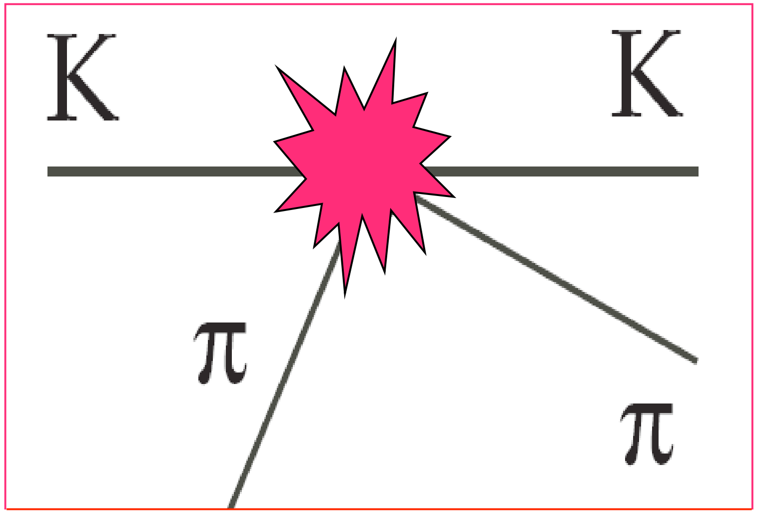
Search for Kπ-atoms with DIRAC II



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(On behalf of the DIRAC collaboration)

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DIRAC II collaboration

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Introduction to DIRAC

Chiral perturbation theory (ChPT) describes the hadronic interactions according to the SM below the chiral symmetry breaking scale (~1GeV).

ChPT gives precise prediction for the S-wave $\pi\pi/\pi K$ scattering length a_0, a_2, $a_{1/2}$ and $a_{3/2.}$

Many $\pi\pi/\pi K$ scattering analysis have been performed in the 70th by measuring the partial and total cross section ($d\sigma/d\Omega$, σ) in a model dependent way to obtain a_0, a_2, $a_{1/2}$ and $a_{3/2.}$

DIRAC's approach is unique :

DIRAC measures the scattering length in a model independent way through the lifetime of $\pi\pi/\pi K$-atoms which provides a **crosscheck of our understanding of low energy QCD**

DIRAC's main goals

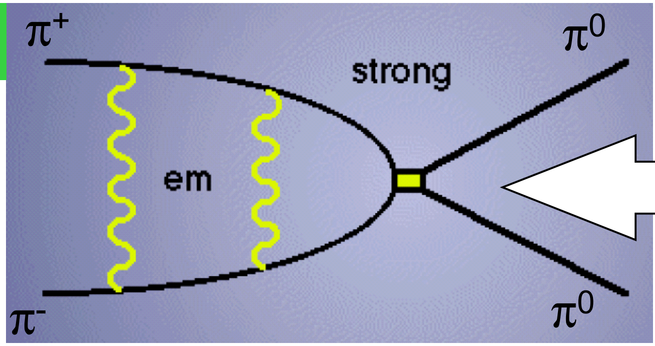
- Lifetime measurement of $\pi^+\pi^-$ atoms (pionium) in a model-independent way with precision better than 6%,which gives a precision for $|a_0 - a_2|$ better than 3%;

- Observation of $\pi^- K^+$ and $\pi^+ K^-$ atoms.

The measurement of the lifetime with precision of 20% and difference of the πK scattering lengths $|a_{1/2} - a_{3/2}|$ with accuracy of about 10%.

DIRAC so far

Experiment:



DIRAC col., Phys.Lett. B619 (2005) 50

measured by DIRAC:
$\tau = (2.91^{+0.49}_{-0.62}) * 10^{-15}$ **s**

The dominant decay channel of pionium

Theory:

$$\frac{1}{\tau} = \frac{2\alpha^3}{9} p \left| a_0^0 - a_0^2 \right|^2 (1+\delta)$$

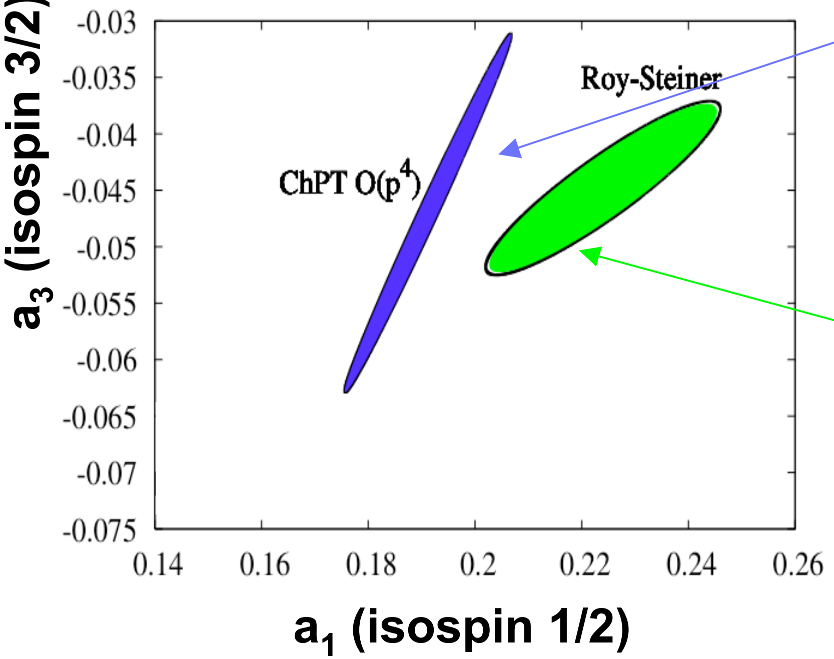
The scattering length can be predicted using QCD ChPT,
$\tau = (2.9 \pm 0.1) * 10^{-15}$ s

G.Colangelo et al., Nucl. Phys. B603 (2001) 125

SU(2) ChPT has been a success. Introducing the s-quark one could check SU*(3)* (u,d and s) symmetry breaking.

πK scattering lengths

S-wave scattering length



theory

ChPT

V.Bernard *et al.*,Nucl.Phys. B357 (1991) 2757

$$m_\pi\,(a_0^{1/2} - a_0^{3/2}) \simeq 0.238 \pm 0.002$$

Dispersions relations

P.Buettiker *et al*,Eur.Phys.J C33 (2004) 409

$$m_\pi\,(a_0^{1/2} - a_0^{3/2}) \simeq 0.269 \pm 0.015$$

experiment

$$K^+ p \longrightarrow K^+ \pi^- \Delta^{++}$$
$$K^+ p \longrightarrow K^+ \pi^+ n$$

e.g.

