Kaon PID for high intensity hadron beams

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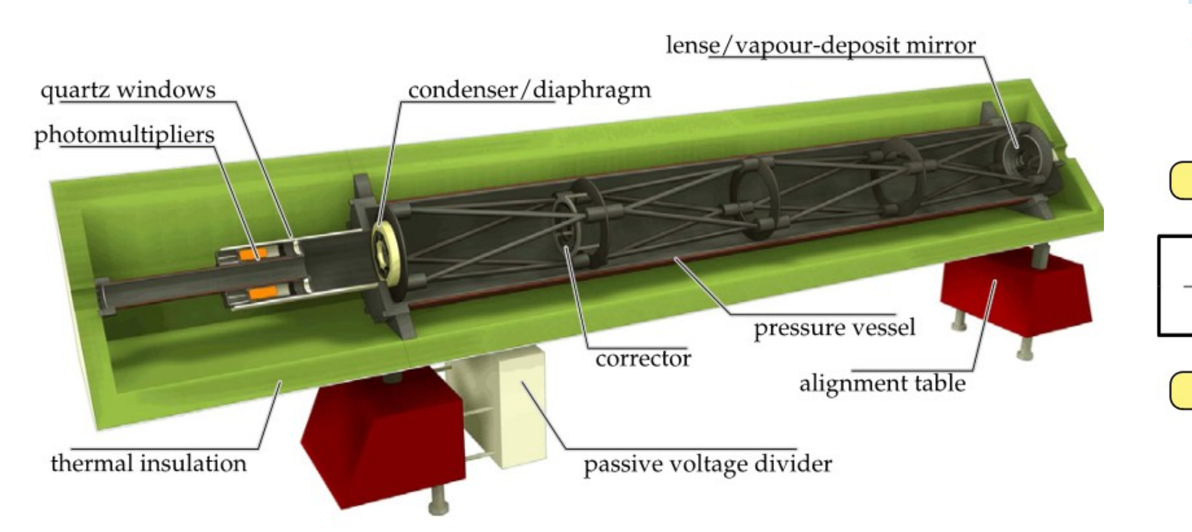
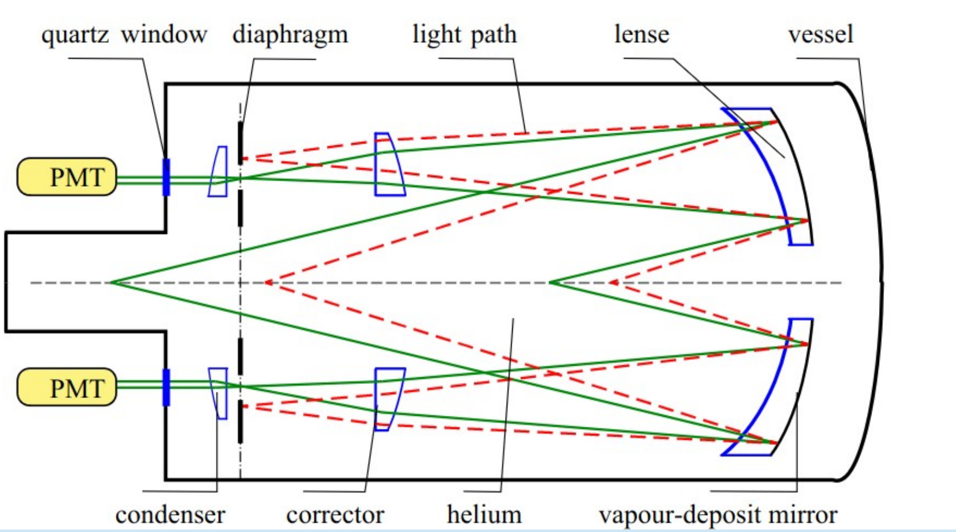
on behalf of AMBER Collaboration

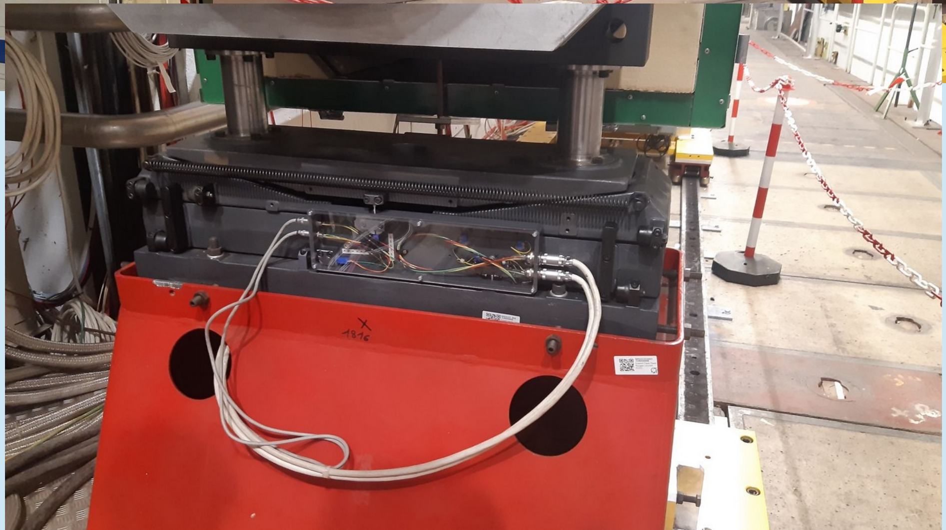
CEDAR detector for beam PID

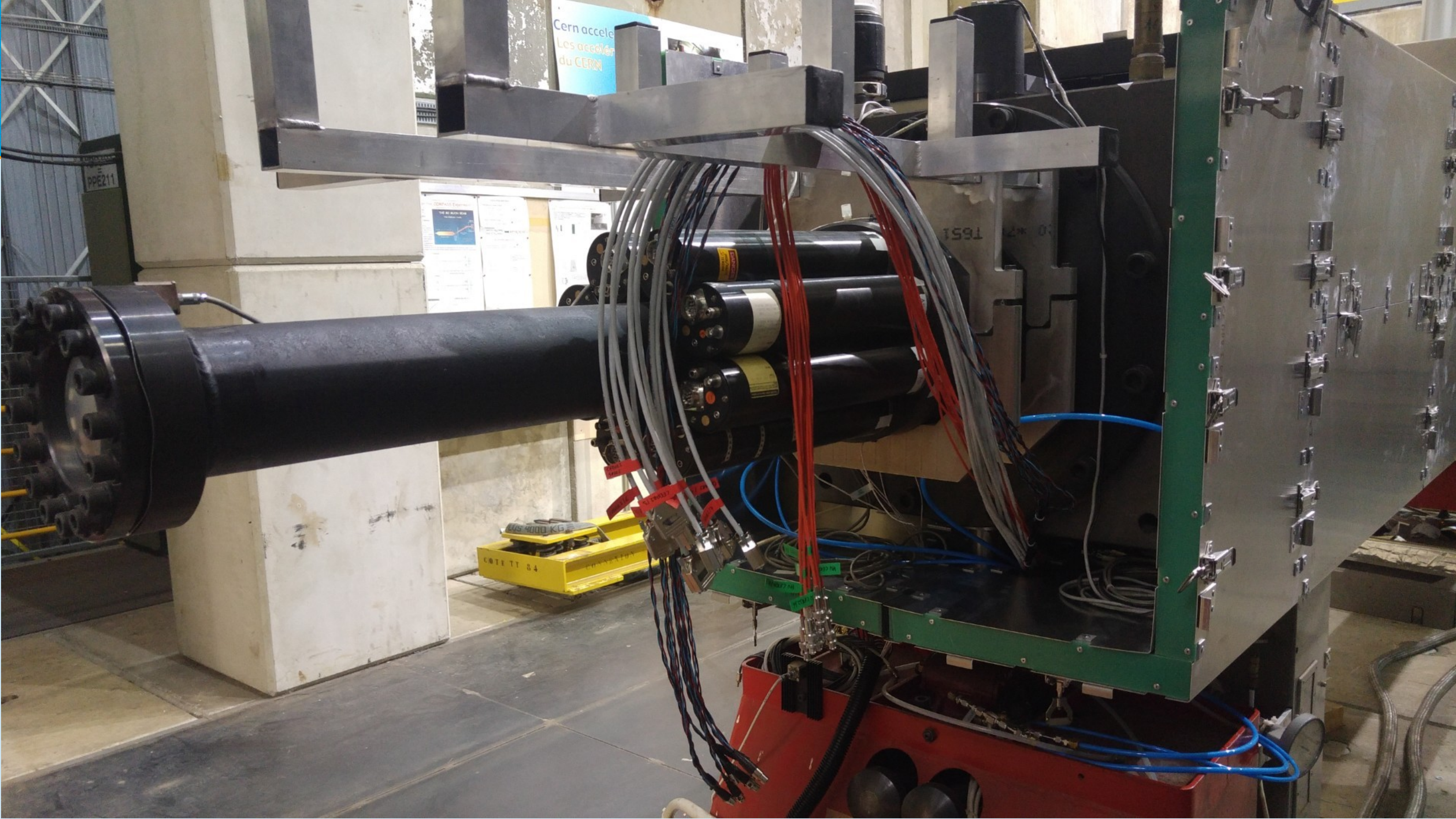
- Cherenkov Differential counter with Achromatic Ring Focus



