Development of an Aerogel Cherenkov Counter for the J-PARC E16 Upgrade

課題番号：22105516（平成22年度～23年度）
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- Motivation
- Aerogel Cherenkov Counter
- Present Status
- Summary

新学術領域「多彩なフレーバーで探る新しいハドロン存在形態の包括的研究」領域研究会
@ 理研 2011/02/28-03/01

Motivation

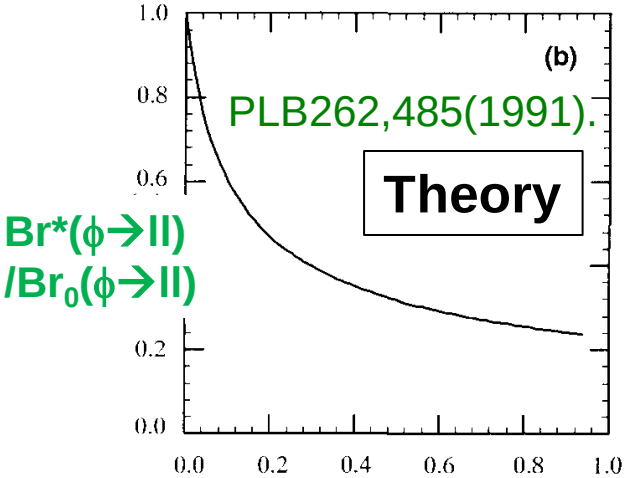
- **J-PARC E16 experiment**
  → measures in-medium ϕ-meson modification in **di-electron spectrum**

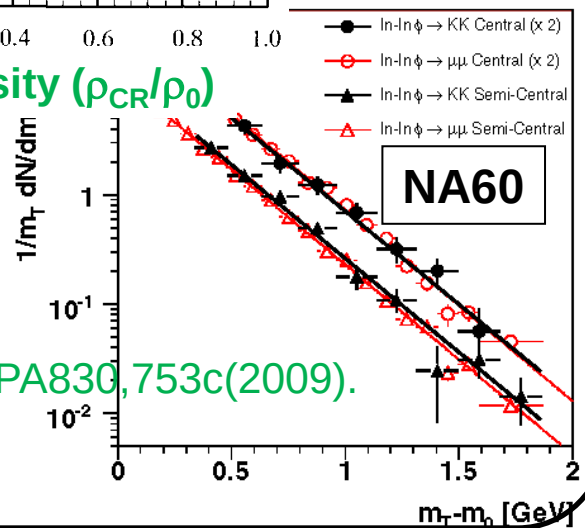
topics of the ϕ-meson
- ✓ di-lepton spectrum
- ✓ Γ_{ll} vs Γ_{KK} (ϕ-puzzle)

- **K^+K^- measurement in the E16 experiment is very important**

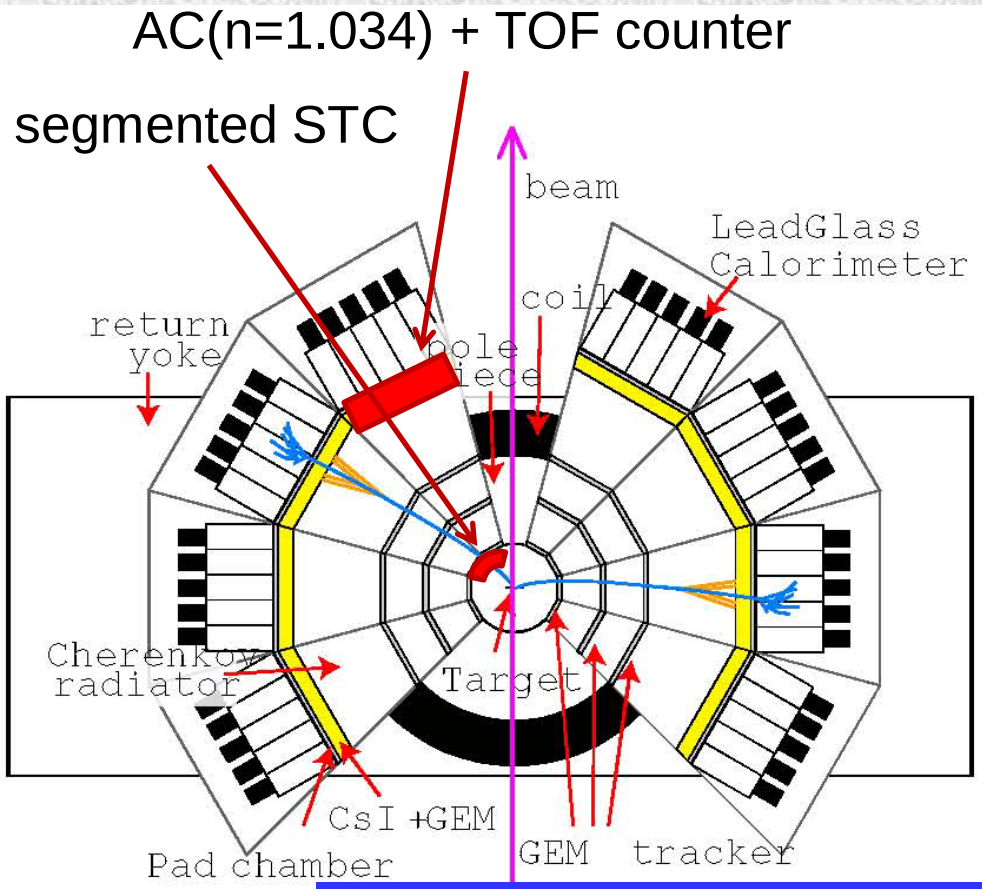
installation of Kaon detectors in the E16 spectrometer is desired

