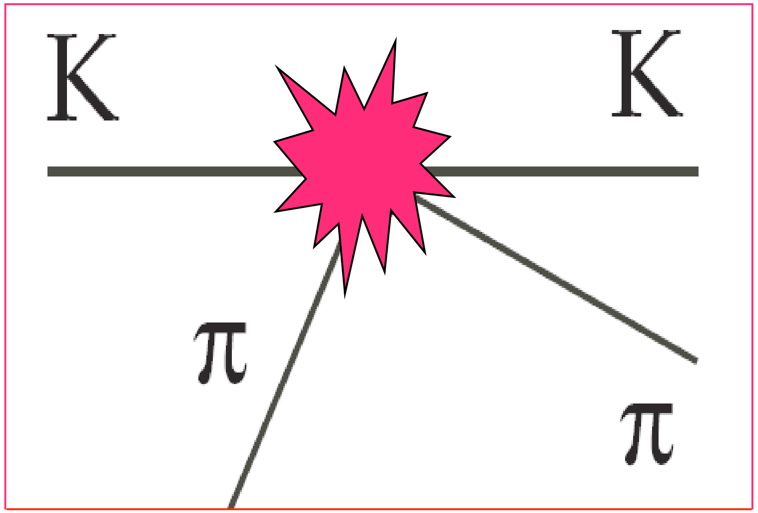
Search for Kπ-atoms with DIRAC II



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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

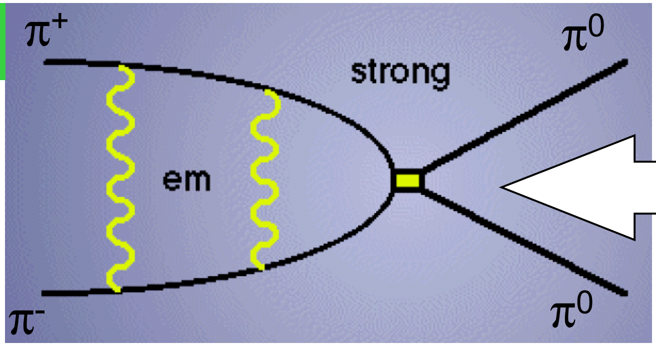
- Lifetime measurement of $\pi^+\pi^-$ atoms (pionium) in a model-independent way with precision better than 6%,which gives a precision for $|a_0 - a_2|$ better than 3%;

- Observation of $\pi^- K^+$ and π^+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:

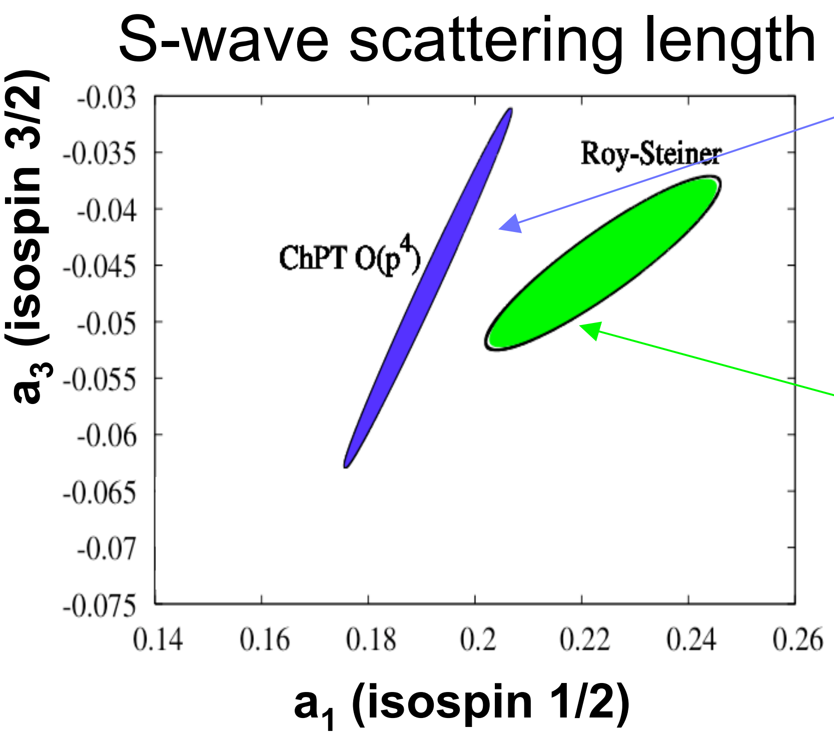
$$\frac{1}{\tau}=\frac{2\alpha^3}{9}p\left|a_0^0-a_0^2\right|^2(1+\delta)$$

The scattering length can be predicted using QCD ChPT,
τ= (2.9 ±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



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

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

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experiment

$$\left.\begin{array}{l} K^+ p \longrightarrow K^+ \pi^- \Delta^{++} \\ K^+ p \longrightarrow K^+ \pi^+ n \end{array}\right\}$$

e.g.

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

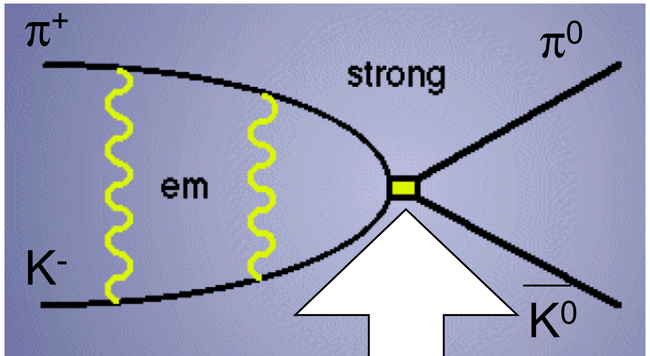
$$m_\pi(a_0^{1/2} - a_0^{3/2}) \simeq 0.475 \pm 0.0013$$

