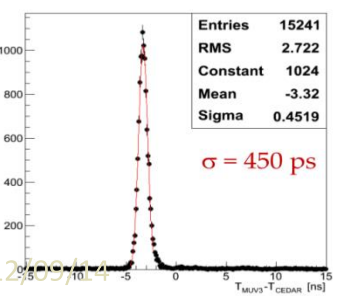
T_{KTAG} - T_{LKr}

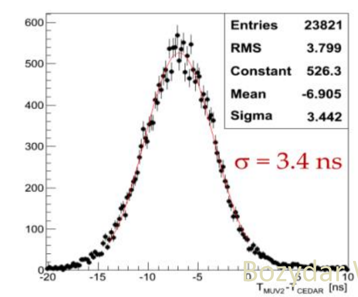




T_{CHOD} - T_{KTAG}

T_{MUV3} - T_{KTAG}



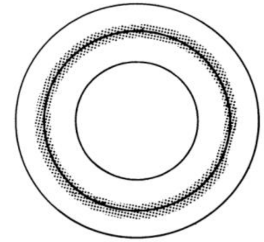


T_{MUV2} - T_{KTAG}

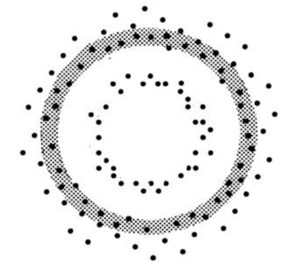
KTAG is efficient detector. Timestamp meets design objectives with 1/2 detector equipped!!

KTAG/CEDAR Alignment Challenge

- CEDAR vessel optical axis alignment w.r.t. the beam direction prerequisite for any measurement i.e. KTAG/CEDAR **not a position sensitive detector but sensitive to the relative position!!**
- Photon distributions from different beam components will mix in the plane of diaphragm i.e. detrimental for K ID
- Current optics more complex makes alignment challenging
- Particles with diferent directions emit non-concentric light rings. i.e. a beam divergence of 80 μrad increases the ring by **~0.26mm**
- Multiple scattering accounts for **~0.05mm**
- Chromatic dispersion in the radiator if not effectively corrected by the optics (e.g running with hydrogen) smears the Kaon/Pion , forces narrower diaphragm aperture (light losses), **~0.13mm**
- **Tot 0.3mm broadening, diaphragm of 1.5mm collects 99% Cherenkov from K(N_2)**

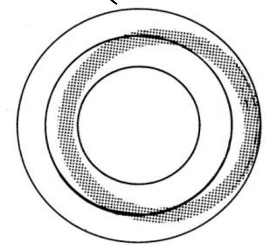


a) Good alignment

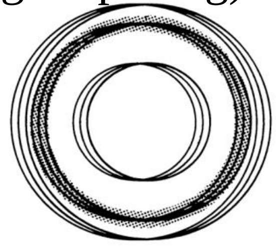


b) Broadening of the light spot due to multiple scattering incurred by the particle along the radiator

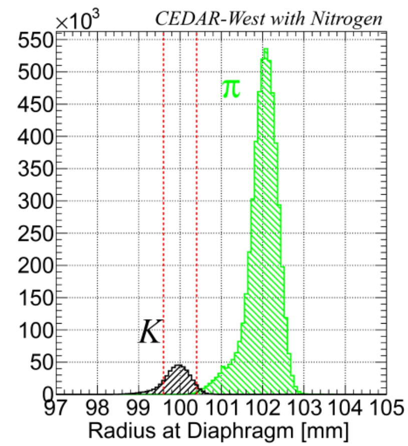
(shaded is the diaphragm opening)