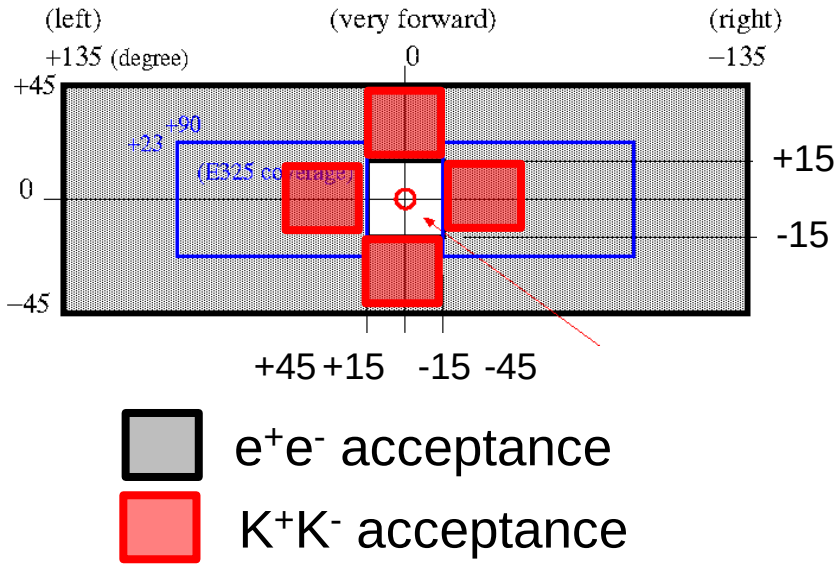
Do decay widths of ϕ→ll / KK change in nuclear matter caused by ϕ / K spectral modification?