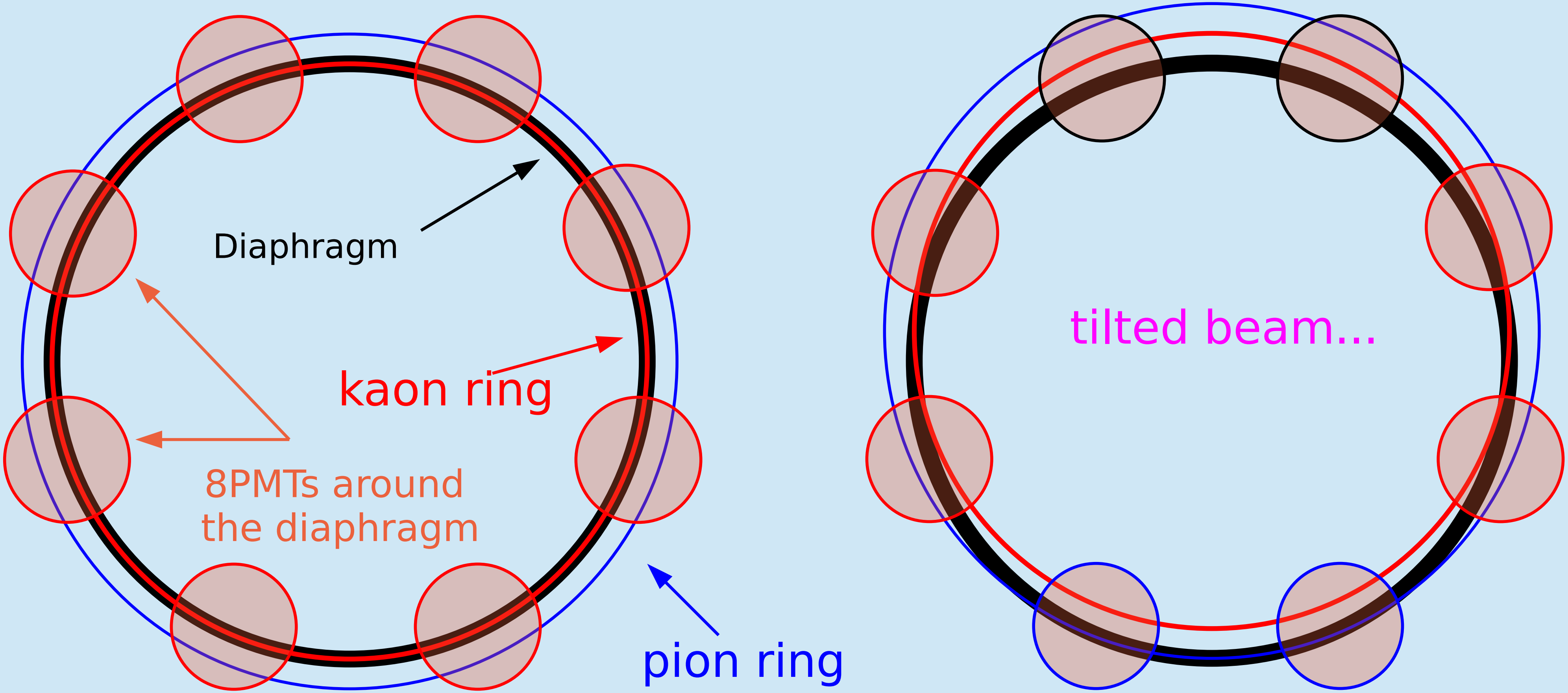



1100KG




PPE211
du CERN

Working principle...



CEDAR Detector

- At 190 GeV beam:
  - Pi-K separation 120 urad for polar angle for Cherenkov photons
  - Corresponds to 0.46mm of ring radius @ PMTs
  - Corresponds to pressure difference of 0.095 bar (CEDAR works at 10 bars)
  - Pi/K - proton separation – 300 urad (easy..)

- Original CEDAR idea – a multiplicity counter
  - Beam of a small divergence, here below 60 urad
  - Small opening of diaphragm (<0.46mm)
  - Leads to 0,1 hit in PMTs for pions and many hits for kaons (6+)
- At high intensity beam is expected on average every 10ns
  - So far COMPASS used CEDAR with 1/100 intensity...

Challenges...

- Beam Composition
- Knowledge of beam parameters @ CEDAR
- Beam Divergence
- The Likelihood method...
- ...and its failure at high intensity beam
  - Background level
  - „Correlated noise“
  - PMT electronic „dead time“

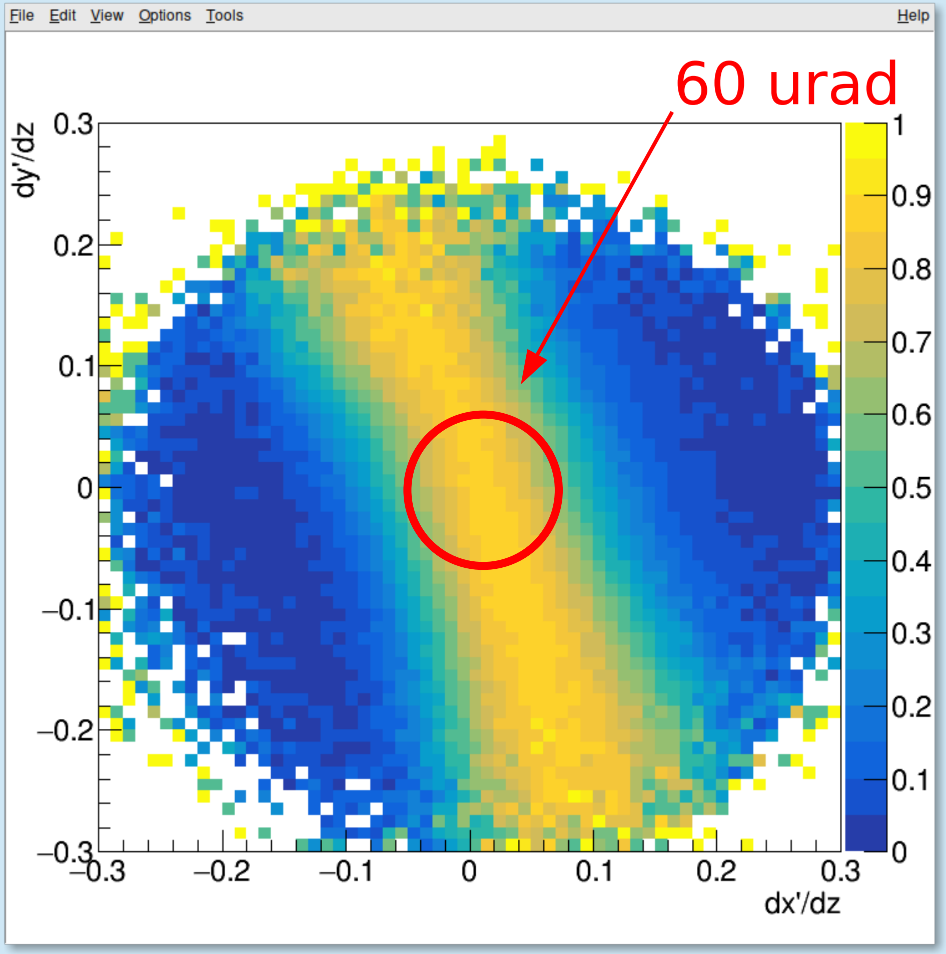
Beam composition @ 190 GeV

- Positive hadron beam
  - 74.4% of protons
  - 24.0% of pions
  - 1.6% of kaons
- Negative hadron beam
  - 0.8% of anti-protons
  - 96.8% of pions
  - 2.4% of kaons