DIRAC's approach

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

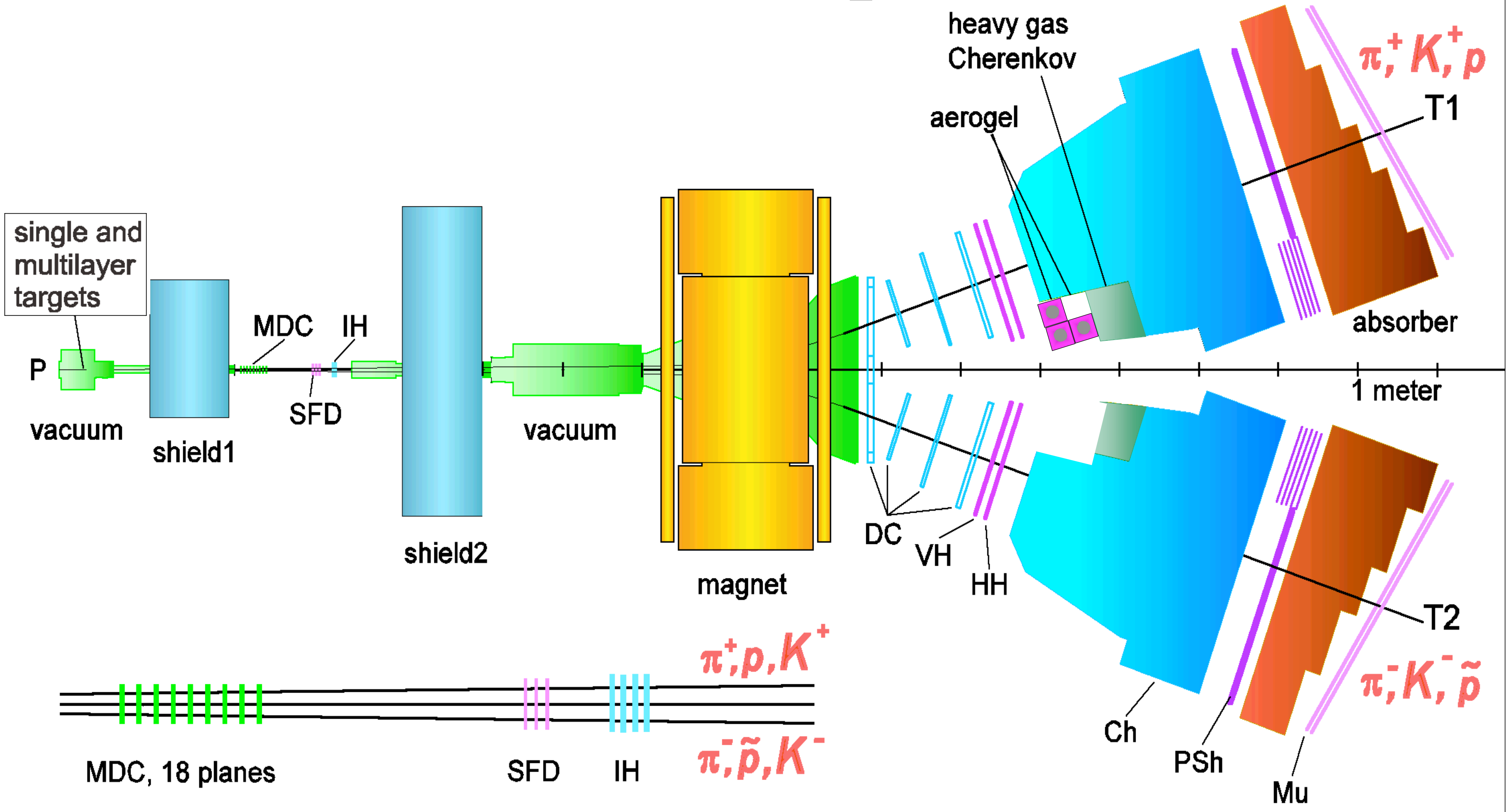
The dominant decay channel of πK-atoms

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



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?

Kaon identification

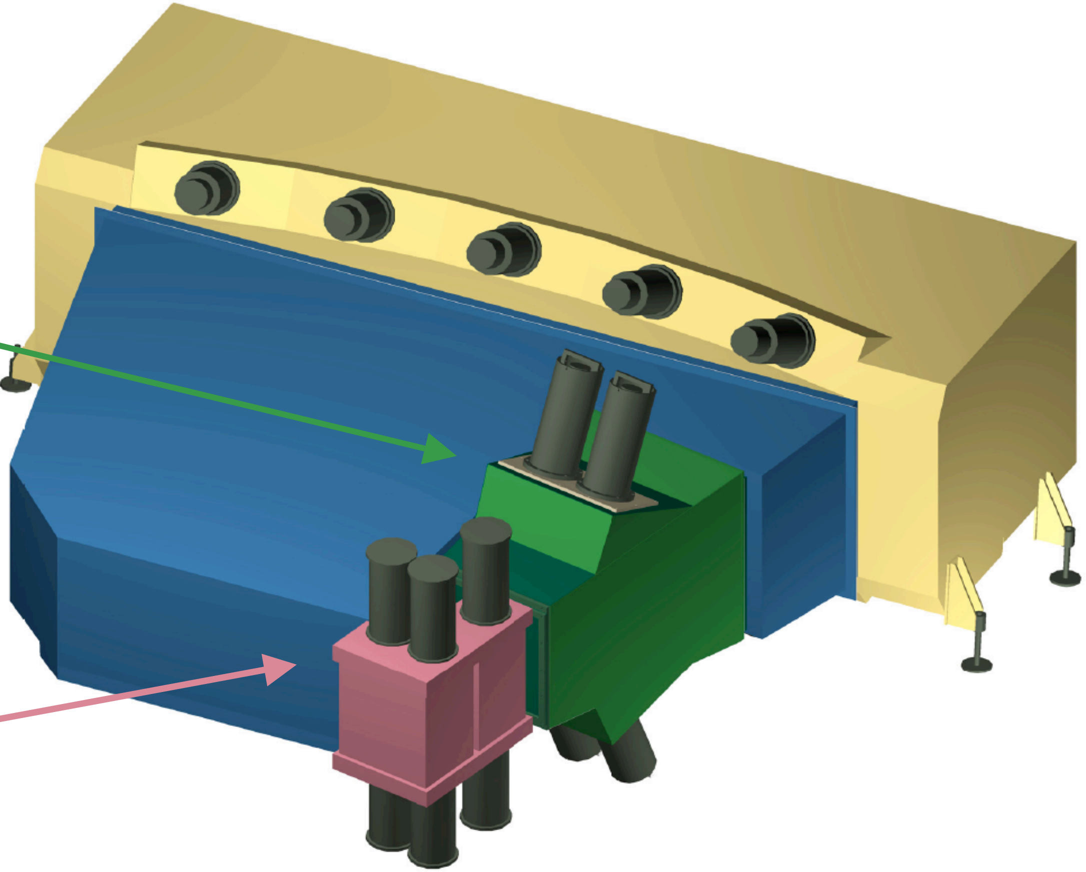
- New aerogel čerenkov detector for kaon-proton separation
- New heavy gas C_4F_{10} čerenkov detector for kaon- pion separation

Detection efficiency x 2

- 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).