Forward Kaon Spectrometer





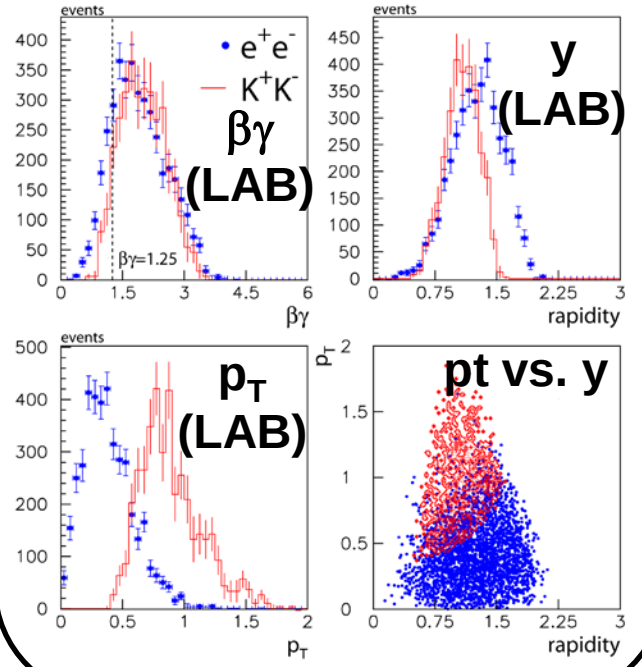
--- Requirements ---

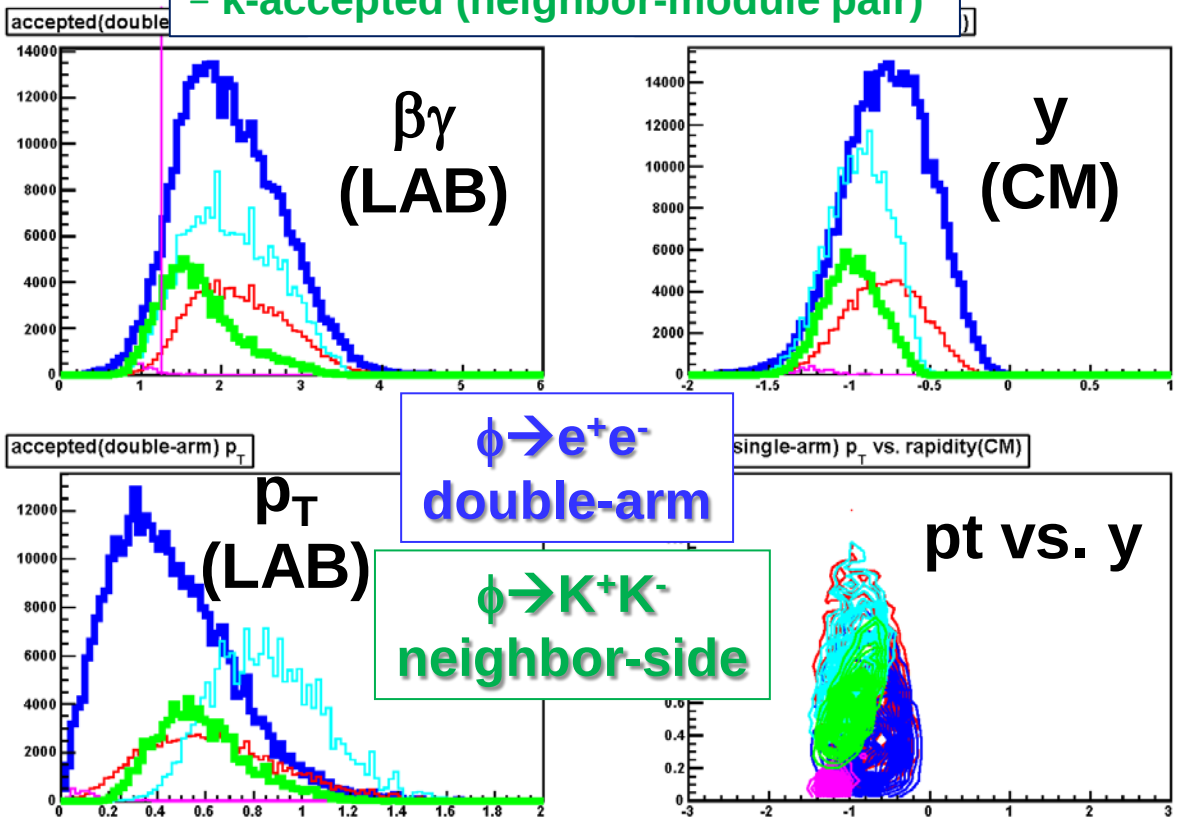
1. **threshold type AC for kaon trigger (veto counter)**
2. **work in magnetic field**
3. **small & compact**

$\phi \rightarrow e^+e^-/K^+K^-$ acceptance

- e-accepted (double-arm)
- e-accepted (single-arm)
- k-accepted (opposite-module pair)
- k-accepted (same-module pair)
- k-accepted (neighbor-module pair)

E325 acceptance

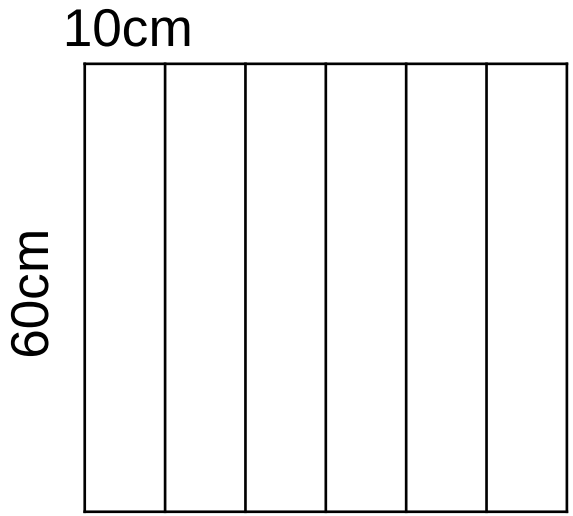




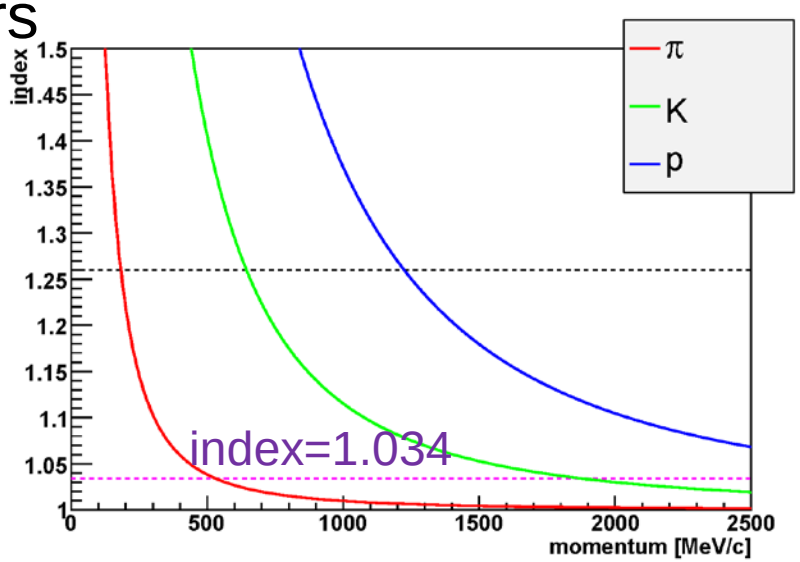
Improvement of the acceptance overlap between e^+e^- and K^+K^-