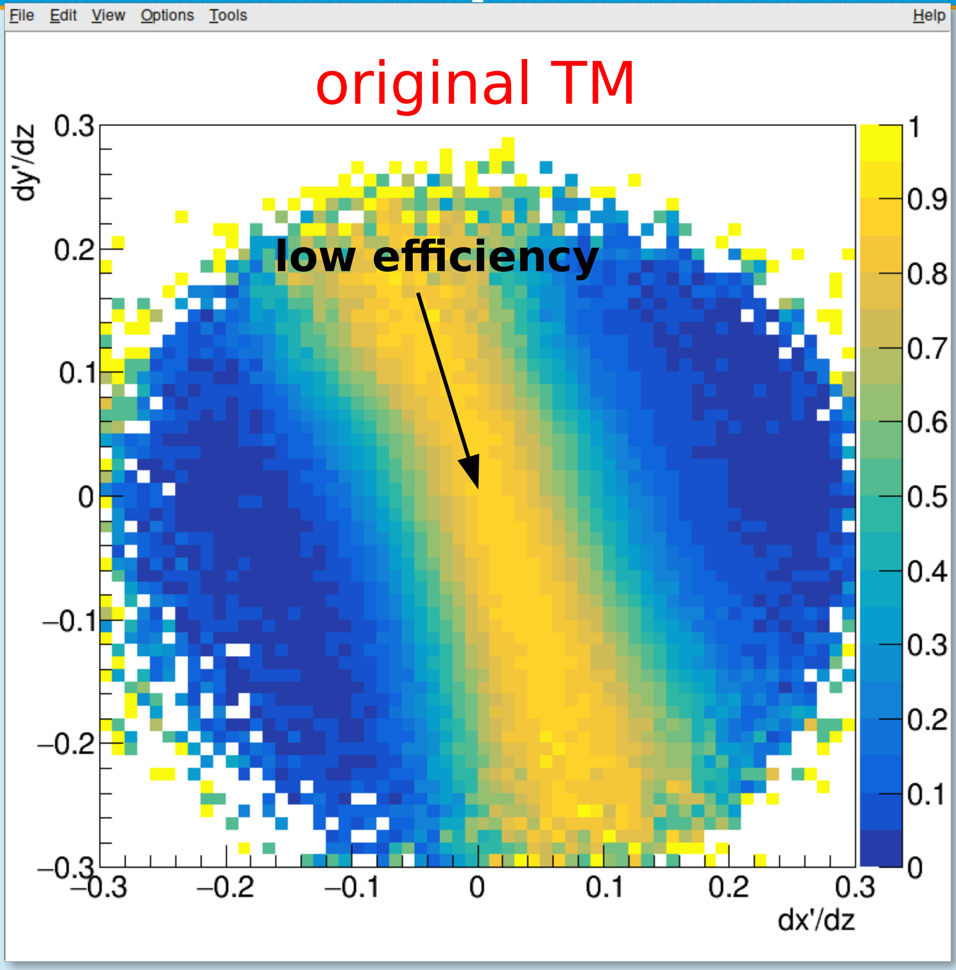
- Kaons consist only a small fraction of the beam!

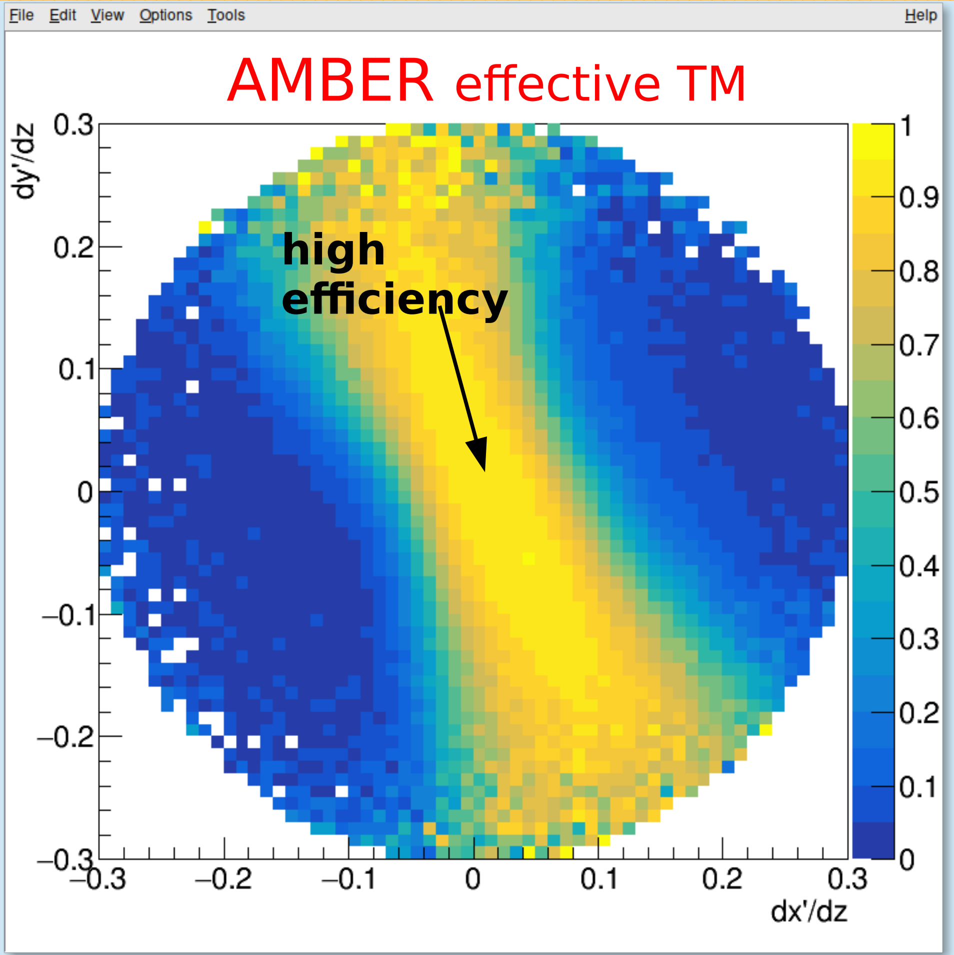
Knowledge of beam parameters @ CEDAR

- Beam parameters are measured c.a. 40m after CEDARs
- The so called beam transport matrix is used to correlate these measurements which beam parameters at CEDAR
- dx’/dz= a x + b dx/dz
  - x’ @ CEDAR position
  - x is measured in spectrometer
- Precise detectors are needed! (Like SI)

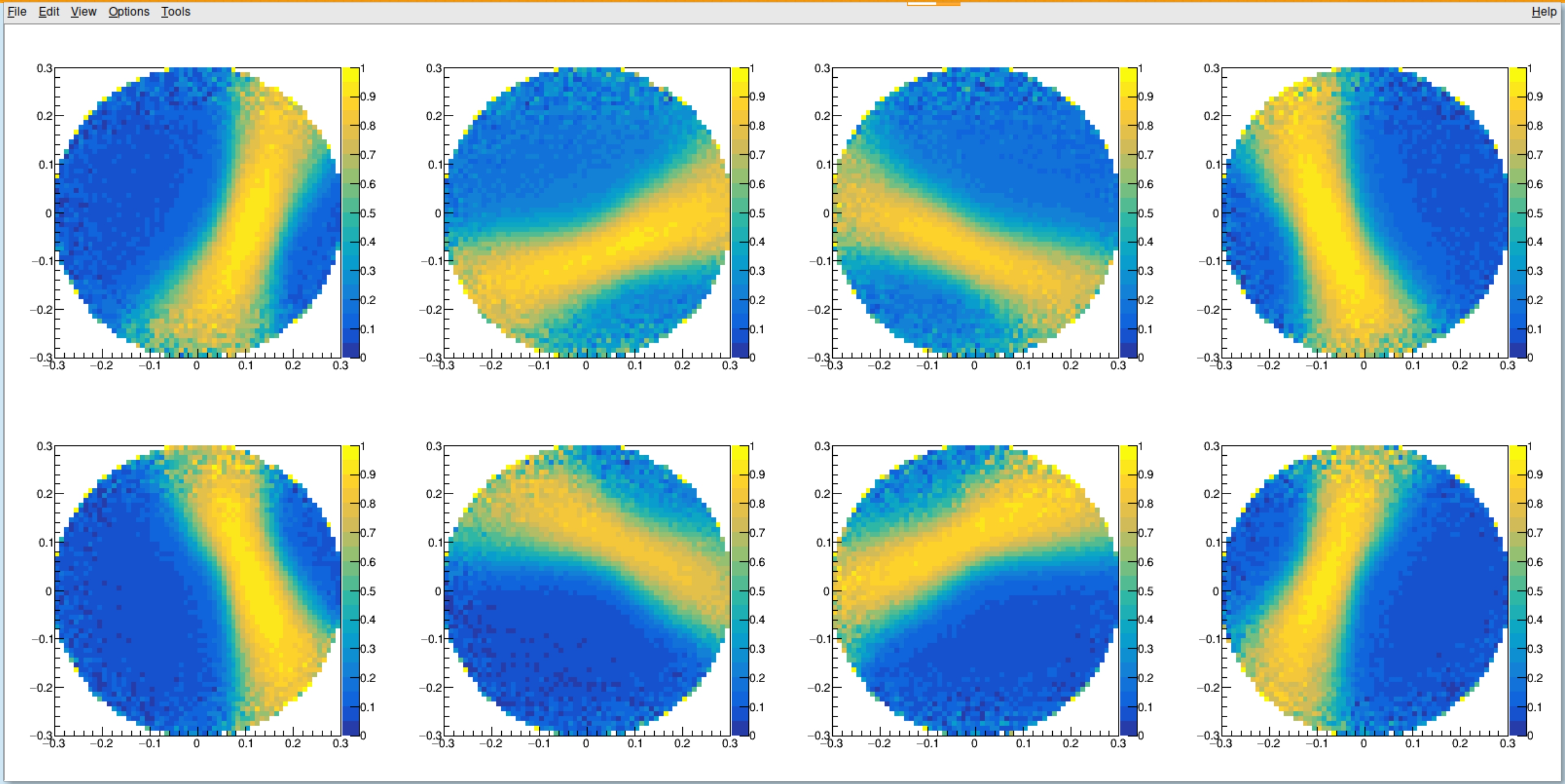


Is transport matrix optimal?