The Čerenkov detectors

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

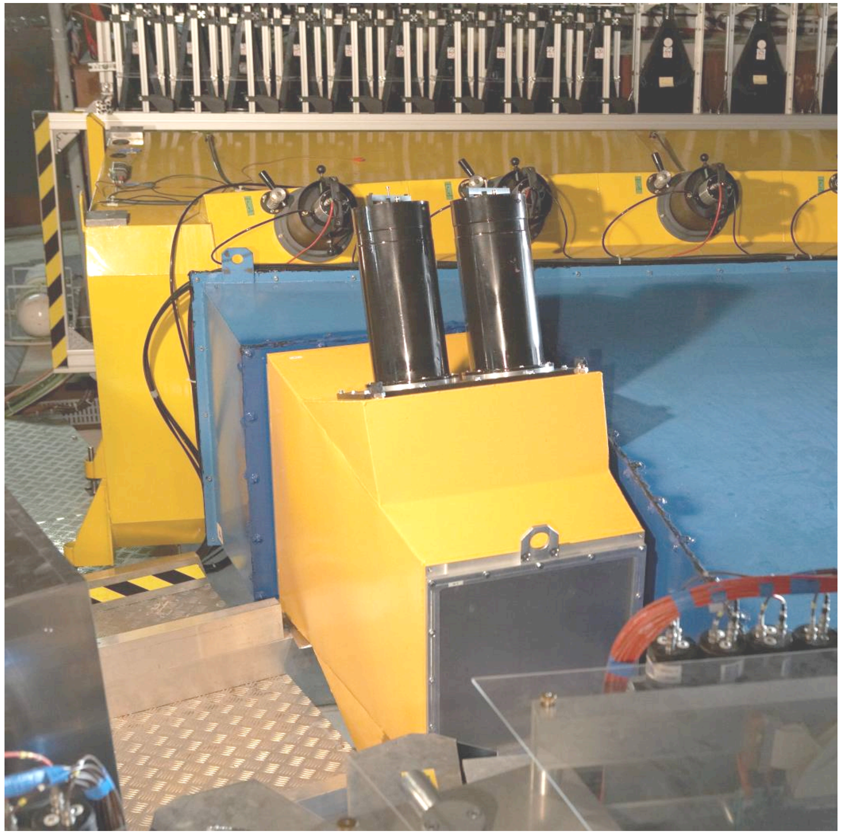


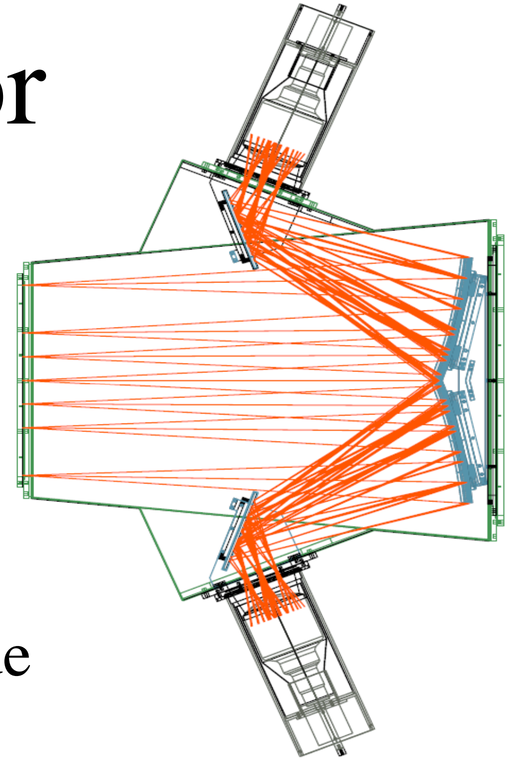
3 aerogel modules in left arm :

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

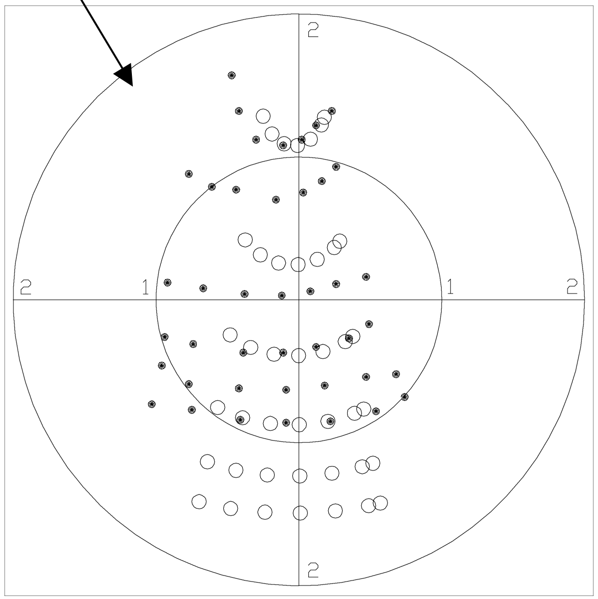
N_2 Čerenkov detector had to be cut for the new detectors.