P.Estabrooks *et al*.,Nucl.Phys.B133(1978)490

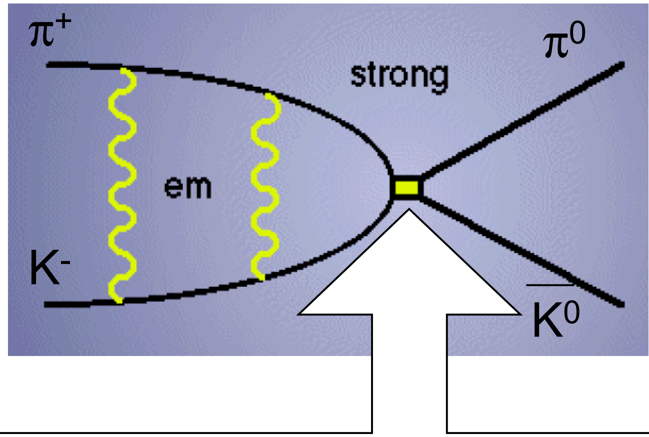
$$m_\pi(a_0^{1/2} - a_0^{3/2}) \simeq 0.475 \pm 0.0013$$

DIRAC's approach

$$\frac{1}{\tau} = \frac{8\alpha^3}{9} \frac{M_\pi M_K}{M_\pi + M_K} p \left| a_0^{1/2} - a_0^{3/2} \right|^2 (1+\delta)$$

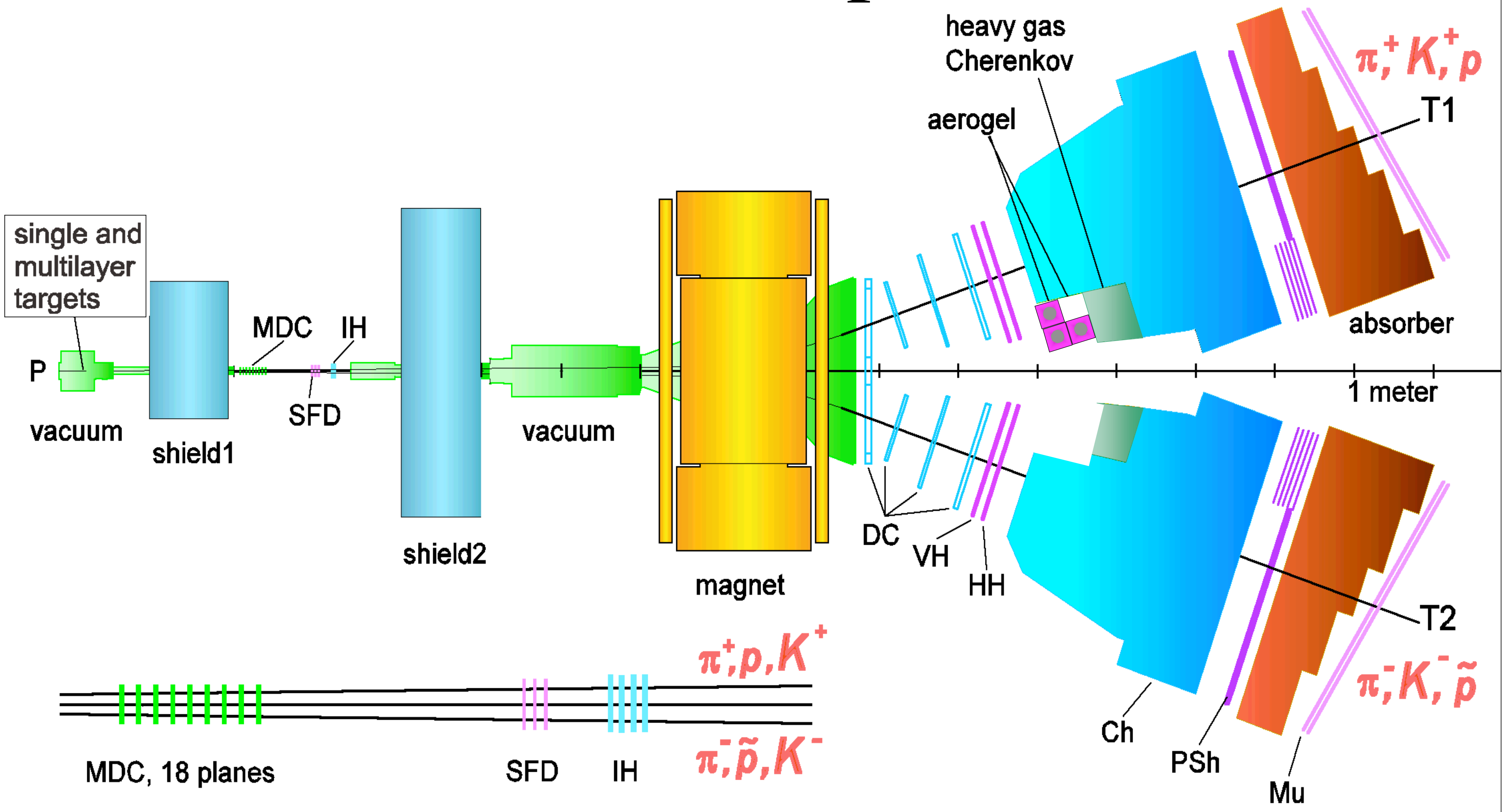
The dominant decay
channel of πK-atoms

$\pi^+ K^- \longrightarrow \pi^0 \overline{K^0}, \quad \pi^- K^+ \longrightarrow \pi^0 K^0$



DIRAC II aims to measure
the lifetime of πK-atoms
in order to check SU(3) ChPT

The DIRAC II spectrometer



DIRAC II : What has changed?

• New aerogel čerenkov detector for kaon-proton separation

• New heavy gas C_4F_{10} čerenkov detector for kaon- pion separation

• New micro drift chambers for a better upstream tracking

• New scintillating fiber detector with pitch of the fibers improved by a factor 2 (~200 μm)

• New preshower detector for better electron rejection

• Upgrade of hodoscopes for a bigger aperture

• New shielding for background suppression

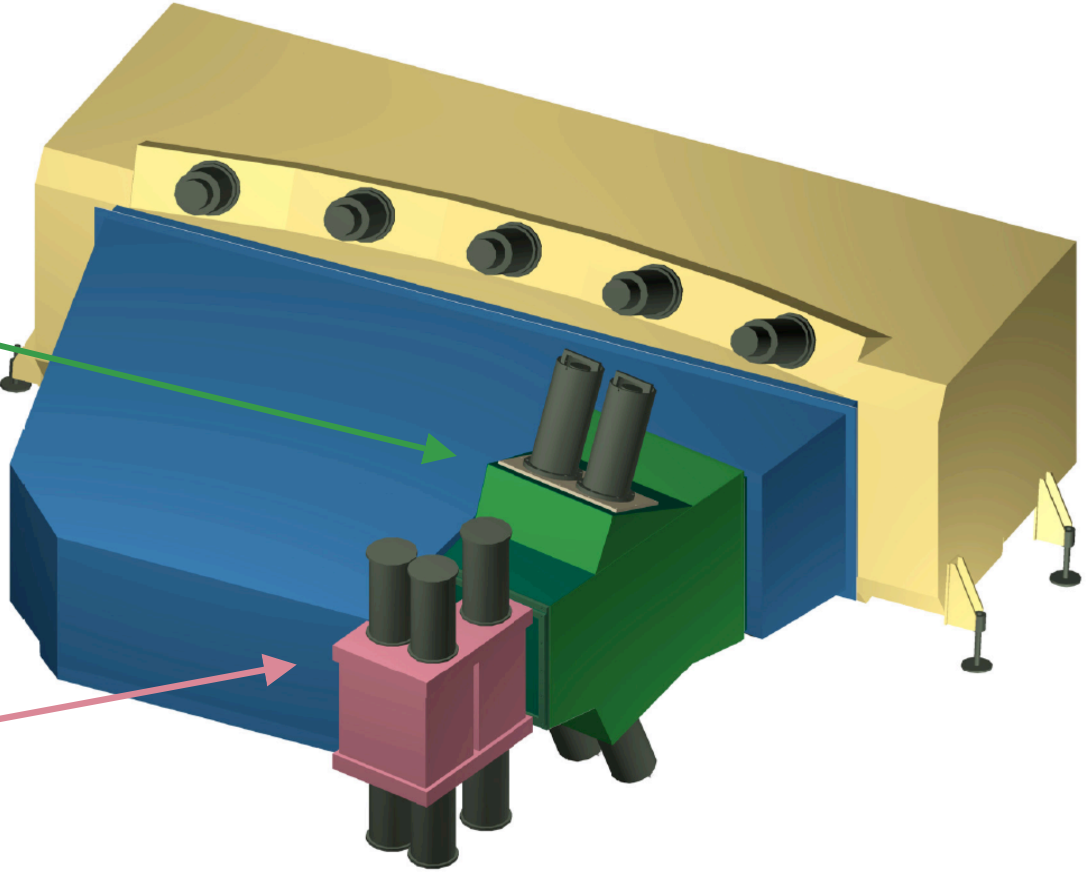
• New electronics for forward detector: ADC and TDC with resolution of 120 ps (instead of 0.5 ns).