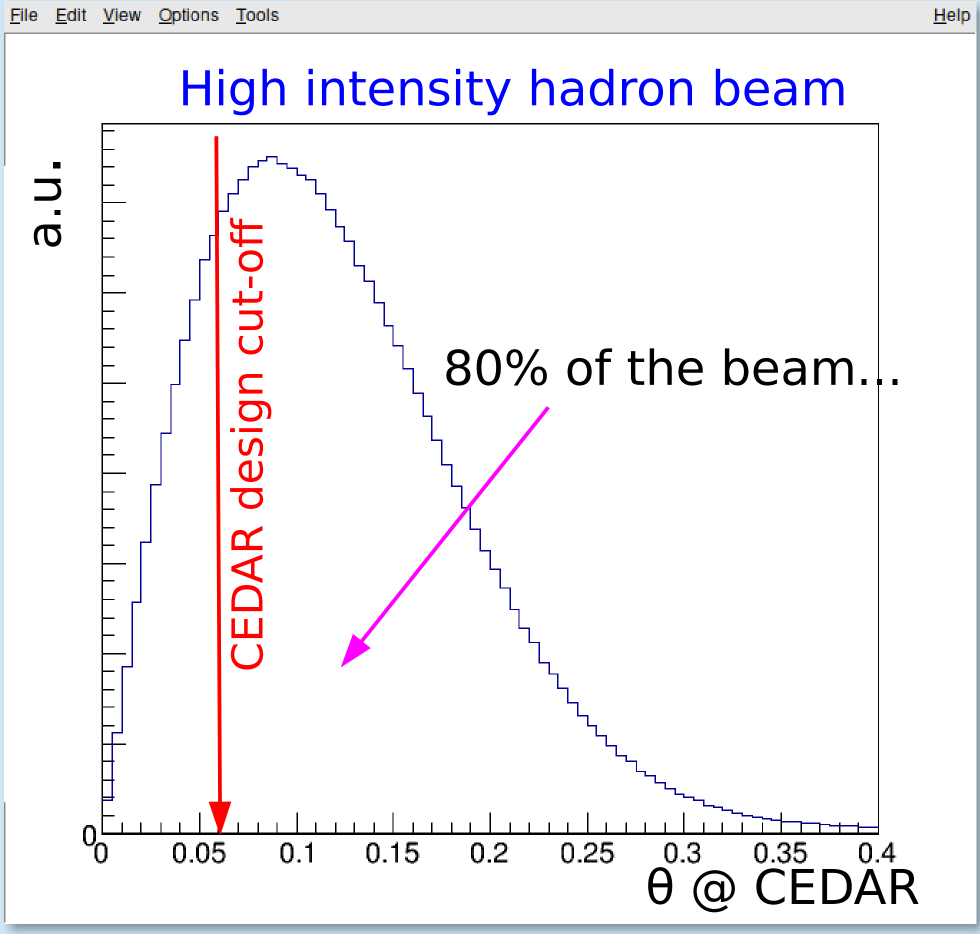


CEDAR response when set to kaons



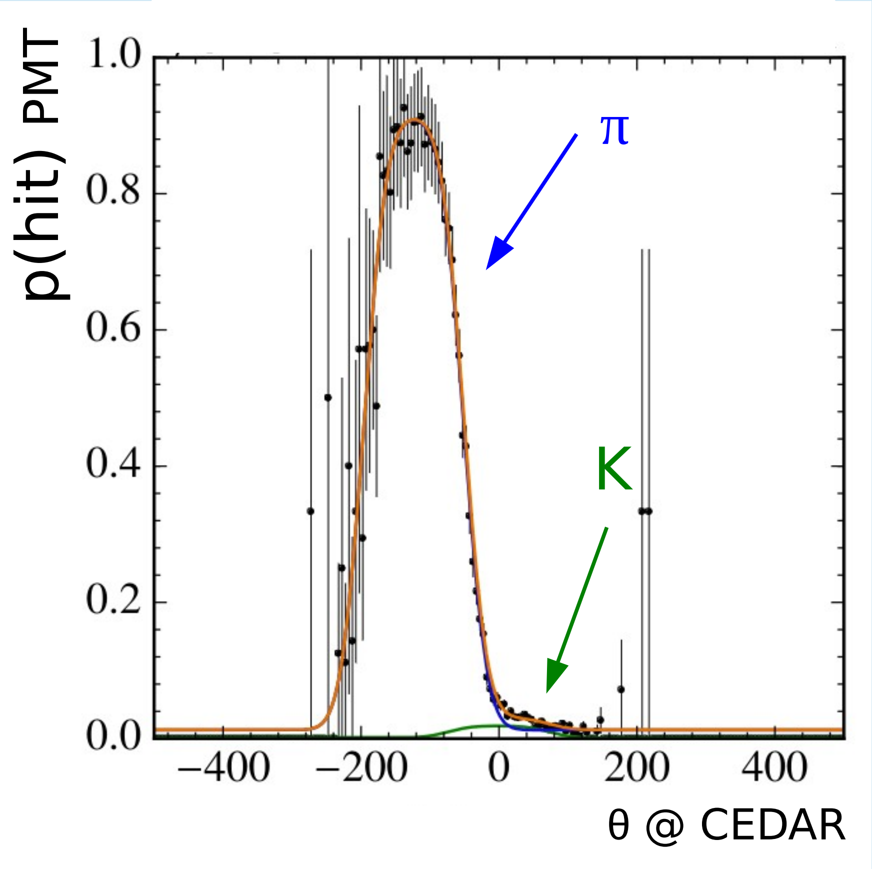
Beam divergence

- M2 beam line is also used for muons…
  - Long decay tunnel
  - Not much room left for magnets to optimize hadron beam parameters
- Large divergence of beam observed at CEDAR
- CERN beam group works to reduce the divergence



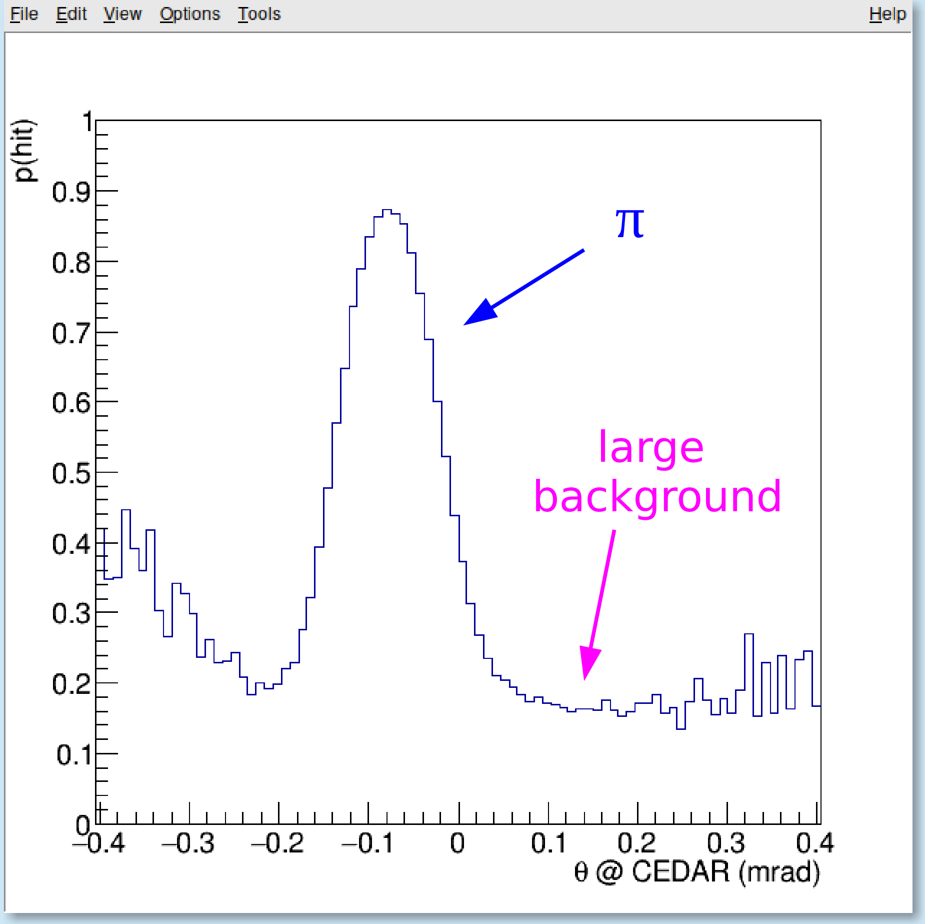
Likelihood method for low intensity beam...