The heavy gas detector





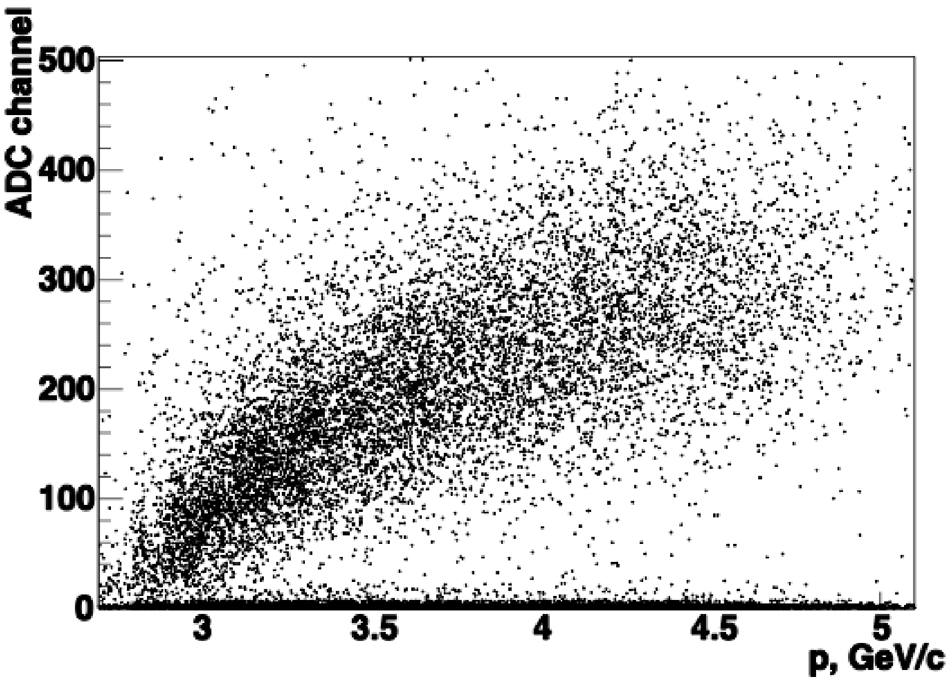
Photocathode of 1 PM



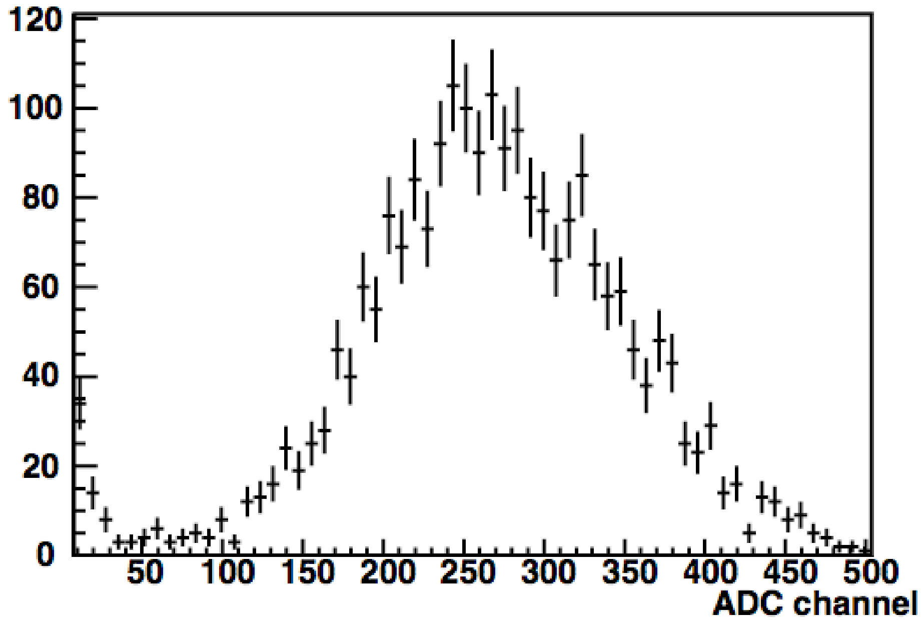
Laser test :
circles are simulation and filled dots are measured

Results from the heavy gas detector

Scatter-plot ADC channel vs. Momentum

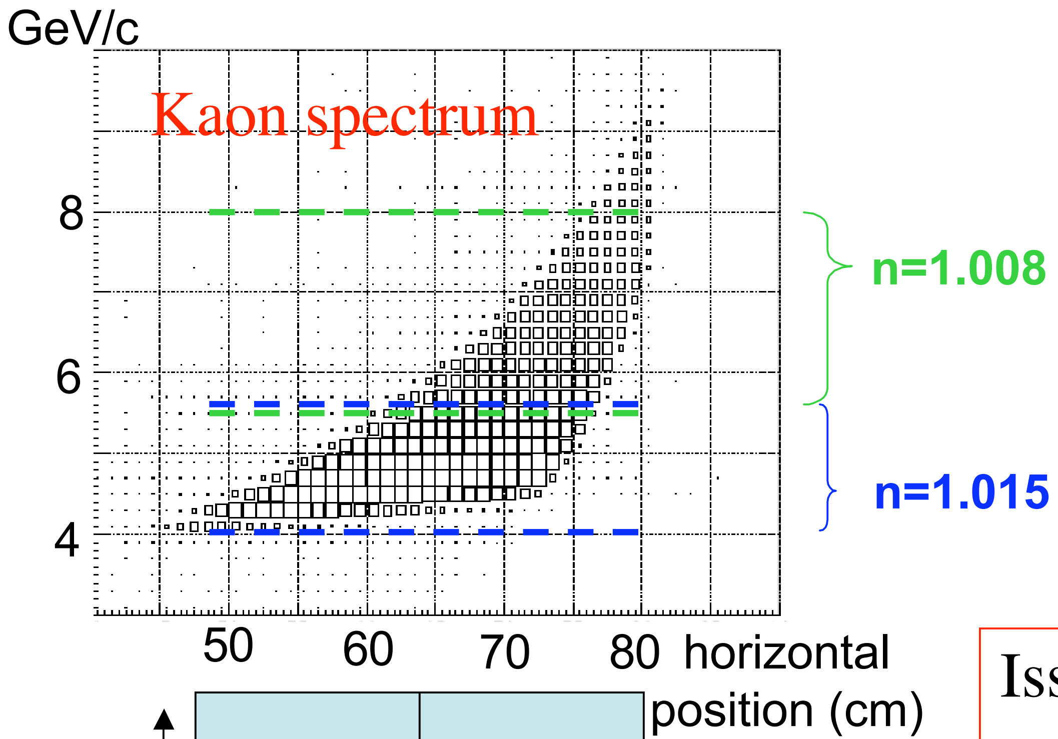


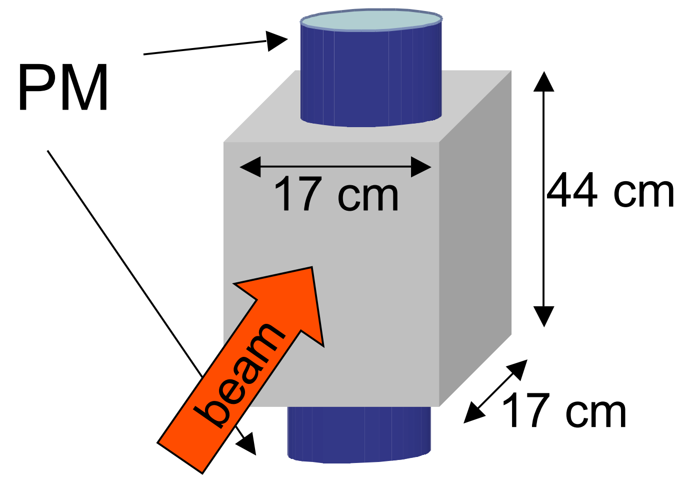
Integrated pulse height spectrum of one PM