Kaon identification

Detection efficiency x 2

The Čerenkov detectors

One C_4F_{10} Heavy gas module in each arm with n=1.00137

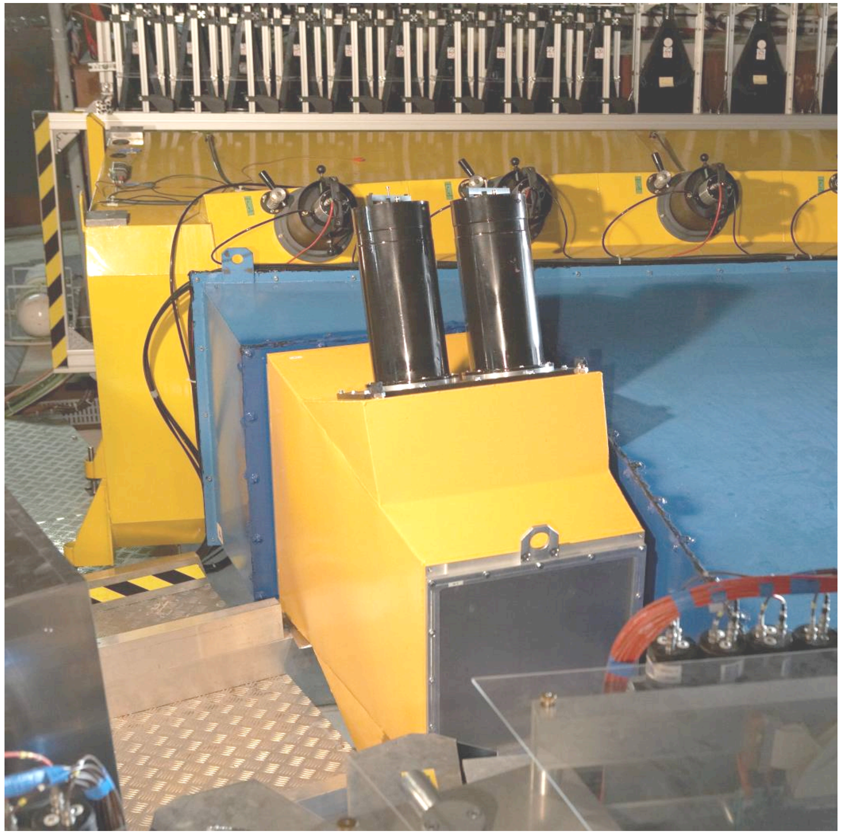


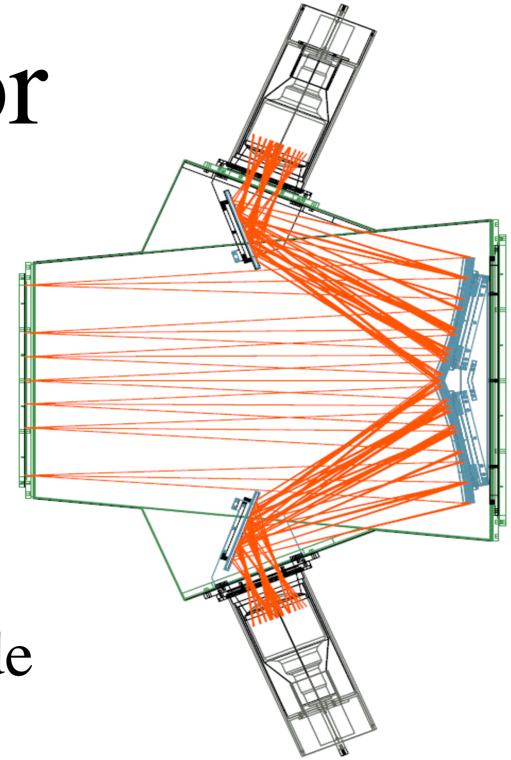
3 aerogel modules in left arm :

- 2 with n=1.015
- 1 with n=1.008

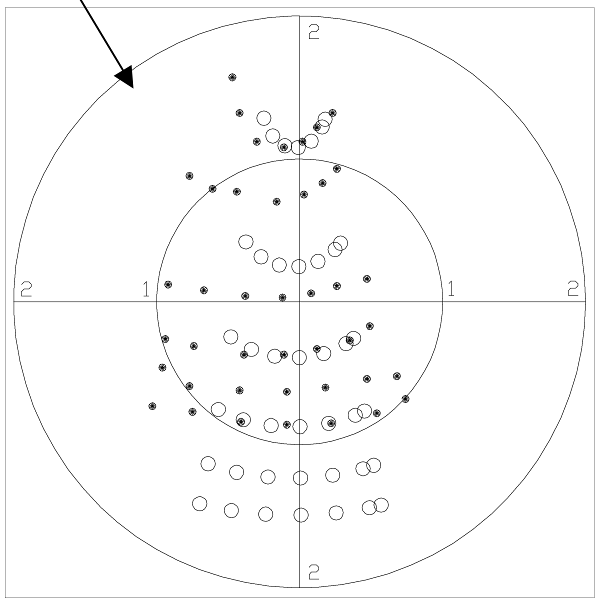
N_2 Čerenkov detector had to be cut for the new detectors.