- Method developed in COMPASS to overcome beam divergence
- Fit each PMT response spectra by functional form to obtain probability functions
- Calculate likelihood for given hit pattern seen by CEDARS
- Kaon-PID: 88% efficiency, π-bcgr. reduction: 1300

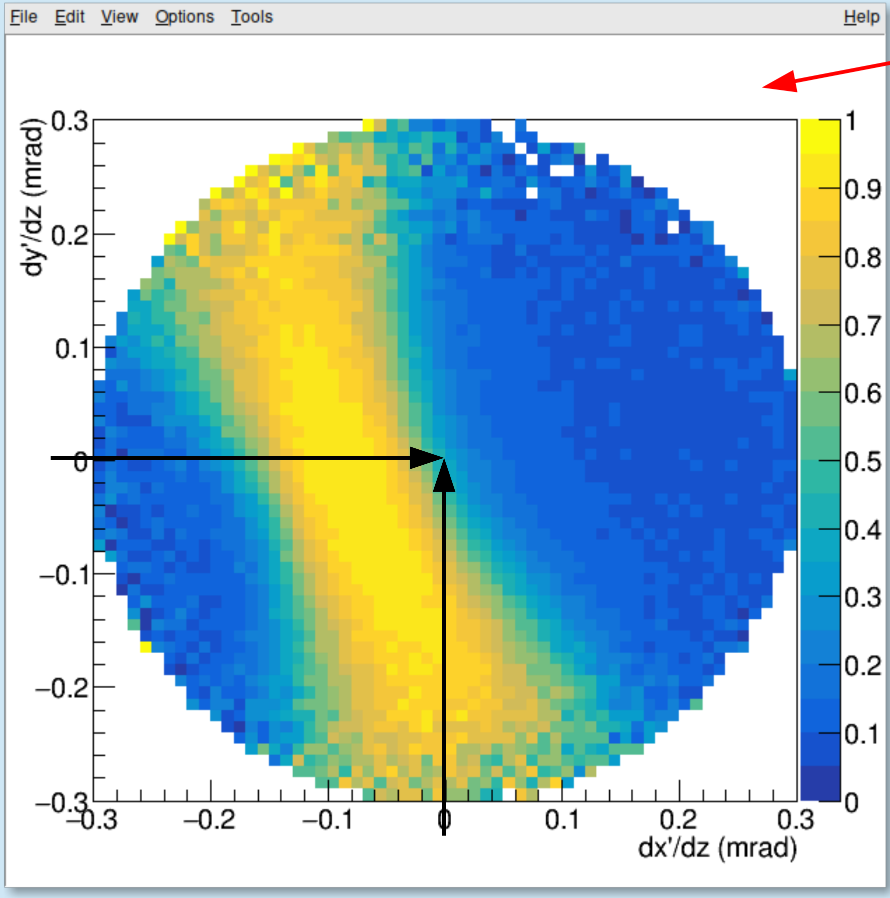


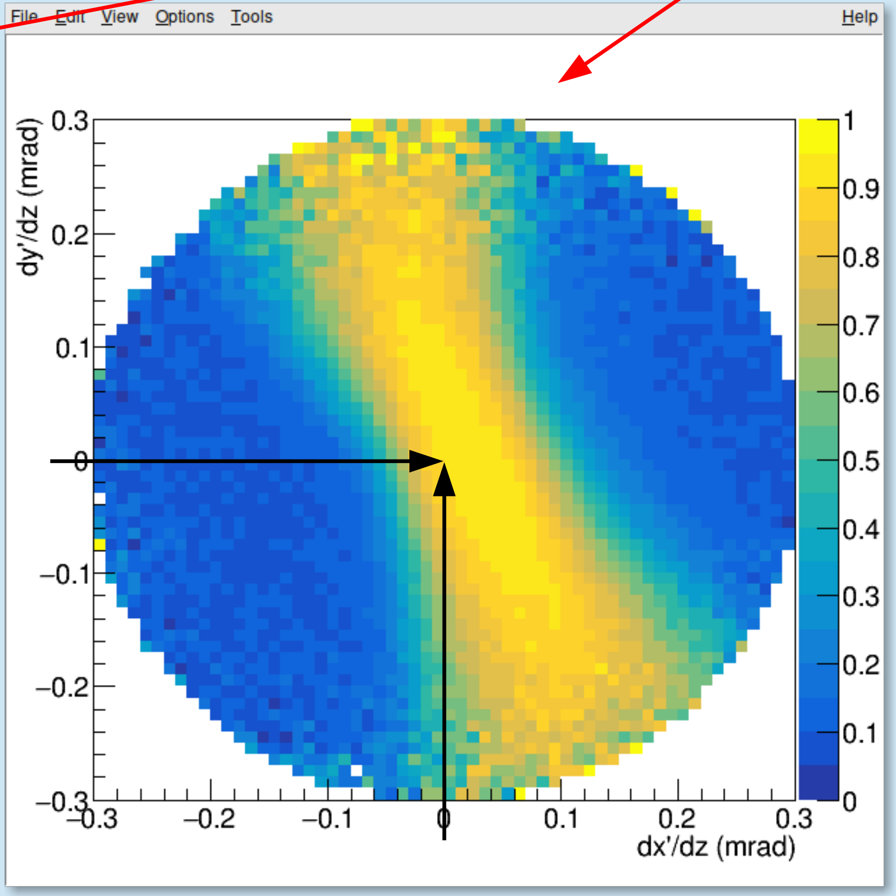
Likelihood method at high beam intensity…

- At high beam intensity background level is very high – reasonable fit of Kaon peak is not possible
- Instead we parametrise kaon response by a proxy setting CEDAR to detect pions… see next slide…