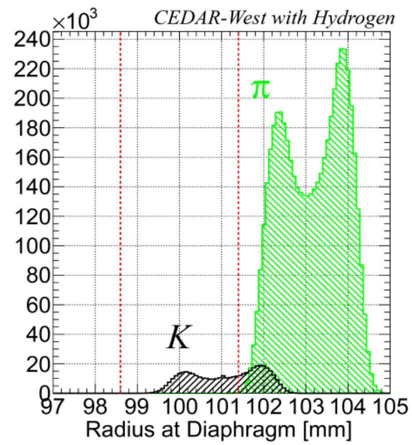


c) Misalignment

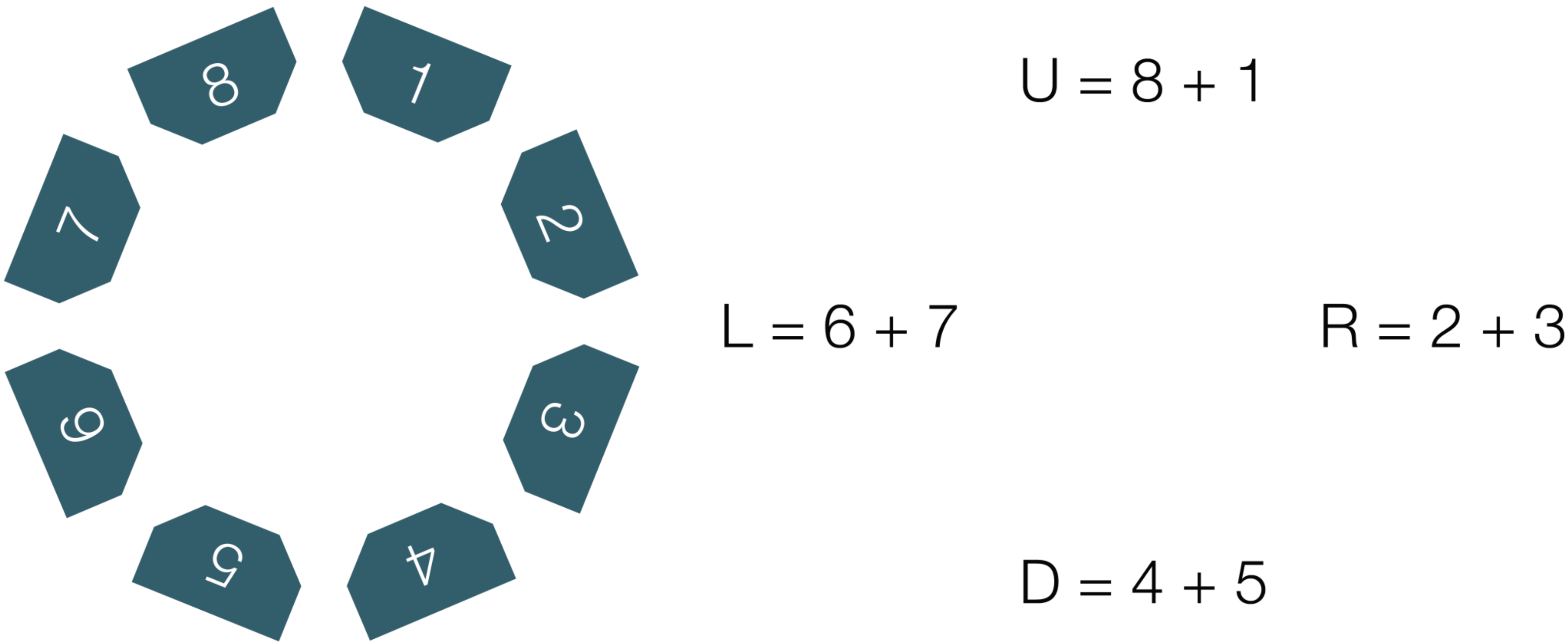


d) Effect of the beam divergence





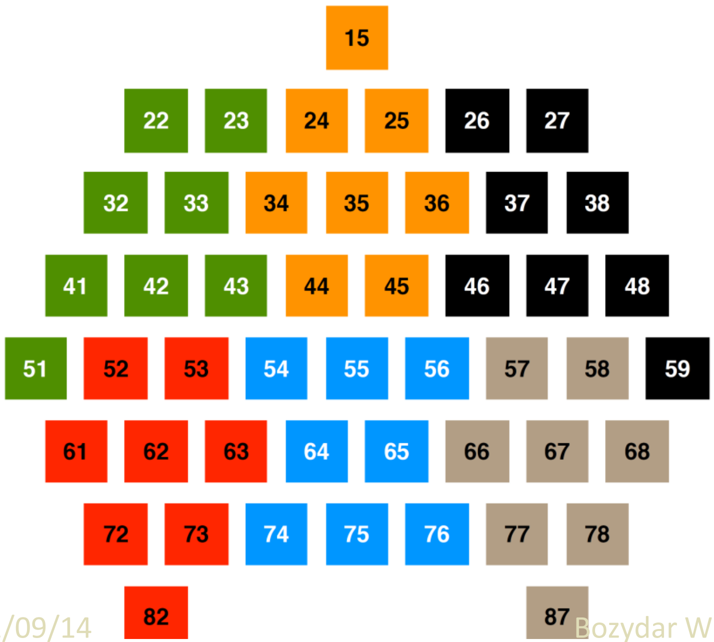
Cedar Alignment (3) Methods: Asymmetry

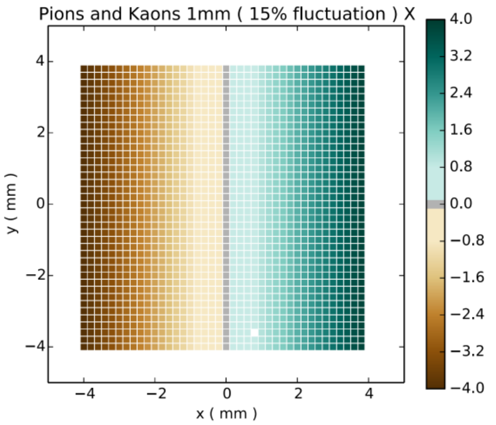


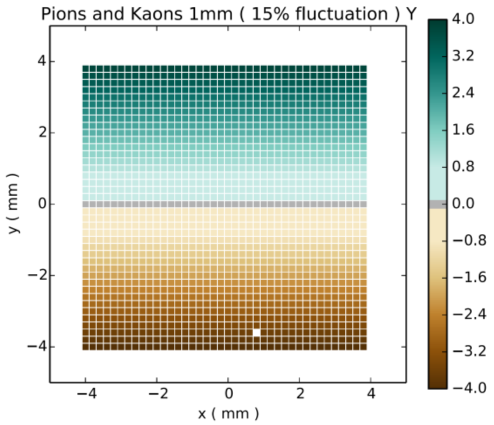
- Monitor the asymmetries (U-D)/(U+D) and (L-R)/(L+R).
- Adjust alignment until all asymmetries are 0