AC design

- use n=1.034, as same as KEK-PS E325
- 60x60cm^2 divided by 6 (or 10) sectors

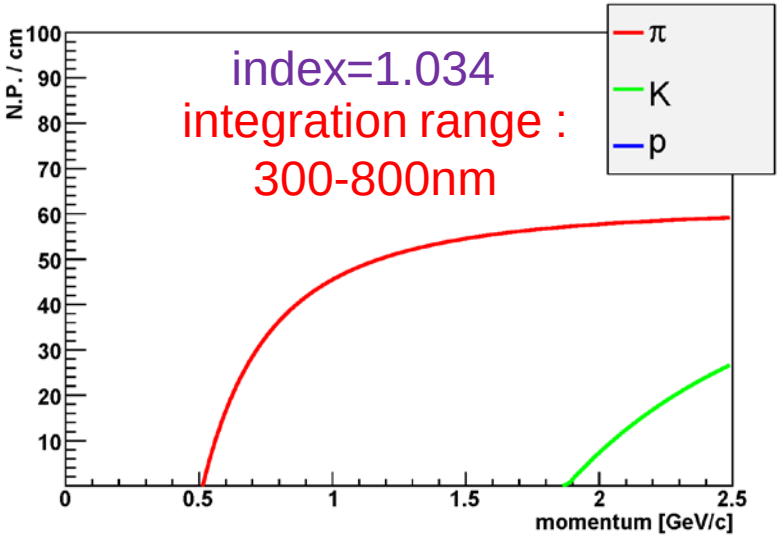


X 4 modules



readout

WLS + fiber + (FM)PMT



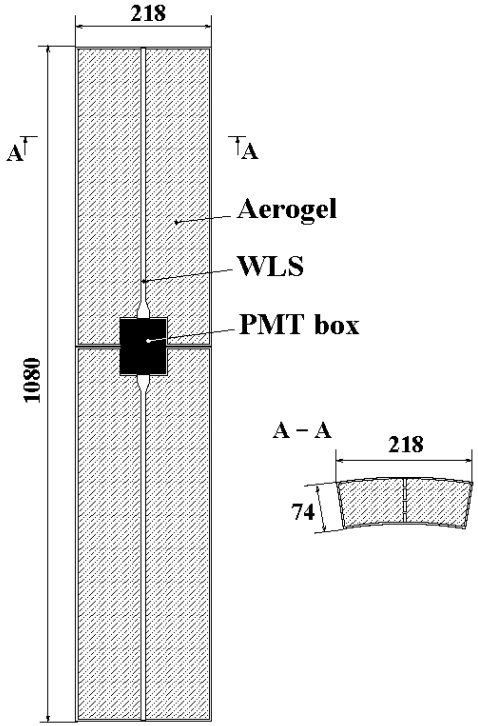
Goal : construct a prototype of ¼ size module

Some Hints in detector development in Russia?