The heavy gas detector





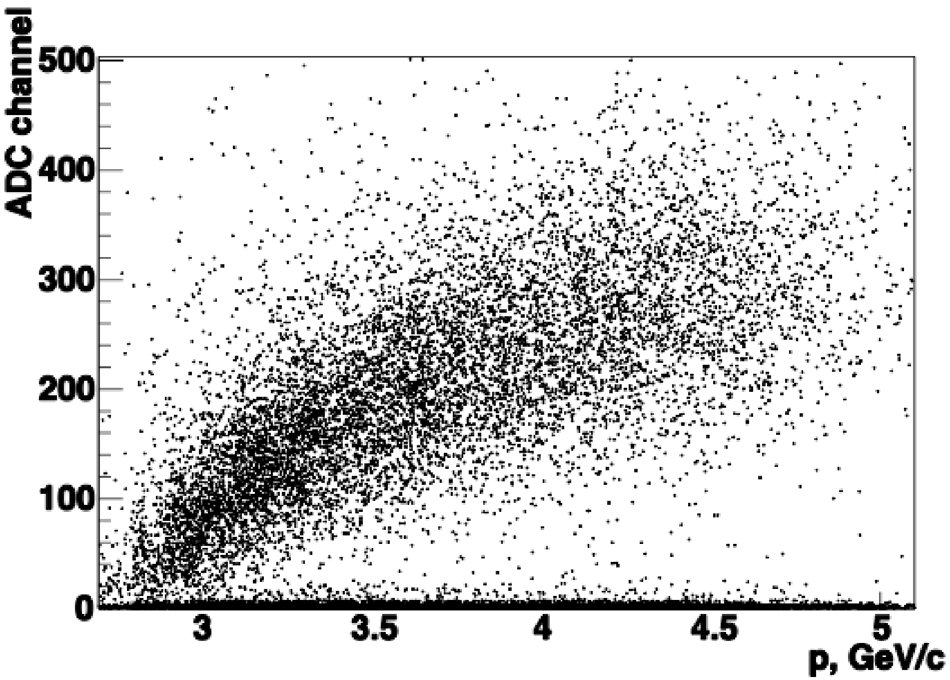
Photocathode
of 1 PM



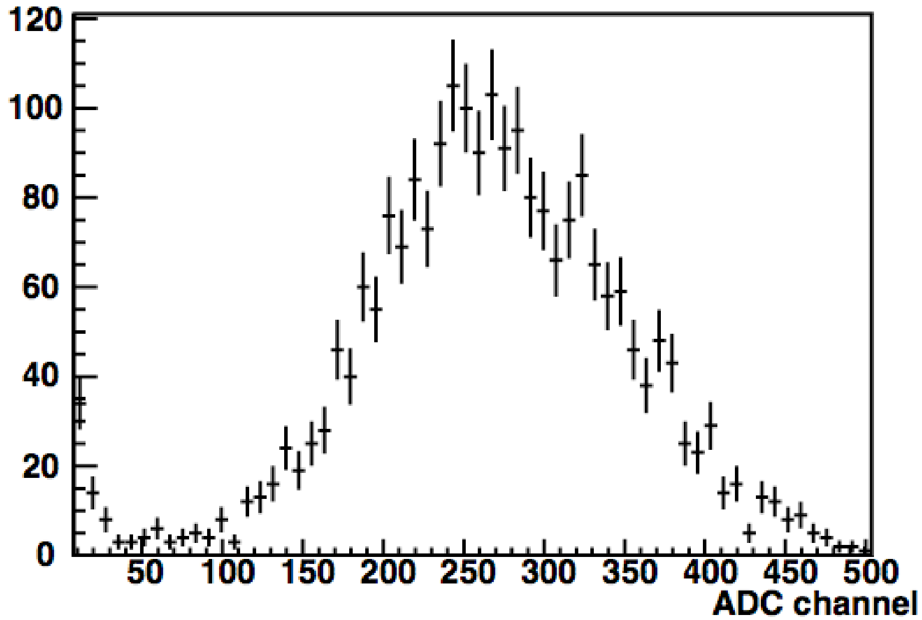
Laser test :
circles are simulation
and filled dots are
measured

Results from the heavy gas detector

Scatter-plot ADC channel vs. Momentum

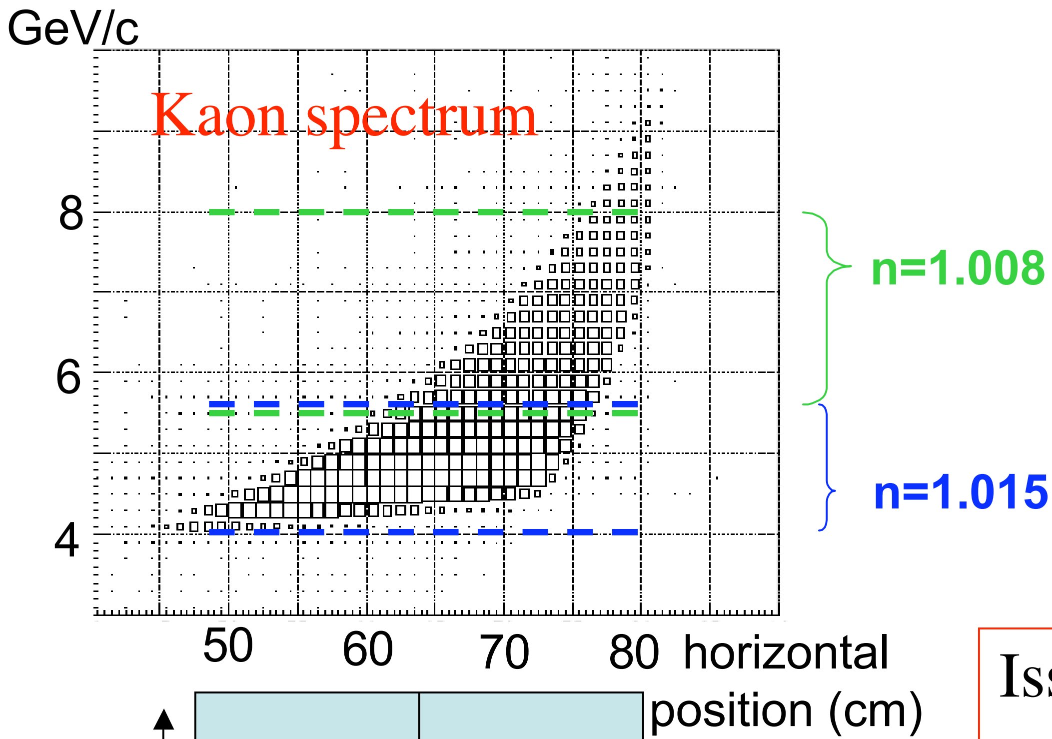


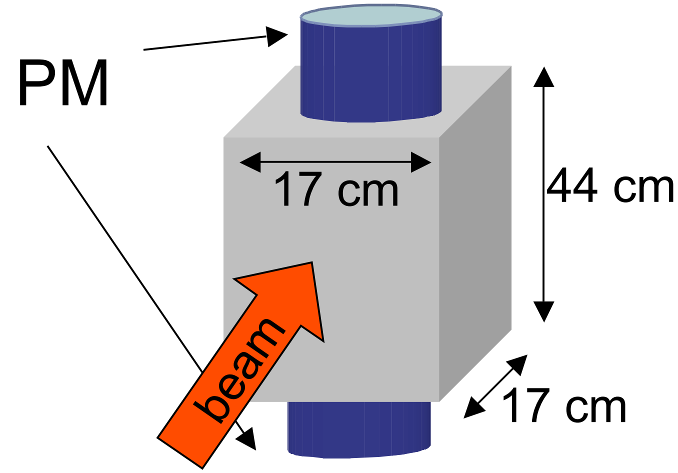
Integrated pulse height spectrum of one PM