- No calibration - just keep moving in the suggested direction until no improvement is possible

χ^2 procedure

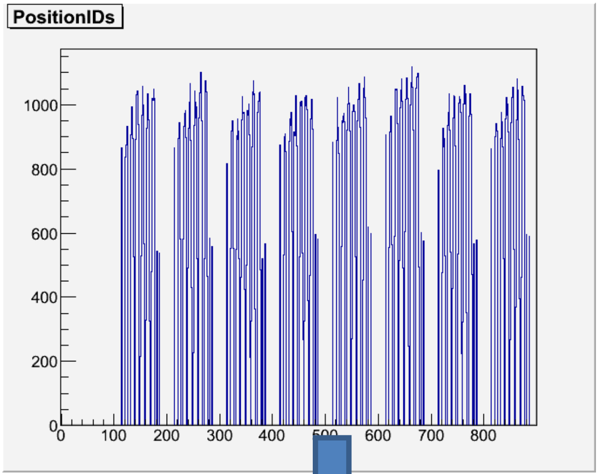
- Divide each octant into n blocks
  (e.g: rows or columns or halves or sixths etc.)
- Count the total number of PMT hits in each group → 8n totals
- Produce MC templates of these 8n totals fro each possible misalignment
- Determine misalignment in data by finding the template which minimises the χ^2 between these 8n numbers.