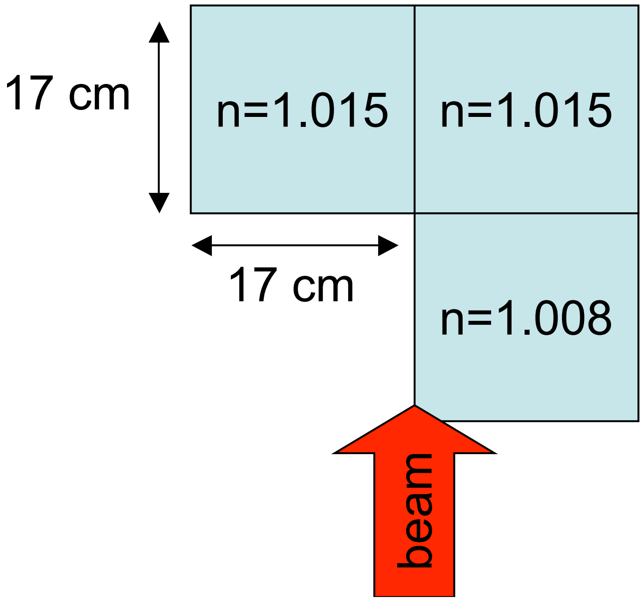


Efficiency for pion rejection is greater than 99.9 %

DIRAC's requirement for k-p separation



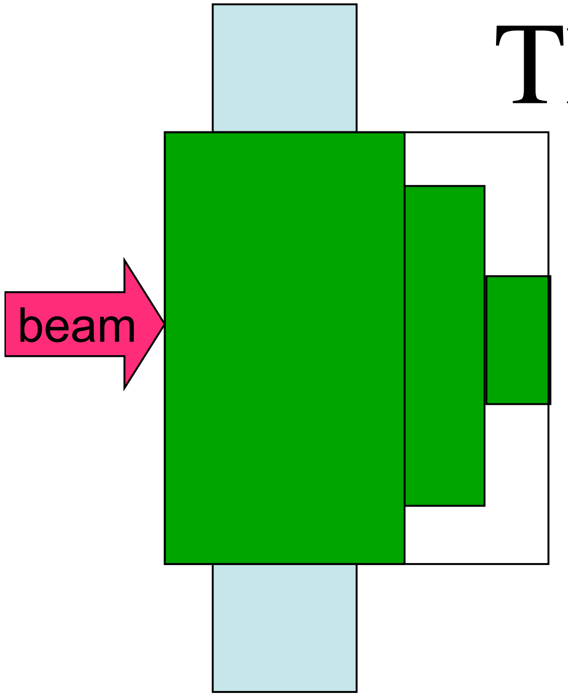


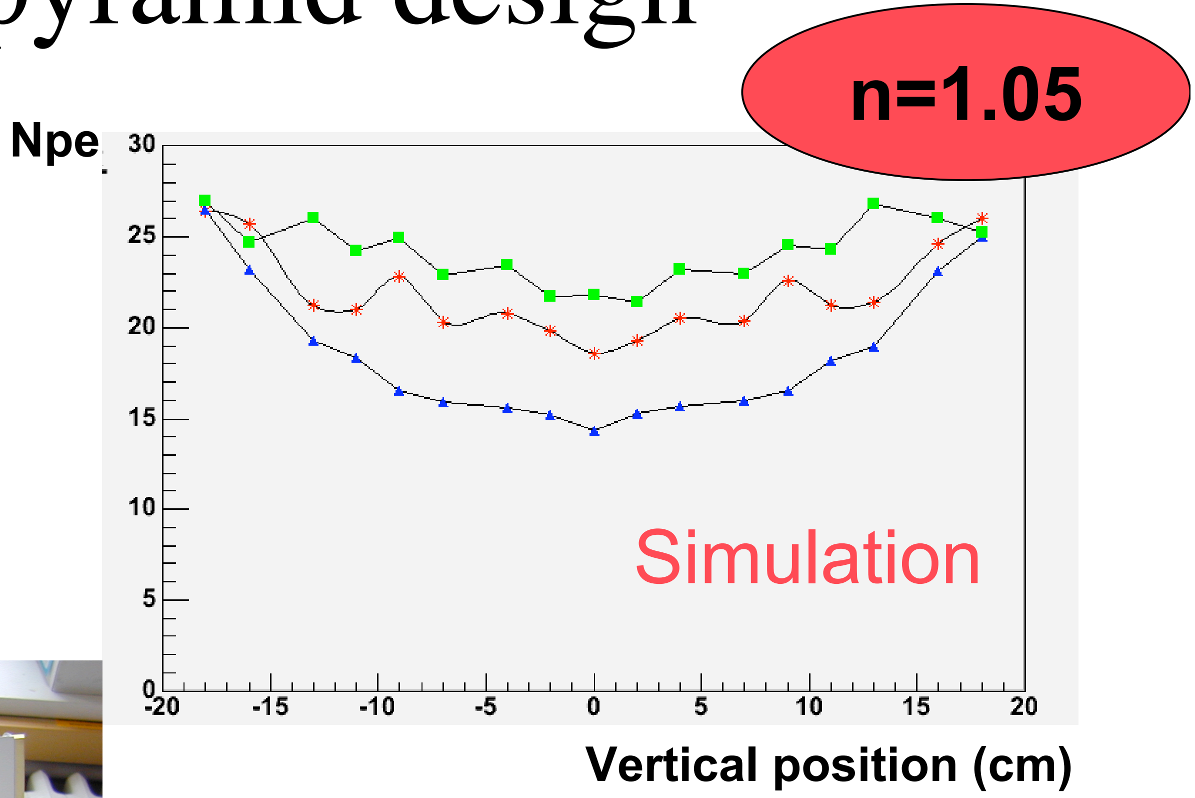


Issues :