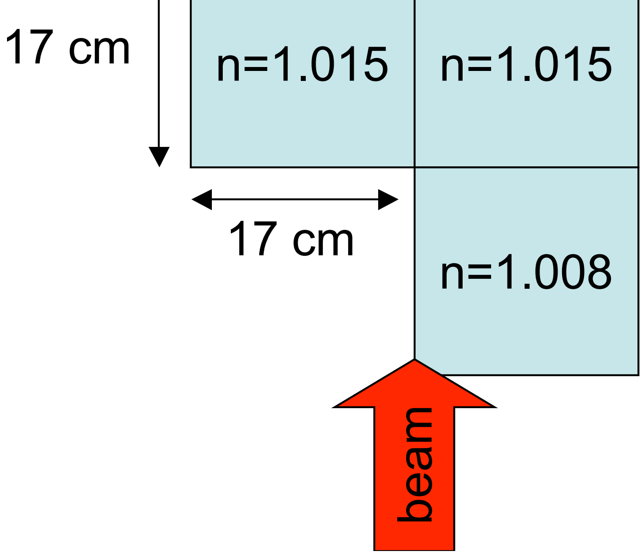


Efficiency for pion rejection is greater than 99.9 %

DIRAC's requirement for k-p separation



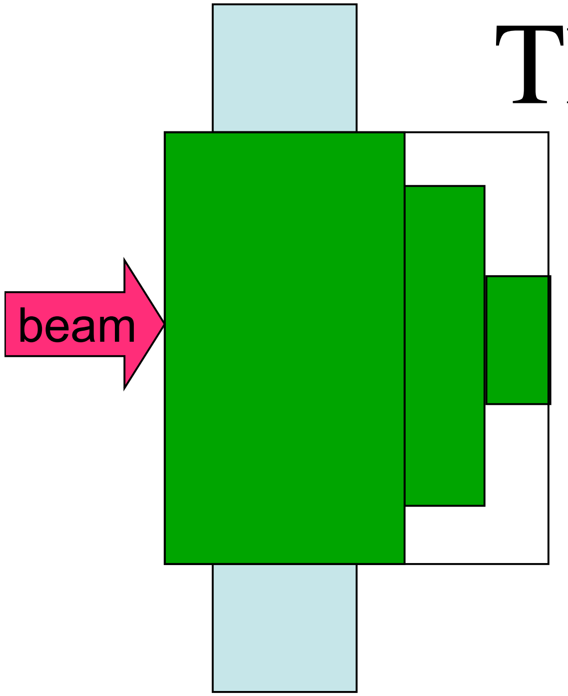


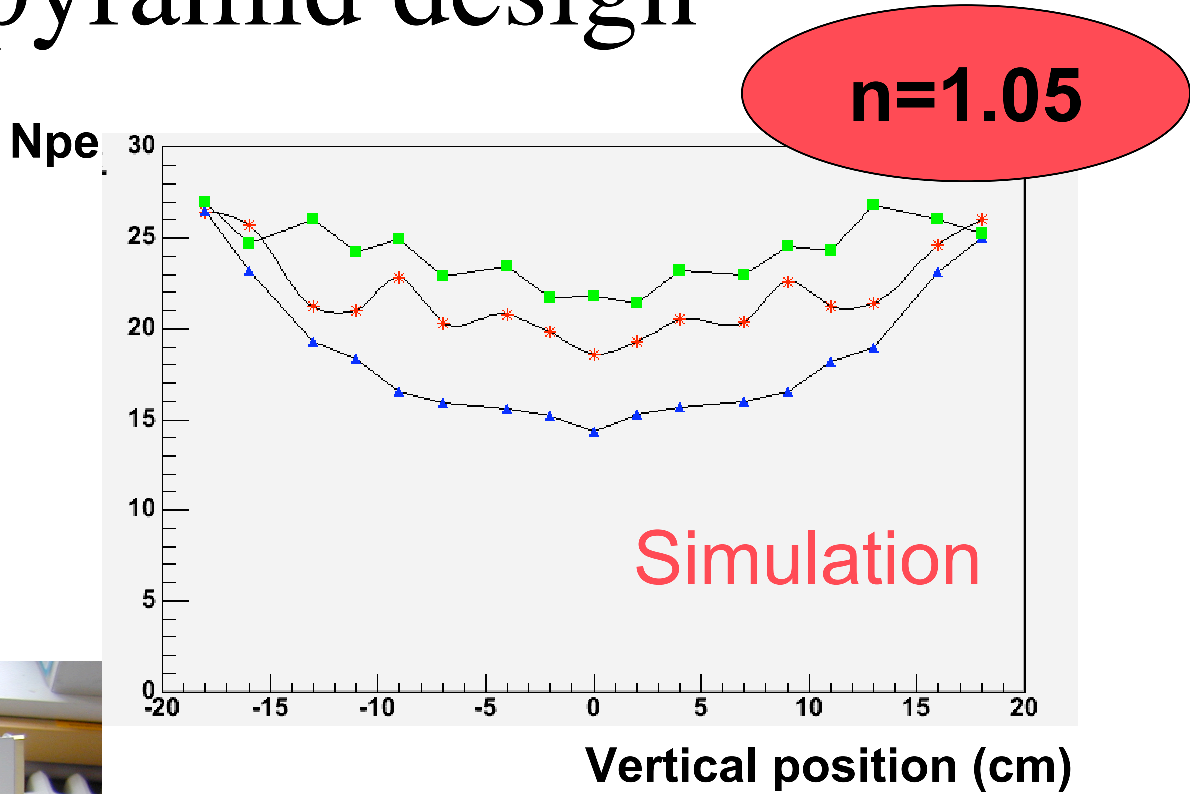


Issues :

- Distance between 2 PMs large
- For the n=1.008 module the light production is small
- kaons suppressed by a factor 6 compared to pions and protons