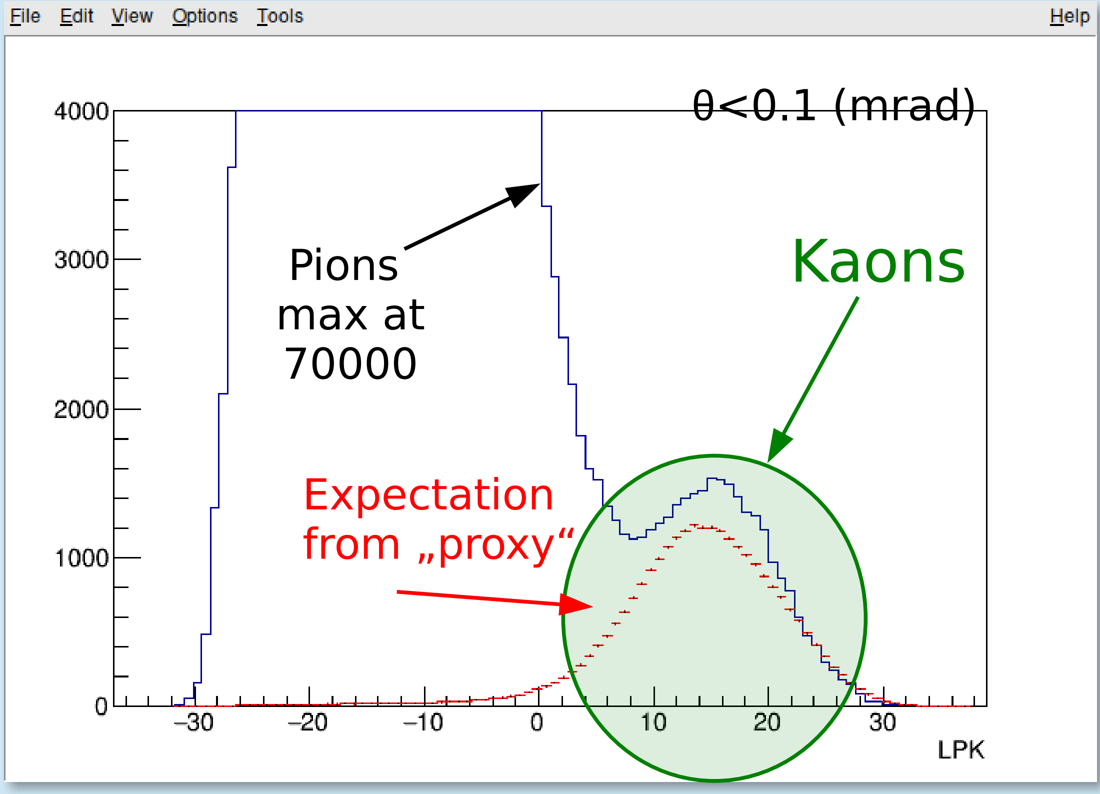
CEDAR response when set on K and pi



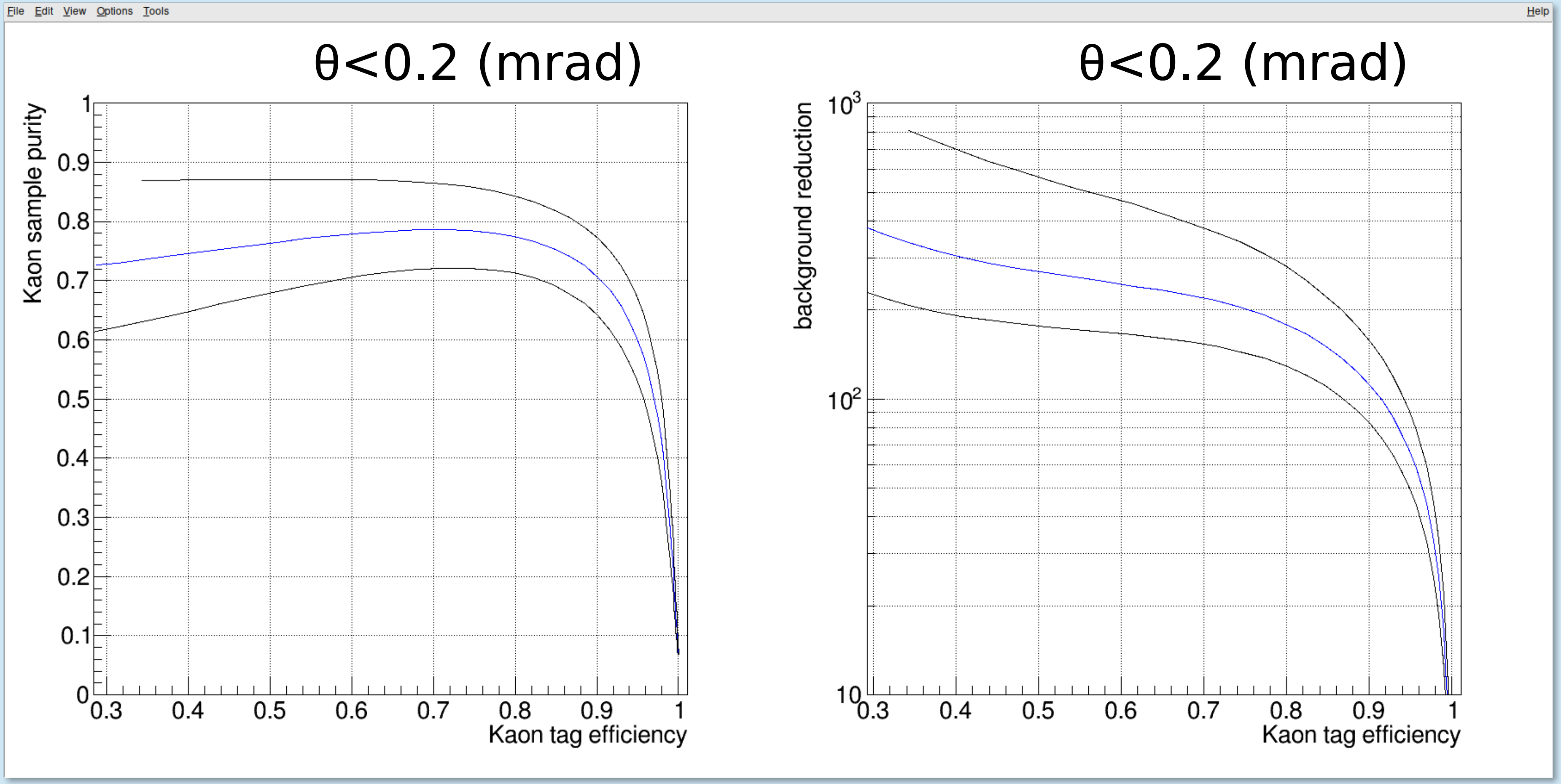


Kaon – Pion Loglikelihood

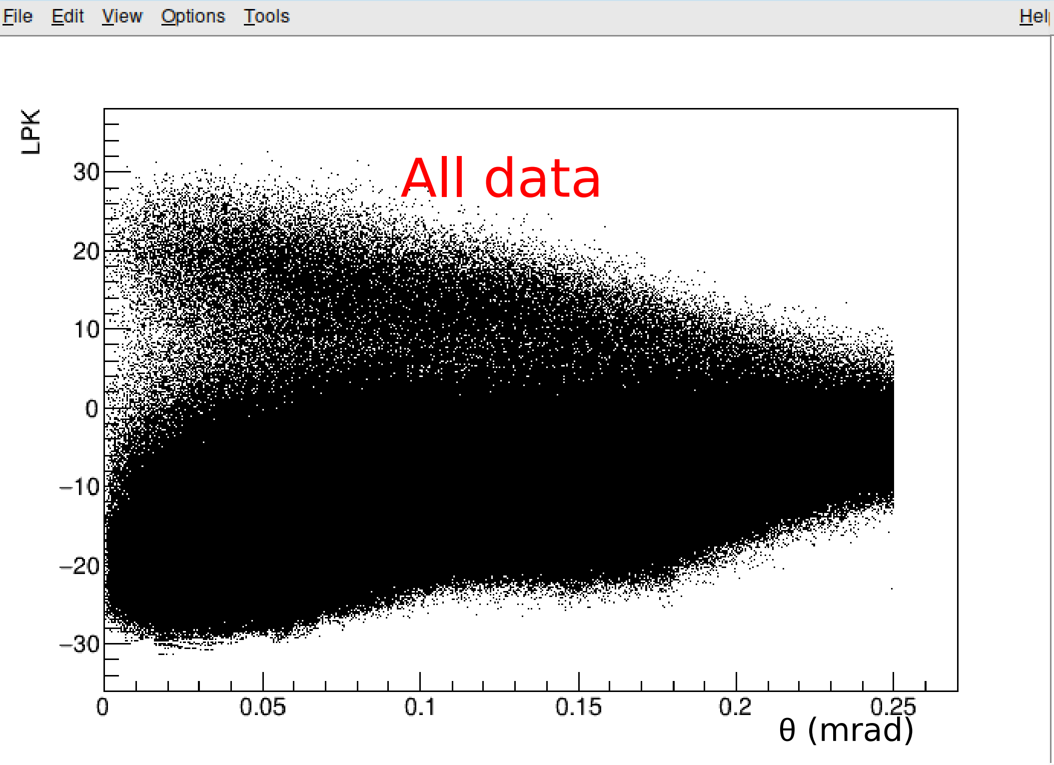
- Based on previous plots Likelihood for pi and K for a given hit pattern is calculated
- For the first time we do see a kaon signal for high intensity beam
- This is a starting point as the method suffers from significant problems!...
- Before discussing them,
  let us enjoy a few more plots...