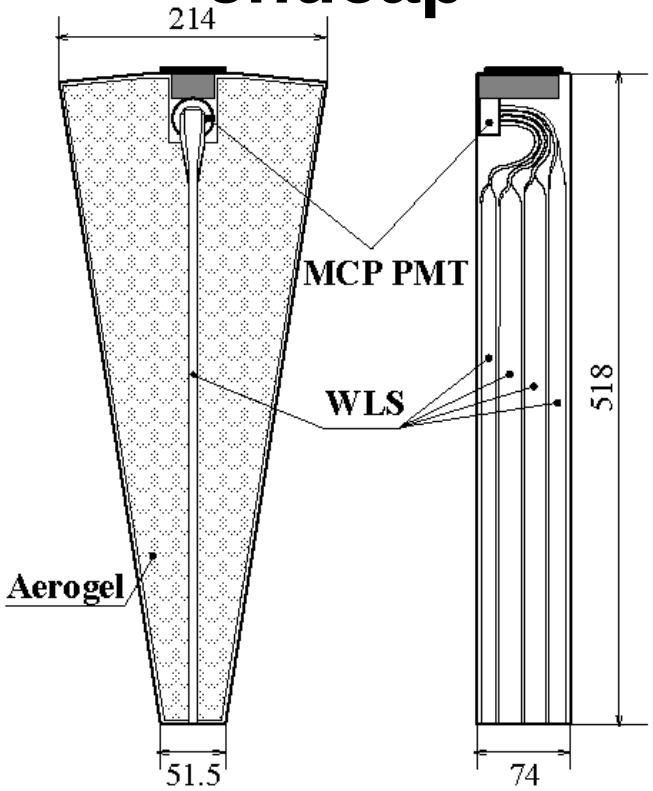
arXiv:hep-ex/0106016

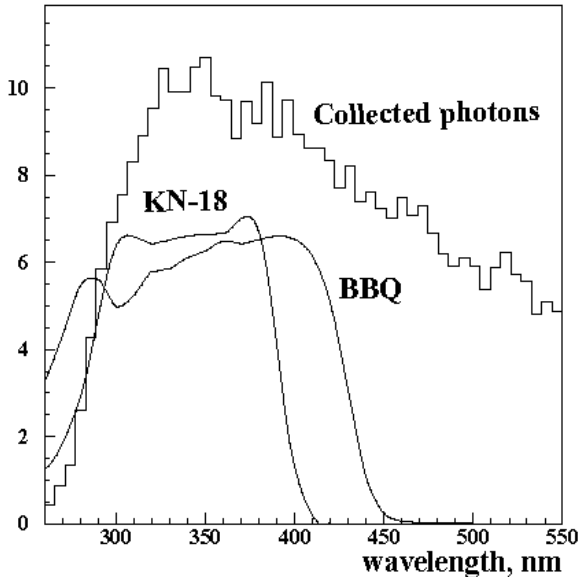
candidate for PEP-N detector @ SLAC

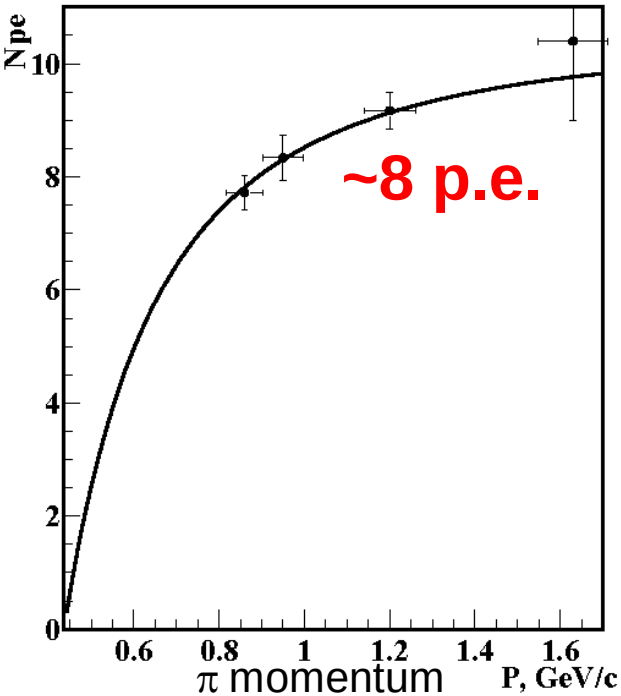
barrel



endcap



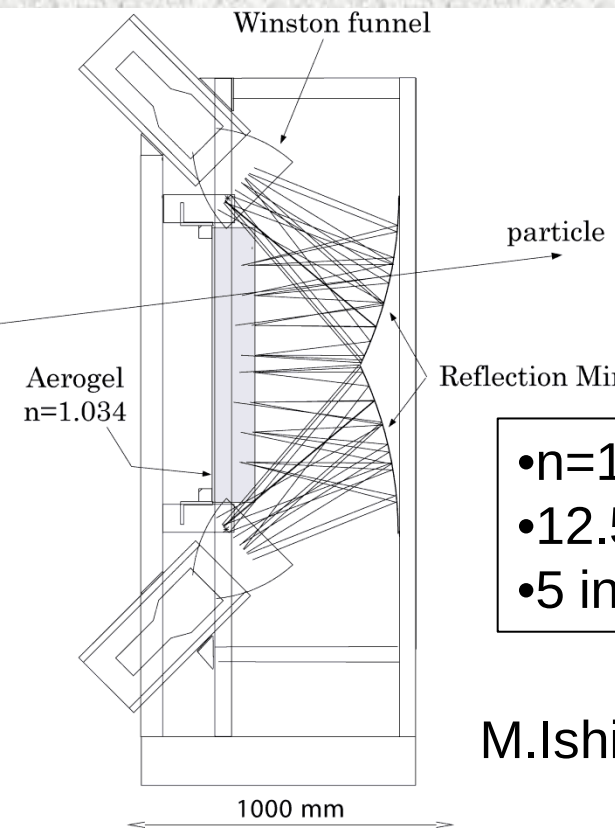