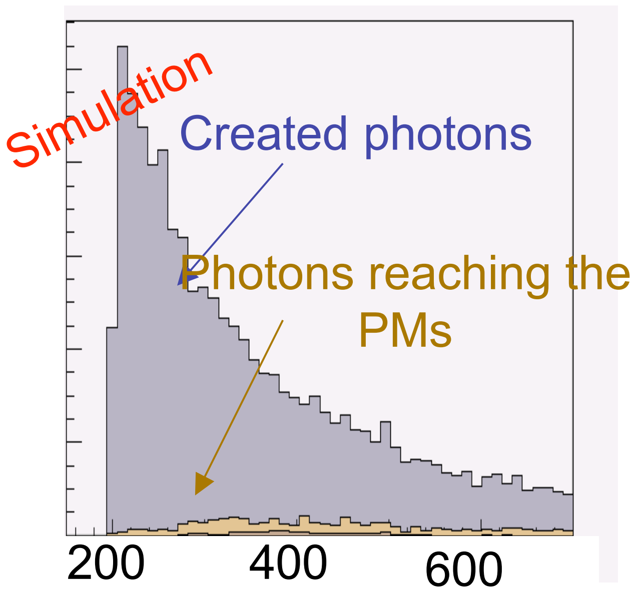
The pyramid design

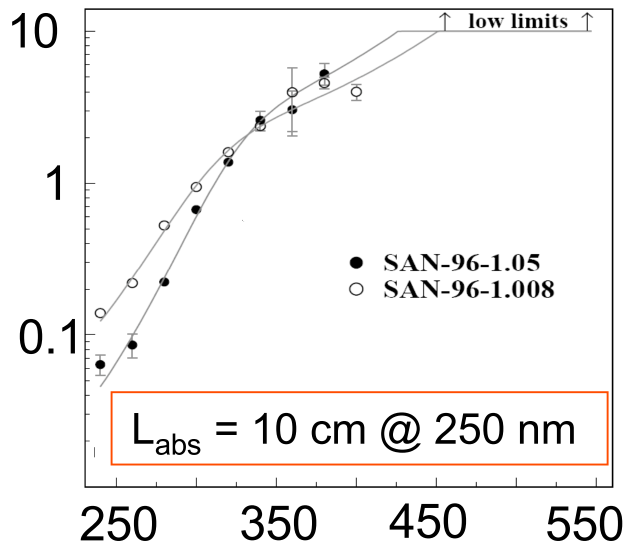


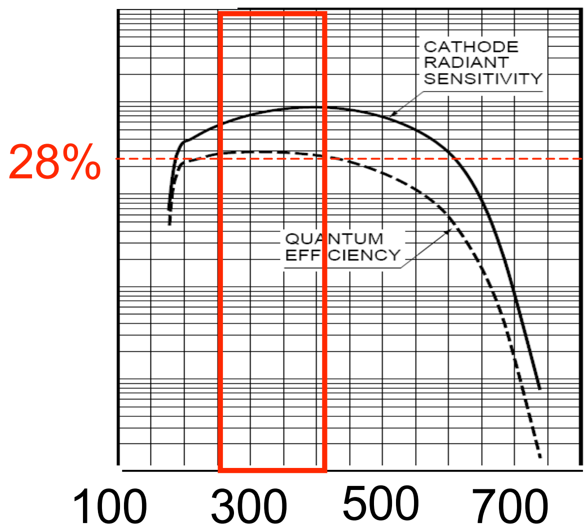


- In blue : box design.
- In red : Pyramid design with 2 layers of thickness 2 cm.
- In green : Pyramid design with 2 layers of thickness 4 cm.

Wavelength shifter (WLS) ?