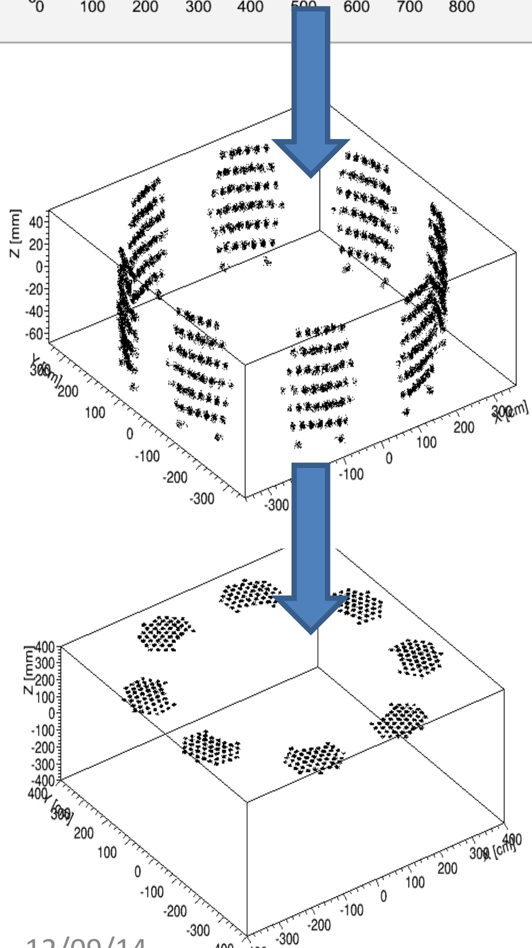


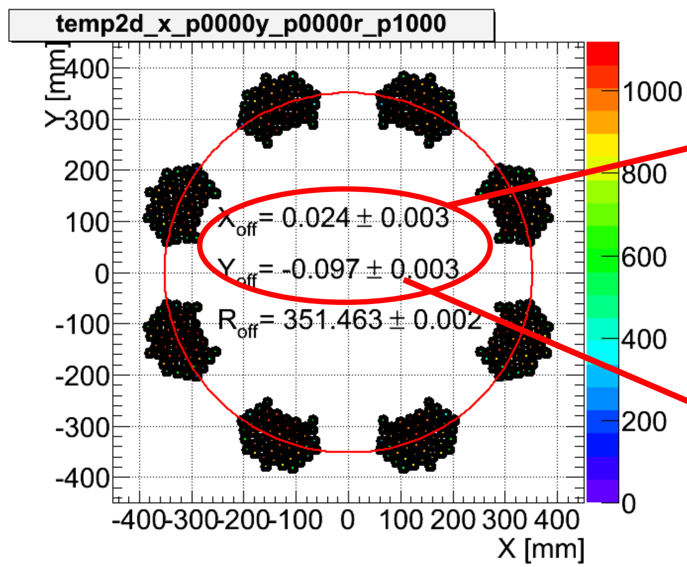


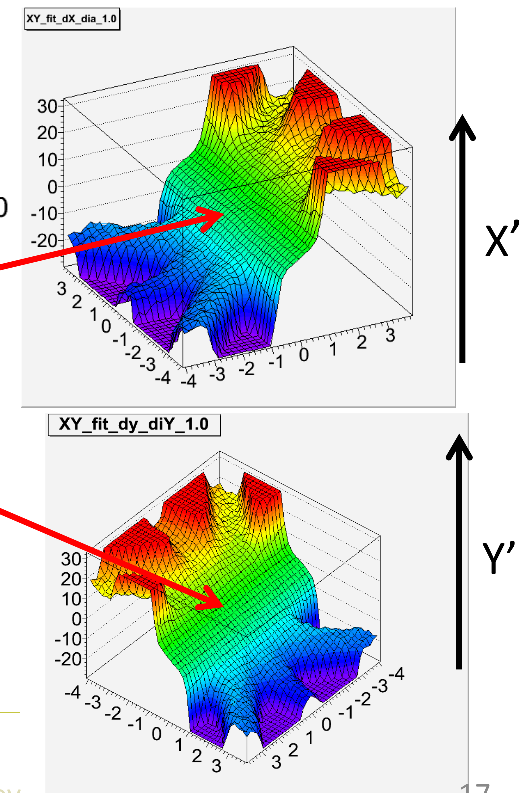
Geometrical fit



- Input photoelectons per PMT (position ID),
- Conversion from ID to (XYZ) of the PMT centres (taken from MC)
- Rotation of the octants to XY plane to exploit circular symmetry of the detector
- Best circle fit performed, minimising (weighted) sum of squares of the distances between PMT centres and the corresponding nearest point on the fitted circle, to extract (X’, Y’) position of the circle centre
- Repeated in each of 1600 (simulated) misaligned bins i.e. for shifts of CEDAR vessel in range of (-4,4)mm in (XY), step 0.2