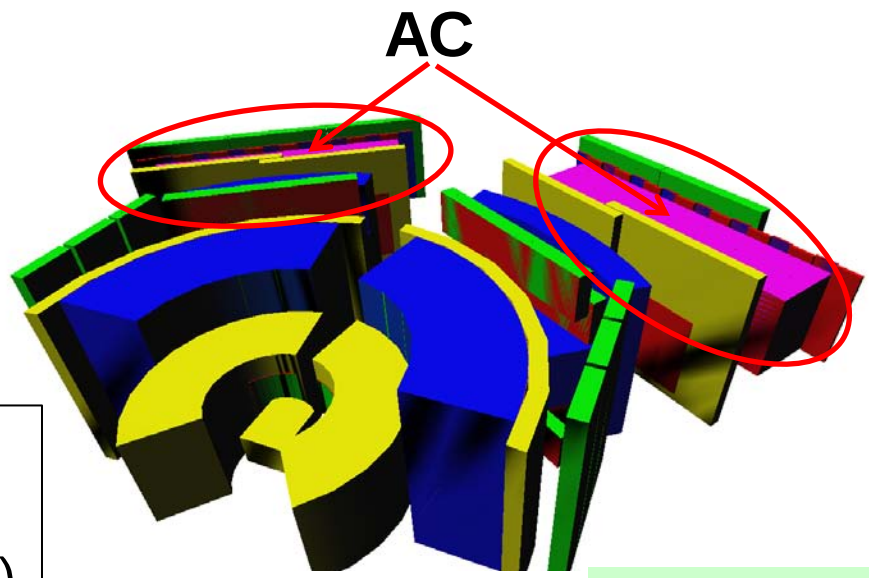


Aerogel : t74mm, n=1.05

WLS : BBQ

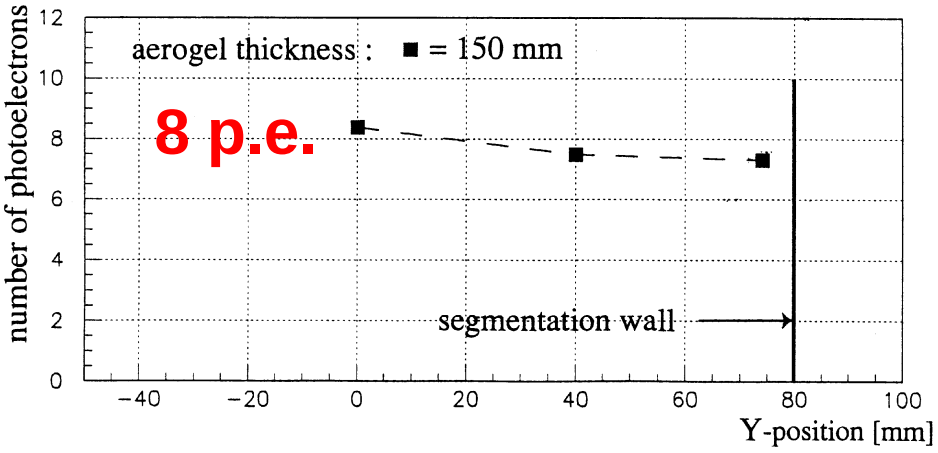
Minimum Goal : KEK-PS E325 AC

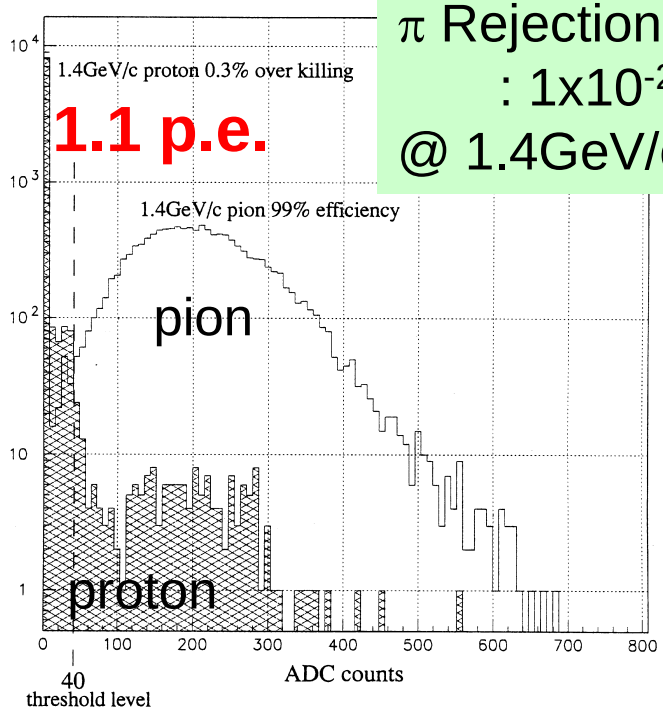




- n=1.034
- 12.5cm Aerogel
- 5 inch PMT (H6527)