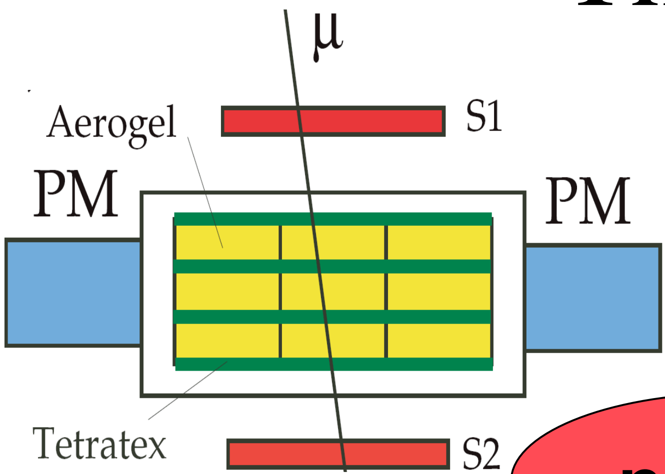


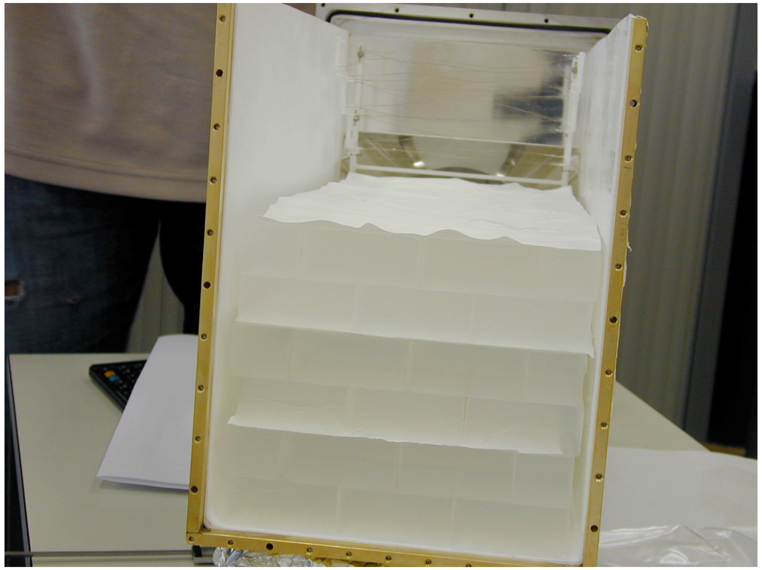


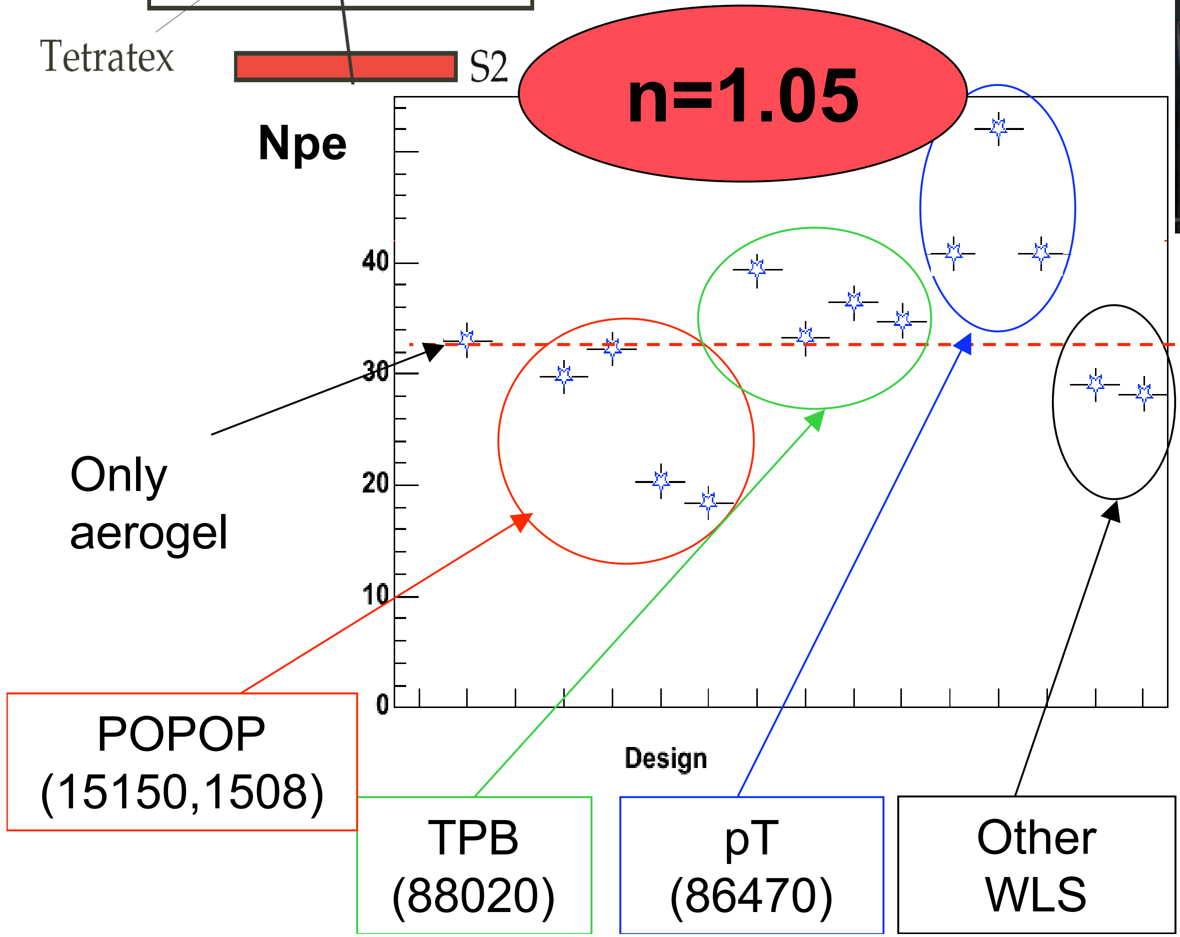


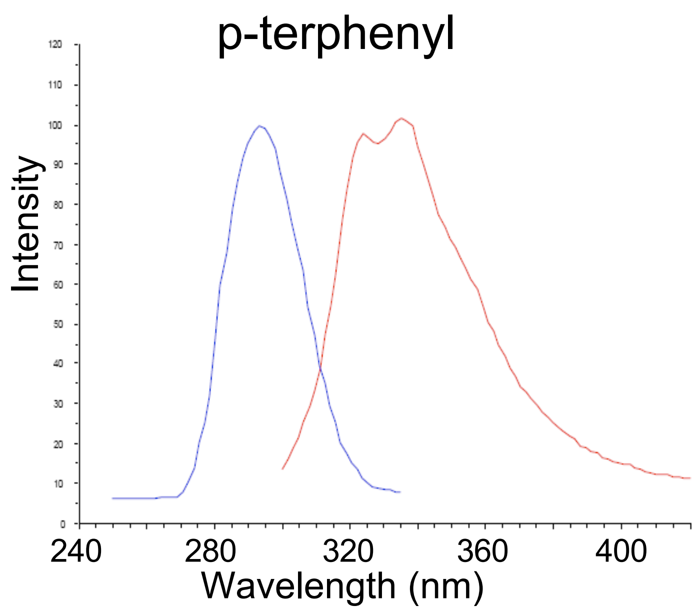
Shifting the light from UV to blue should improve the light collection efficiency