- 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

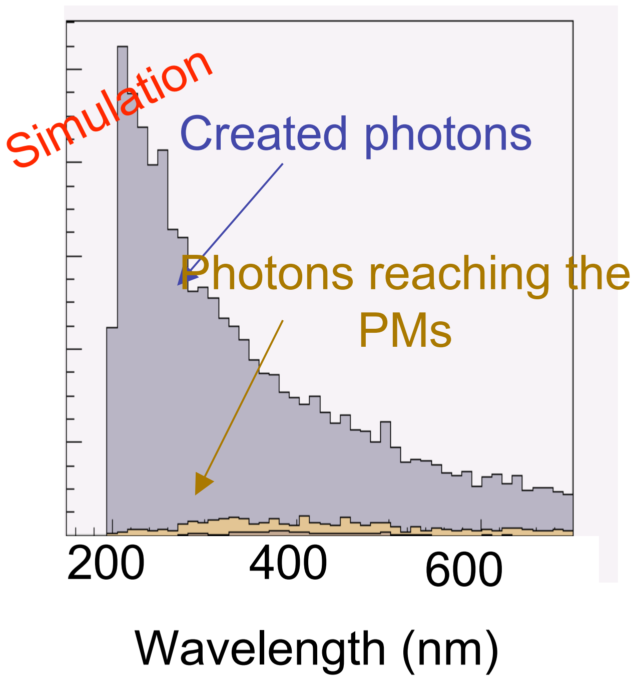
The pyramid design

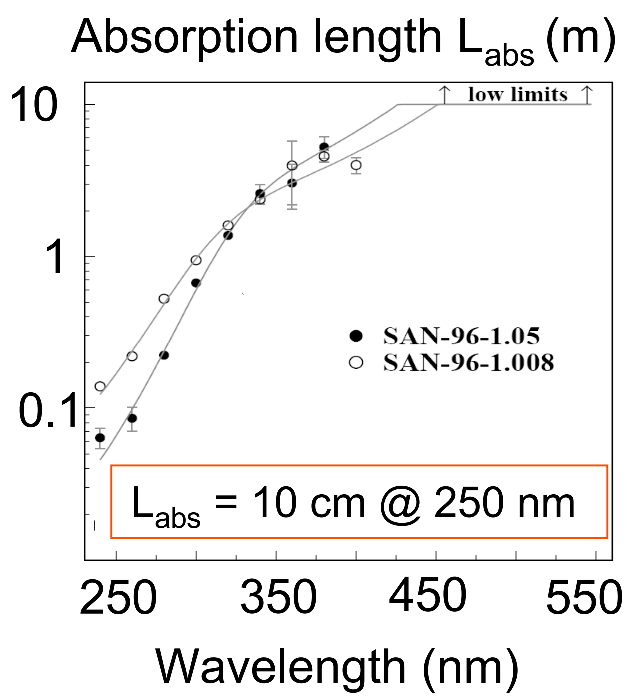


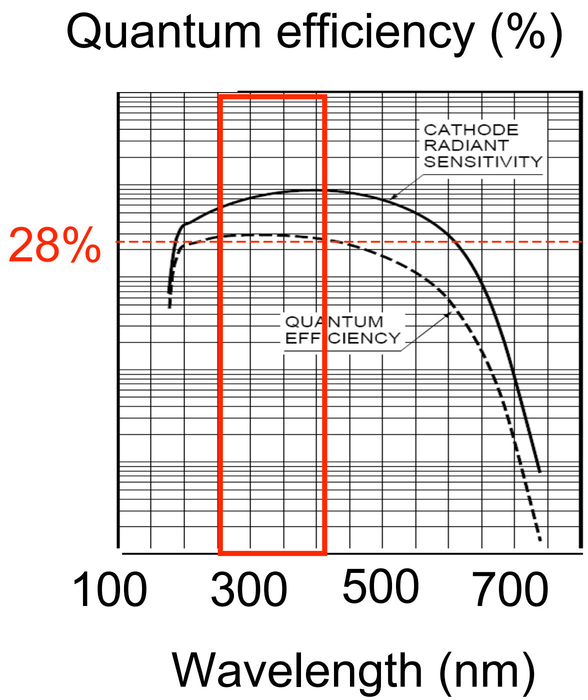


- In blue : box design.
- In red : Pyramid design with 2 layers of thickness 2 cm.
- In green : Pyramid design with 2 layers of thickness 4 cm.

Wavelength shifter (WLS) ?