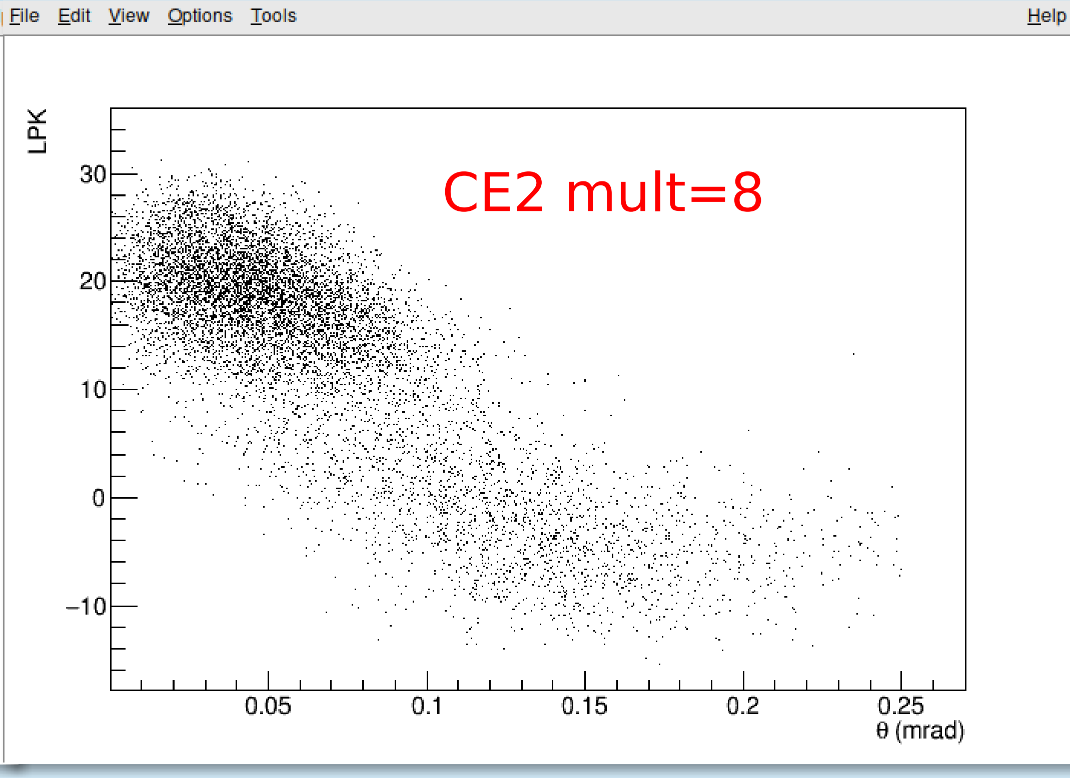


Purity and background rejection vs kaon efficiency…

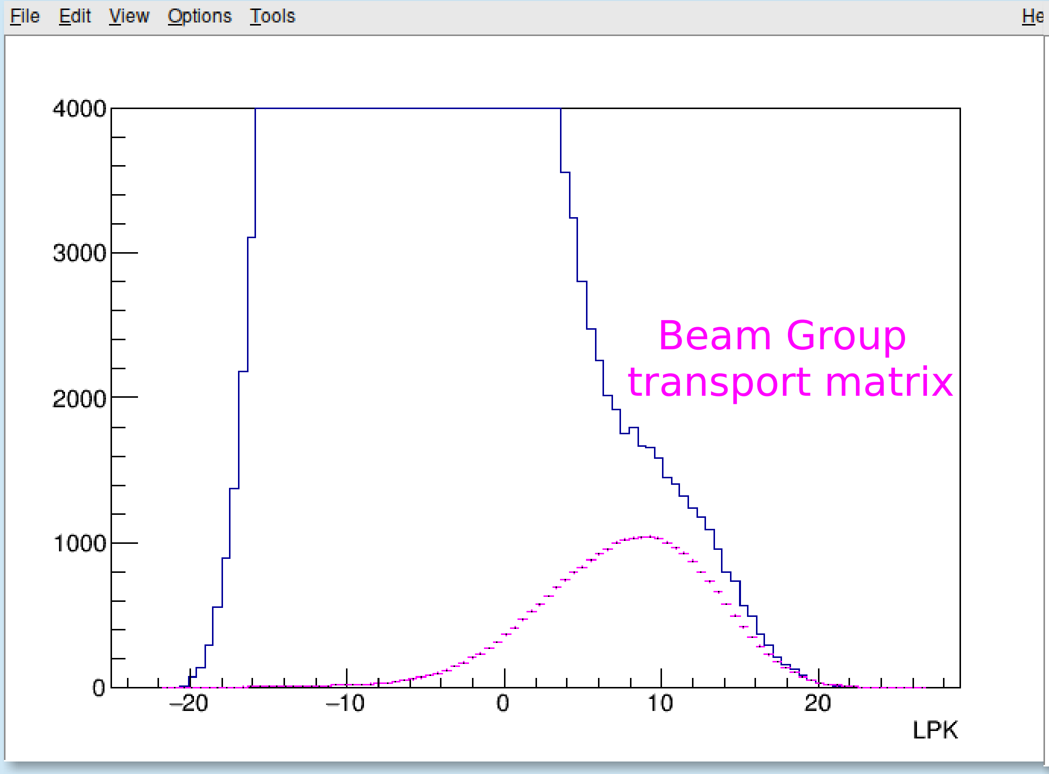


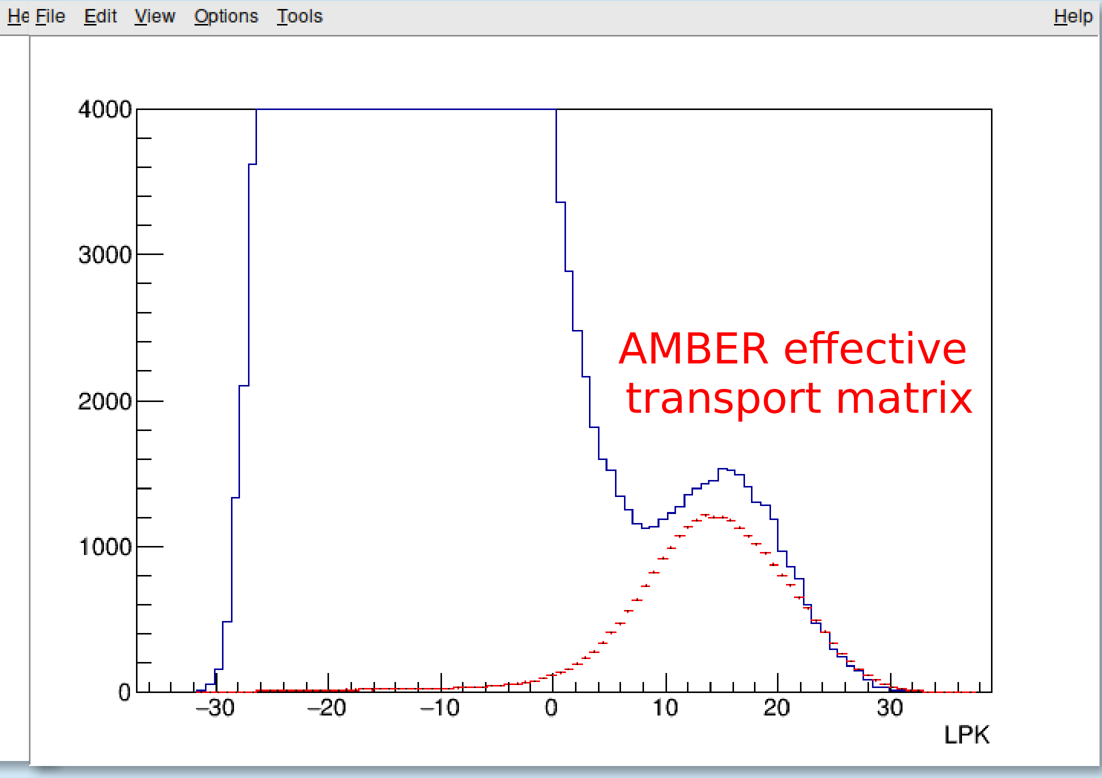
LogLikelihood as a function of θ





Likelihood for different beam transport matrices

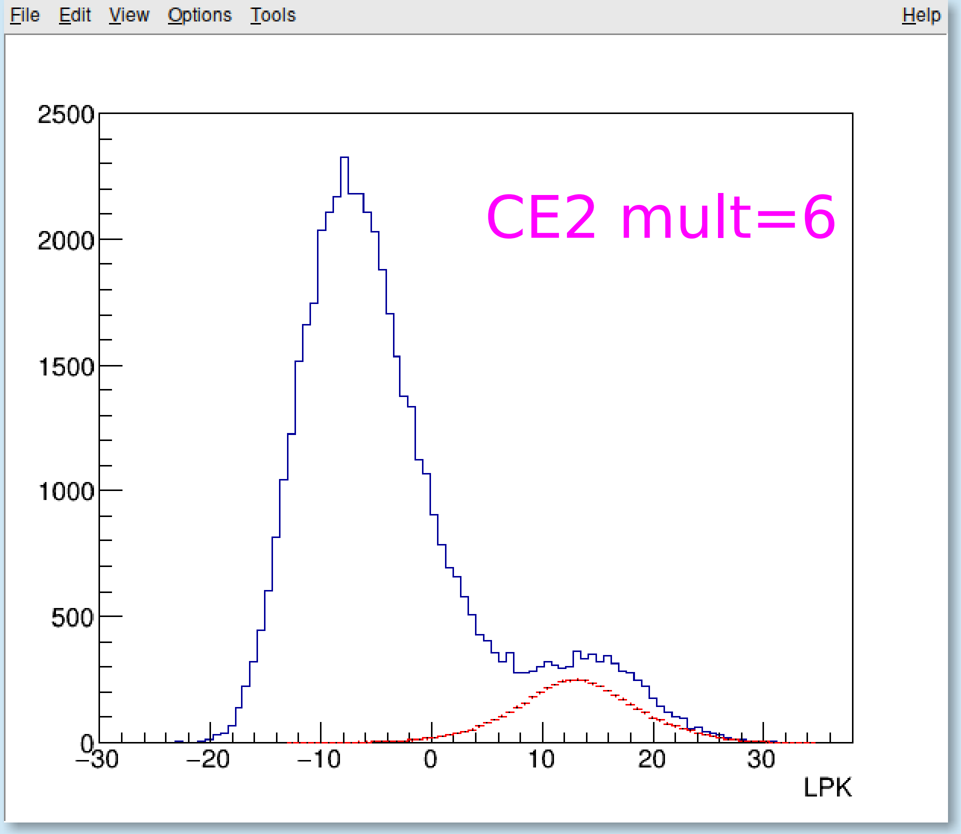


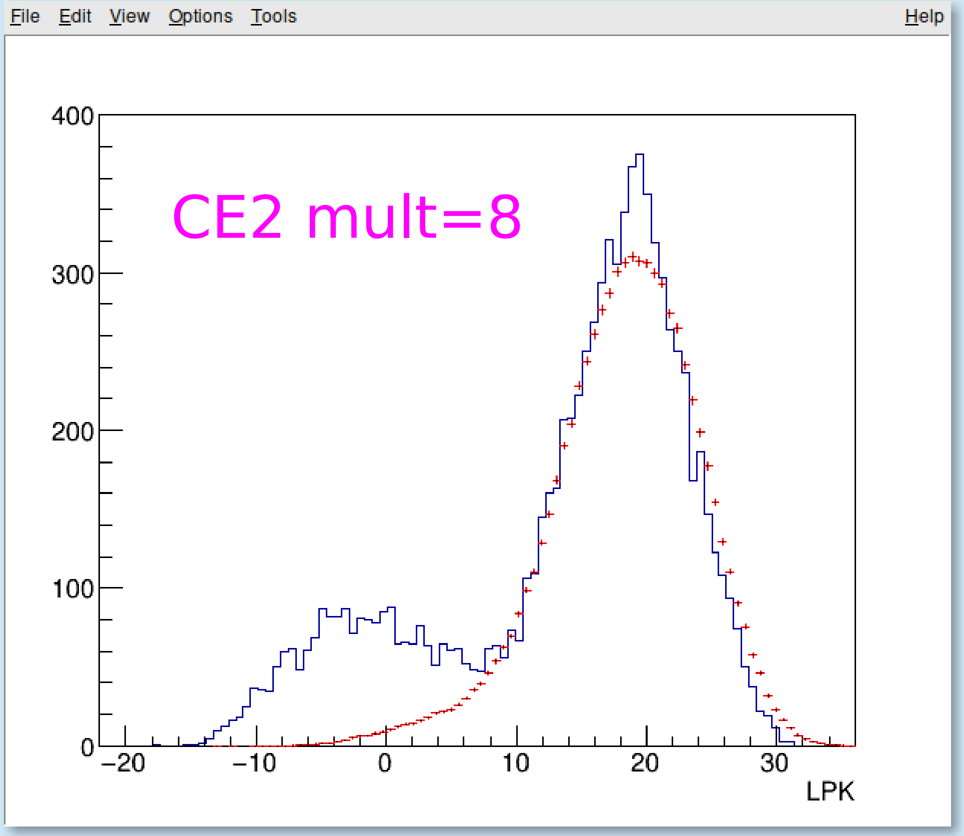


Correlated noise...

- It happens when 2nd beam is crossing CEDARs in the same time window and we are not aware of it...
  (beam reco fails, or beam is outside of acceptance of beam telescope, or beam halo hits directly PMT)
- Typical beam fires on average 2-4 PMTs
- Thus, unknown beam can cause to fire more PMTs than usually leading to false increase for kaon likelihood...
- Especially problematic for when 6 PMTs fired

Log Likelihood for various multiplicities



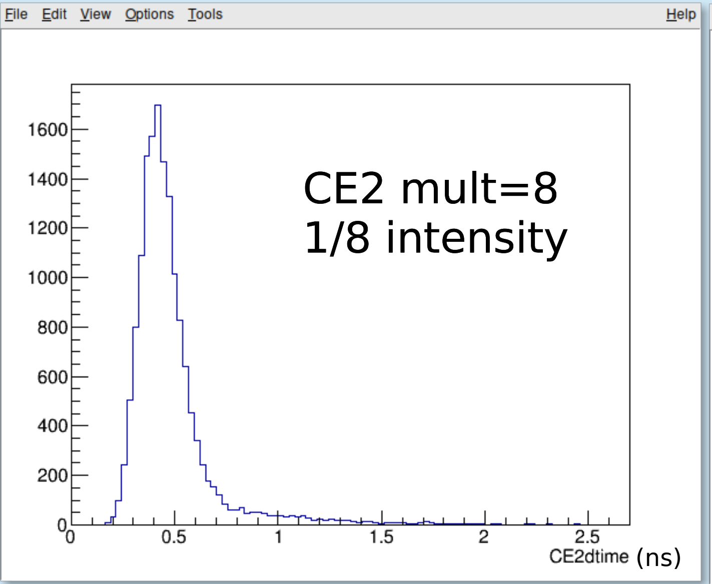


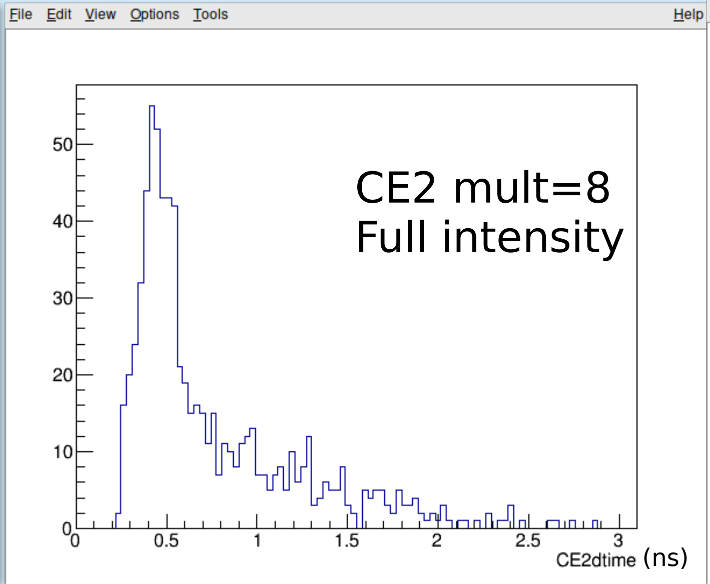
Correlations...

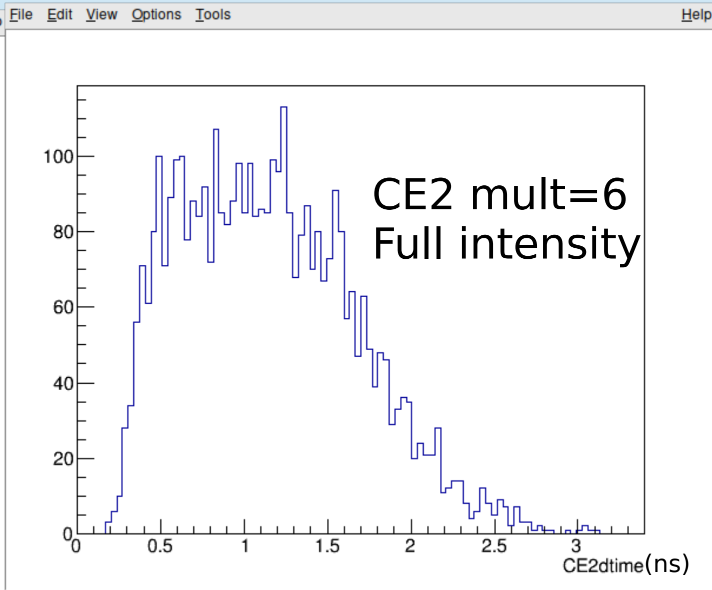
- Correlations are hard to implement in likelihood...
- e.g. consider 3 PMTS and co-variance matrix of PMT response: there are 8 possible hit patterns i.e. 7 degrees of freedom, but covariance matrix has only 6 independent parameters...
- Correlation between various PMTs responses is not a way to go...
- It is easier to use e.g. Neural Network approach...
- However, we have also time information from CEDAR...

RMS of time between different pads of CE2

- RMS of different hit is on average below 500ps
- One can remove suspicious hits, match CEDARs time with FI detector in beam







PMTs „dead time“

- For the moment the signal length in CEDARs PMTs is 10ns, quite large, as the beam is expected every 10 ns…
- Presently, a given PMTs fires for 1/3 beams
- From electronic point of view signal can be reduced to 2ns
- For now, special care must be taken regarding hits that occur 10ns earlier than the trigger time (not yet addressed)

Summary

- **We detect a kaon signal in negative beam at full intensity**
- The demonstrated Likelihood method is not optimal
- Enhance the utilization of time information in analysis
- Shorten the length of the signal
- Beam quality will be improved by the beam group!
- Additionally, reducing the beam energy, e.g. to 160 GeV, would simplify operations… (i.e. increase in pi-K separation from 120 to 170 urad).