M.Ishino *et al.*, NIM **A457**, 581



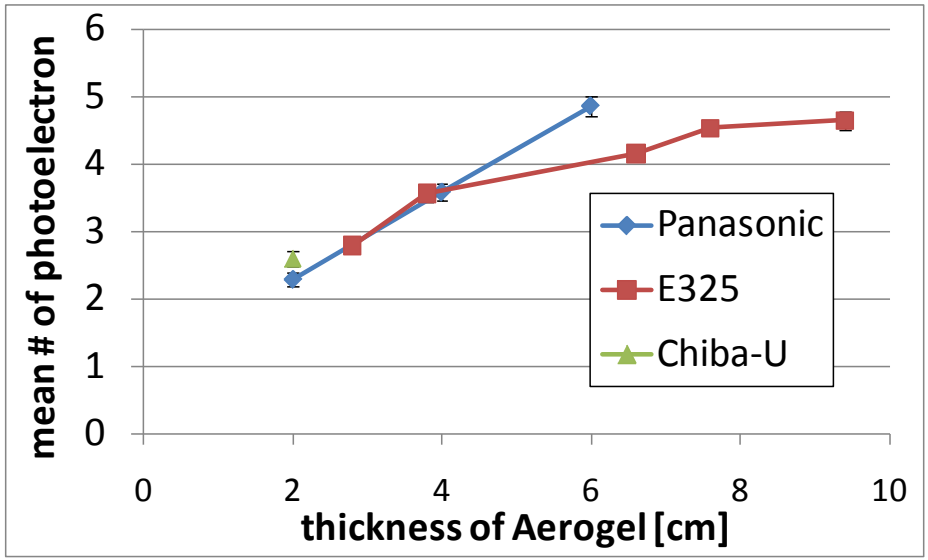


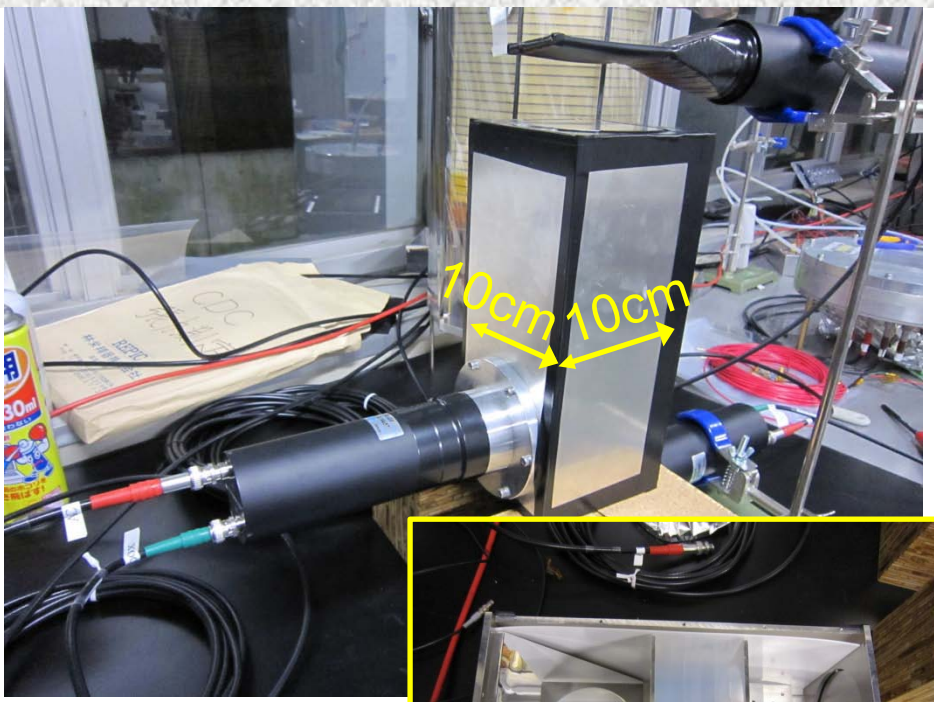
π Rejection
: 1×10^{-2}
@ 1.4GeV/c

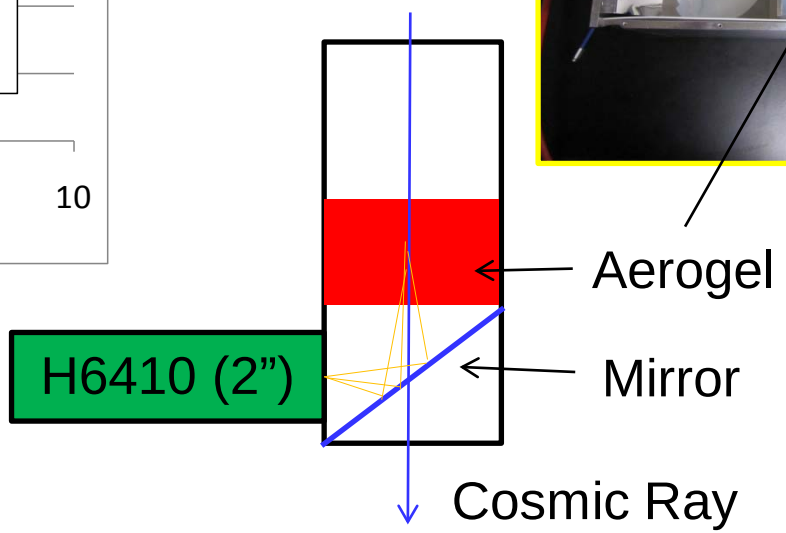
Aerogel