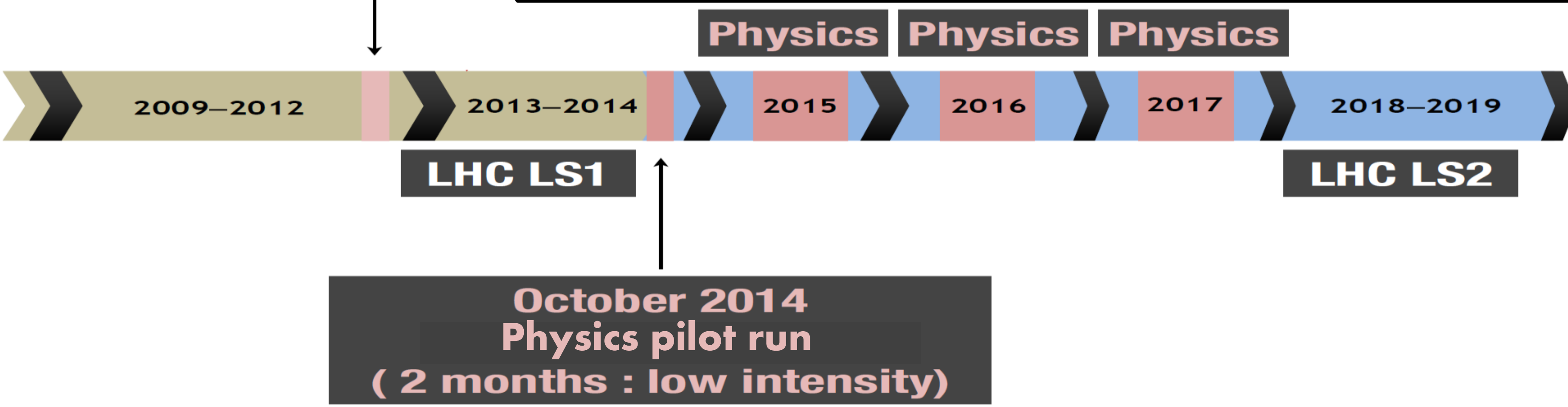






Schedule and Conclusions

Nominal intensity beam in 2015-2018 for full physics runs (100 days) officially scheduled by CERN
3 years of data-taking before LHC Long Shutdown 2 (LS2)



- NA62 Beam line ready
- KTAG installation completed by the end of September 2014
- **6 October 2014:** start of Physics pilot run (60 days)

Immediate Goals:

- ✓ Commissioning of hardware and readout with particles at lower intensity
- ✓ Address **SM sensitivity**

Long term :
Collect **O(100) $K^+ \to \pi^+ \nu\nu$** **SM** events
Measure **BR($K^+ \to \pi^+ \nu\nu$)** with ~10% accuracy