The sandwich design



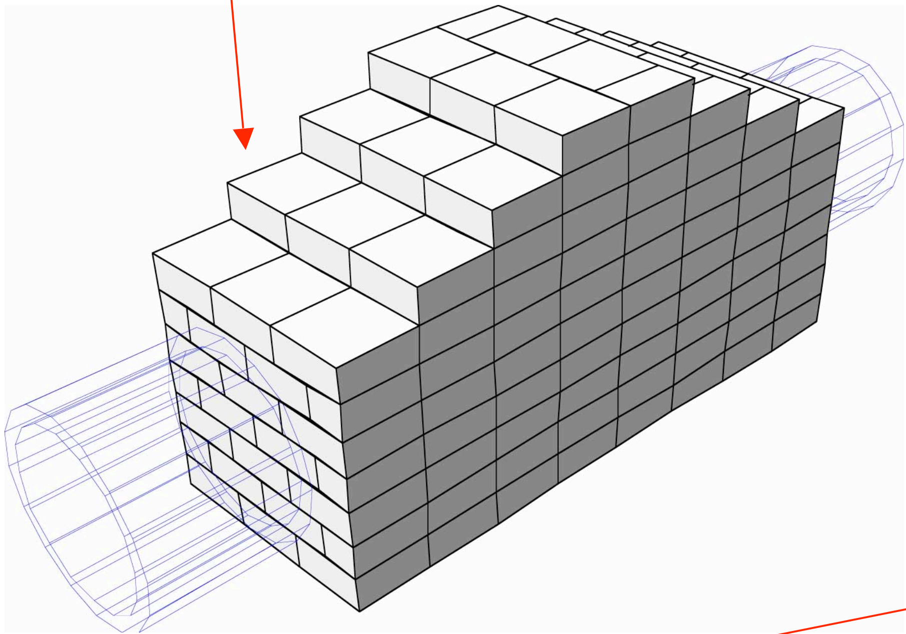


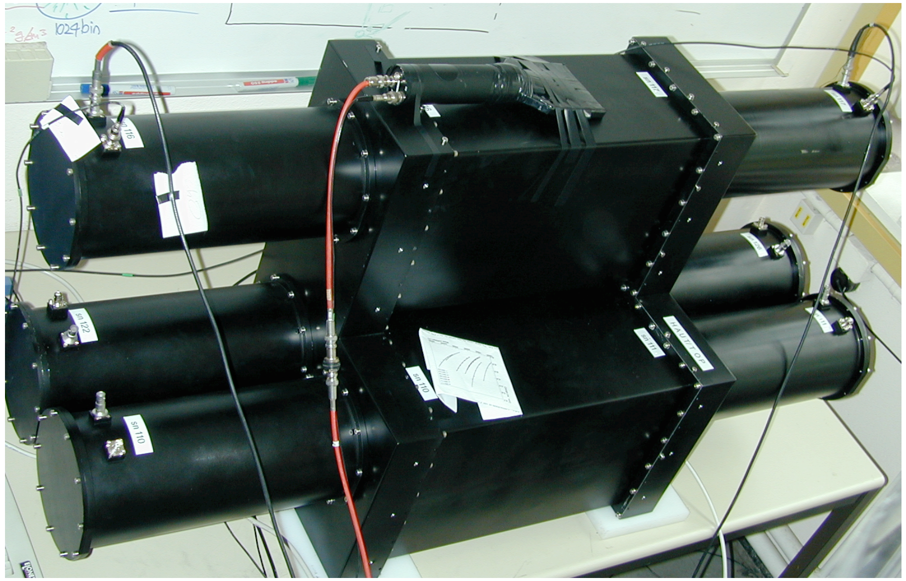


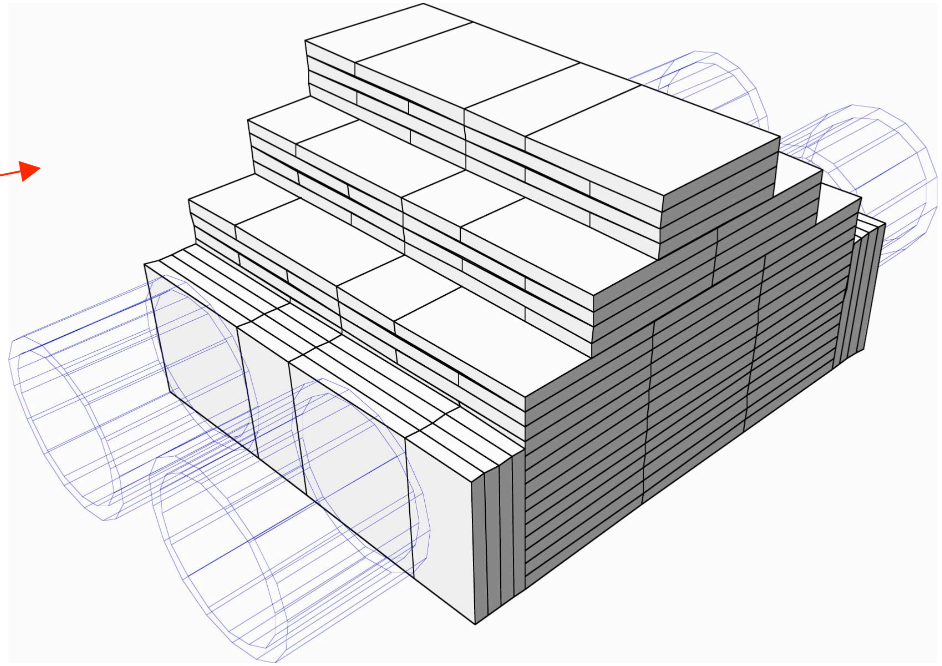


The aerogel counter

- Aerogel with n=1.008
- 14 liters (250 pieces)





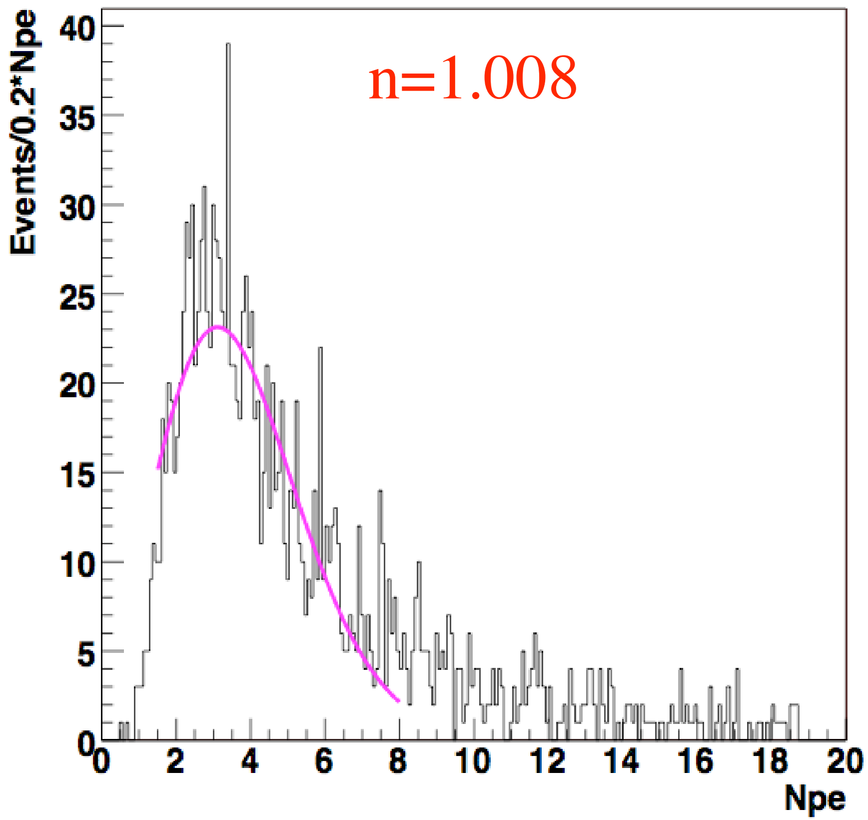


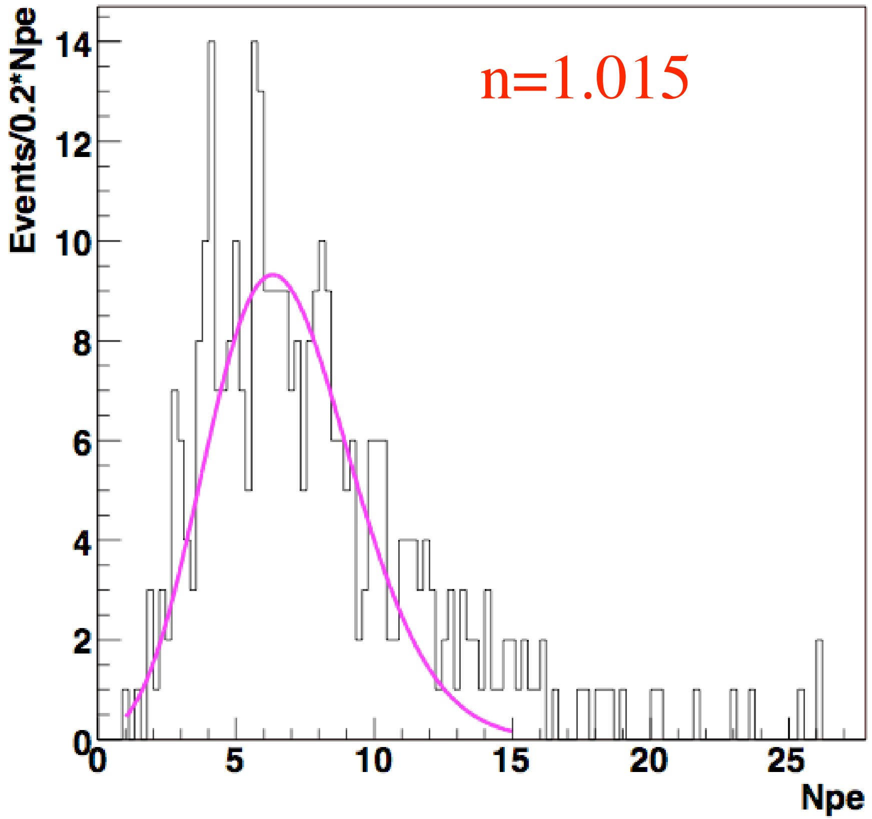
- Aerogel with n=1.015
- 24 liters (248 pieces)

Kaon signal

Kaon identification efficiency: 85-95 % for a proton rejection factor of 50.

Inefficiencies are mainly coming from the voltage divider of the PMs. → Will be changed for next run.





Expected number of πK-atoms

From Ni(2001) data: $N(\pi^+\pi^-)$=1600/month

Simulation (FRITIOF 7.02)

$N(\pi^+\pi^-)$ ~P(production) ·P(ionization)

$$\frac{N(\pi^+\pi^-)}{N(\pi^+K^- + \pi^-K^+)} \approx 15$$

DIRAC II detection efficiency improved by a factor 2

For Ni target (per month): $N(\pi^+\pi^-)$= 3200, $N(\pi^-K^+)$ +N(K$^-\pi$+) =190

For πK-atoms the ionization probability is 31% for Ni and 55% for Pt.

For Pt target : $N(\pi^-K^+) + N(K^-\pi^+)$ =340

Expected significance for run 2007:

3 σ for π^-K^+ and $K^-\pi^+$ separately

Outlook

- End of this run on the 10th of November
- Data taking for observation of π^-K^+-atoms and π^+K^--atoms (hopefully) in a few months
- Lifetime measurement of π^-K^+ and $K^- \pi^+$-atoms for the end of 2008
- DIRAC II is ready for interesting physics:
    - long-lived atoms
    - study of the possibility of K^+K^- atoms detection