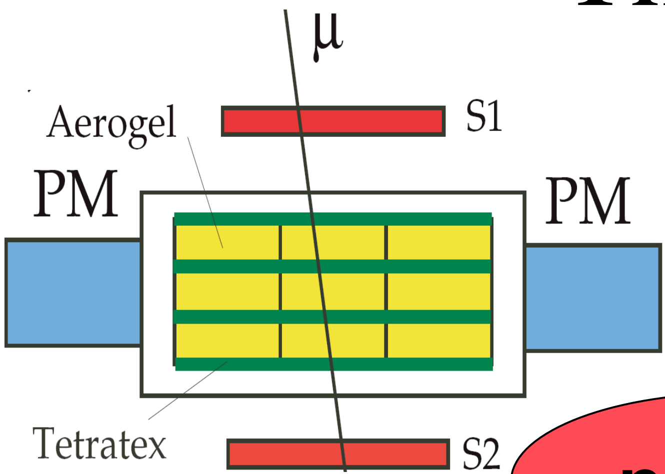


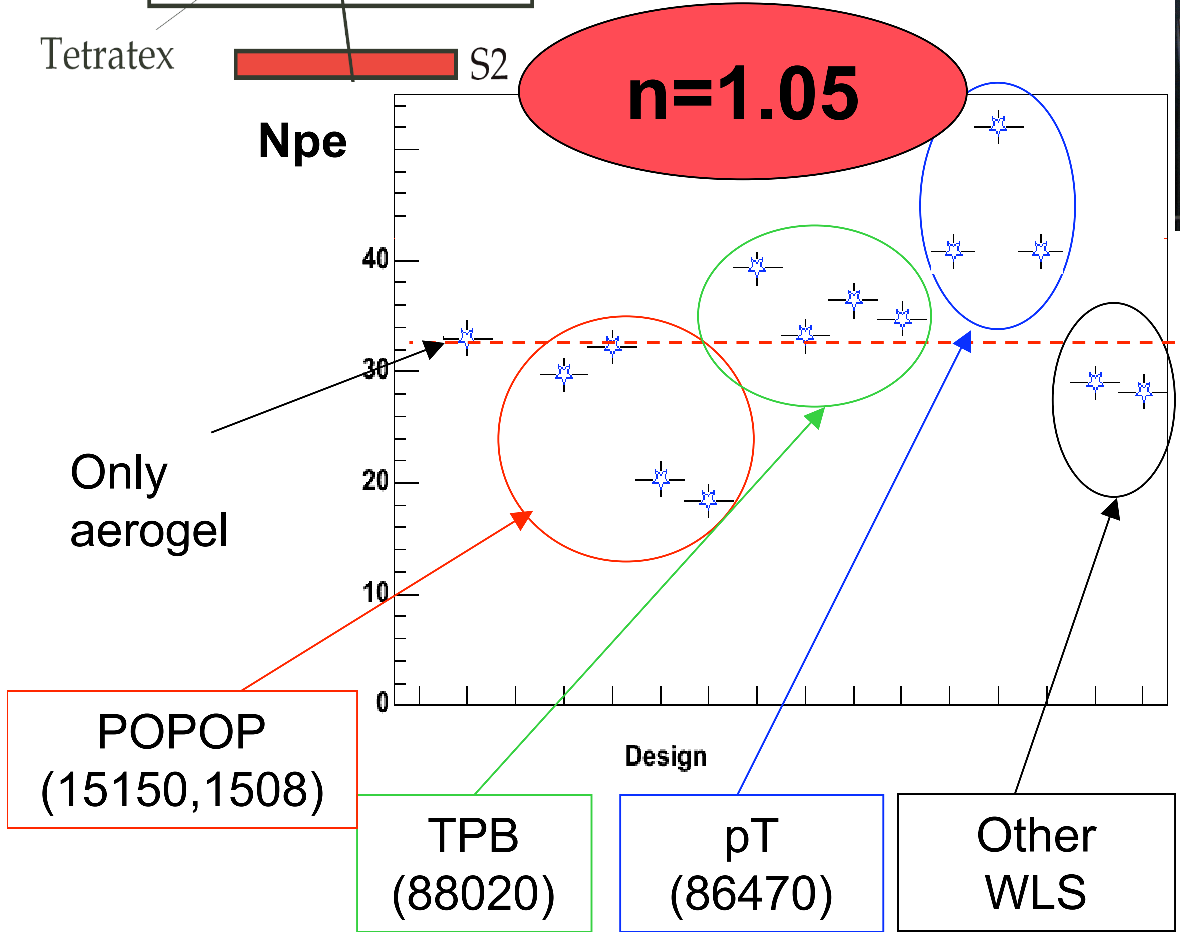


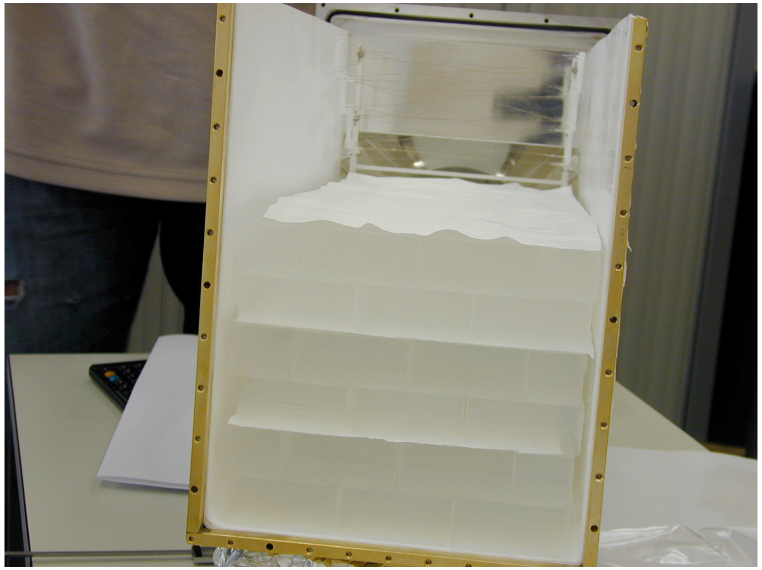


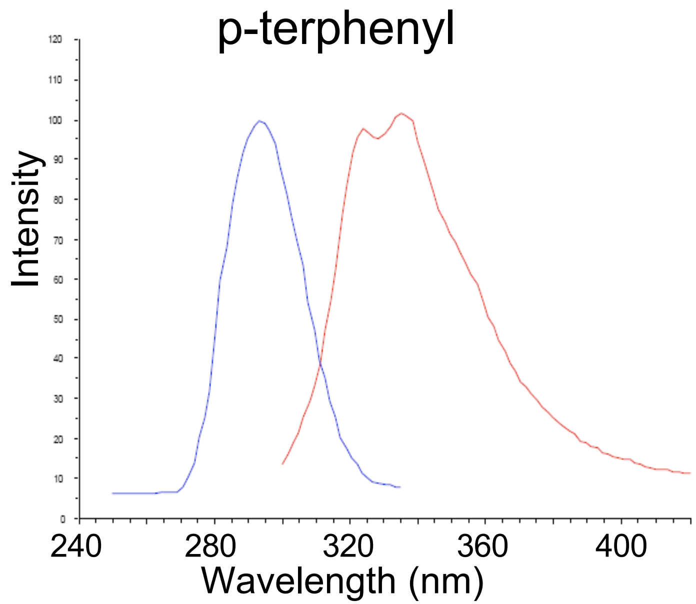
Shifting the light from UV to blue should improve the light collection efficiency

The sandwich design



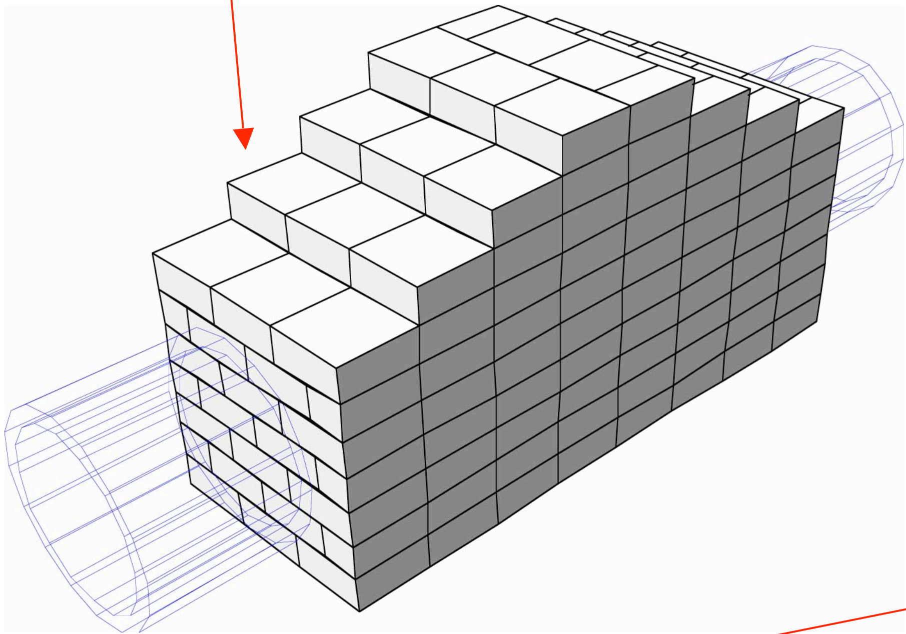


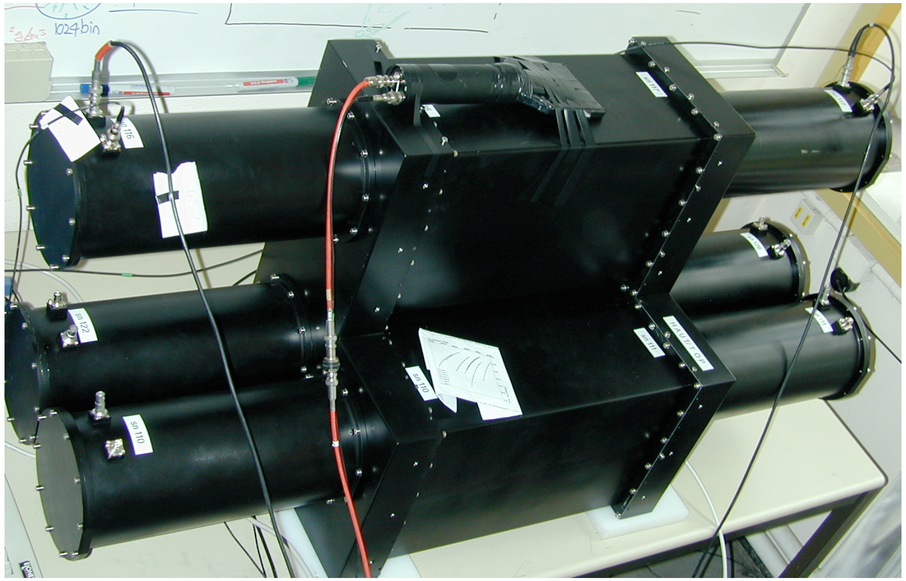




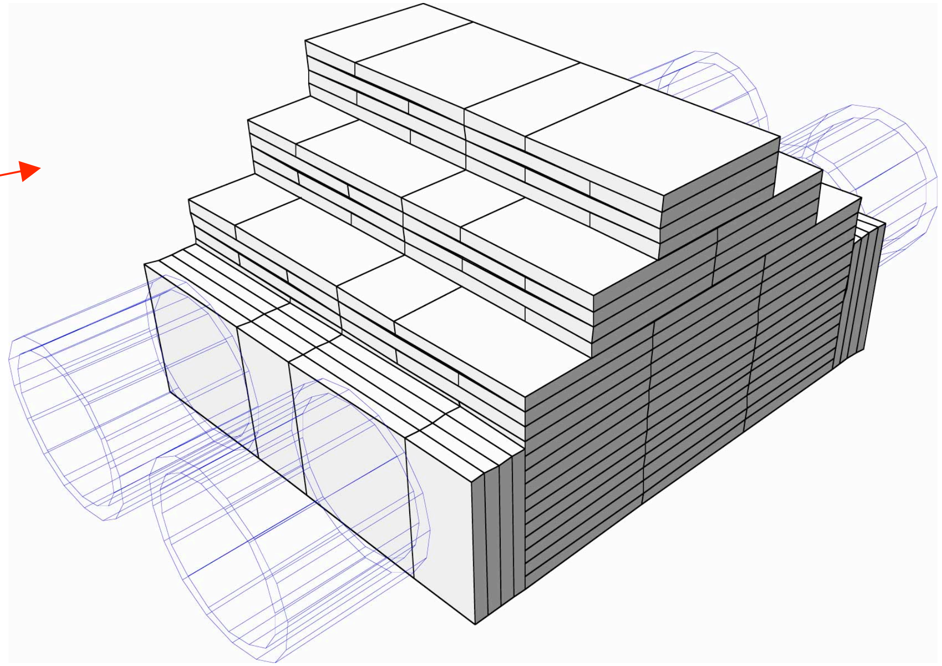
The aerogel counter

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





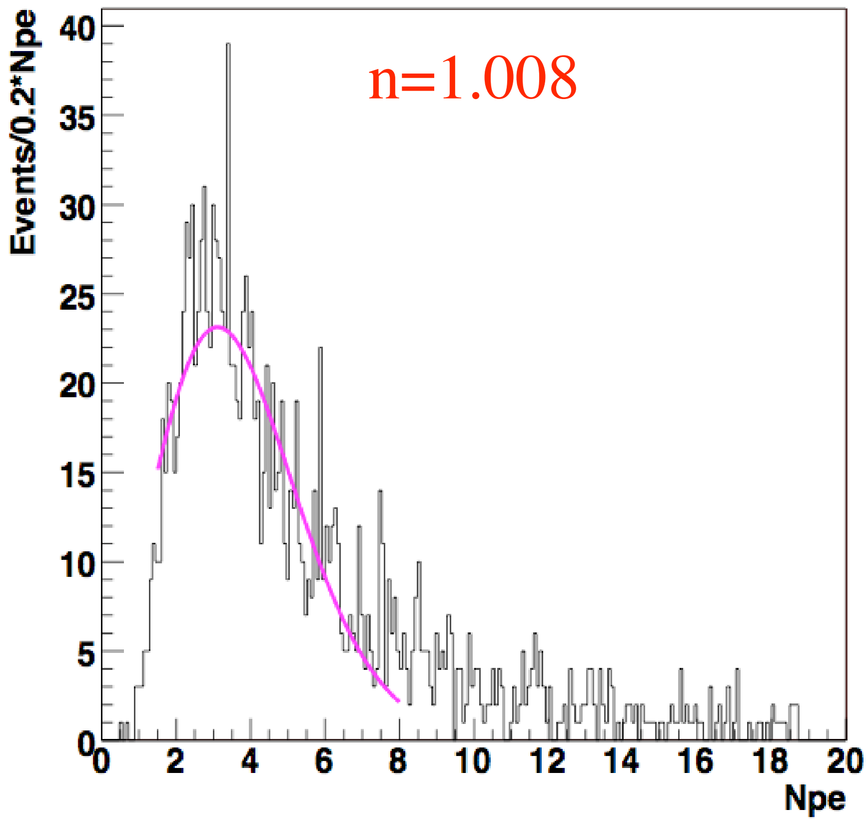
- Aerogel with n=1.015
- 24 liters (248 pieces)

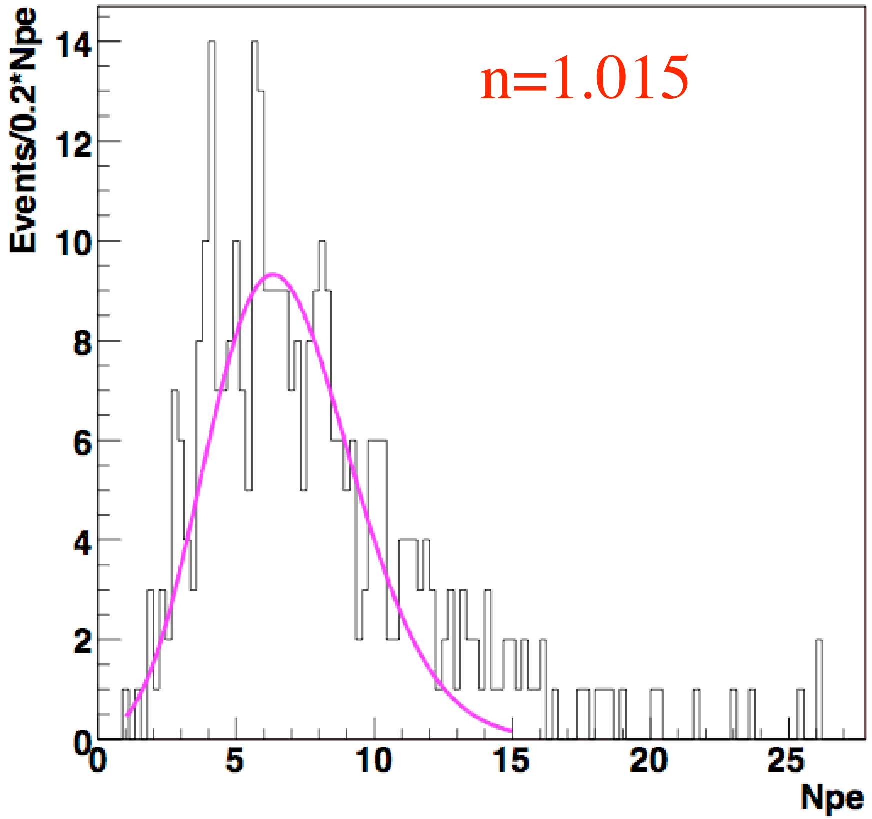


Kaon signal

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)

$N(\pi^+\pi^-) \sim P(\text{production}) \cdot P(\text{ionization})$

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

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 10^{th} 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