We have checked 3-types of the aerogel (n~1.034):

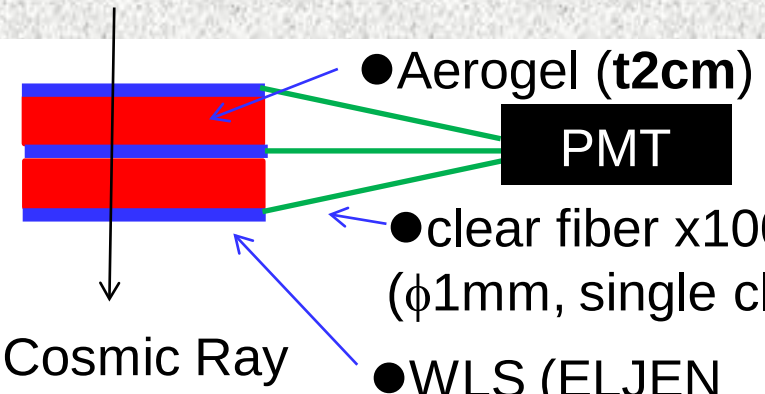
- Panasonic-denko
- KEK-PS E325
- Chiba-U



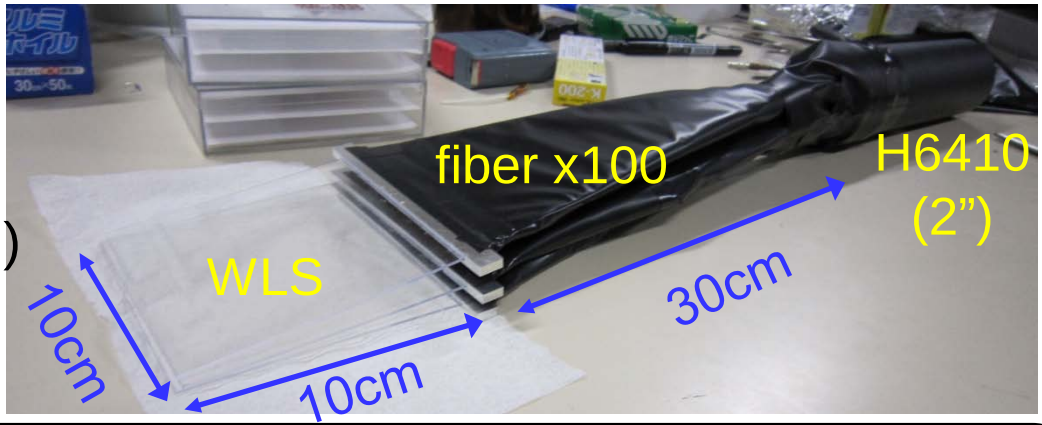


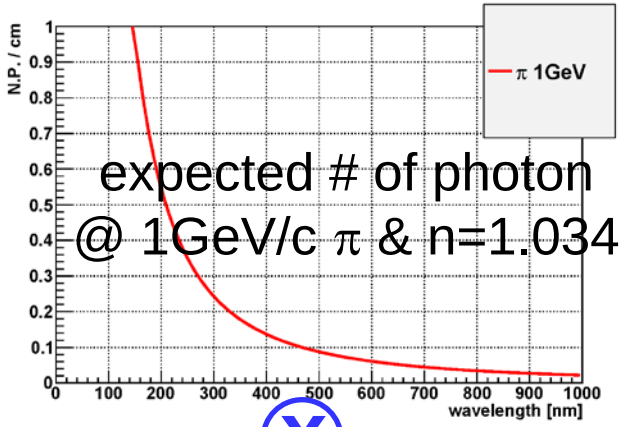


WLS



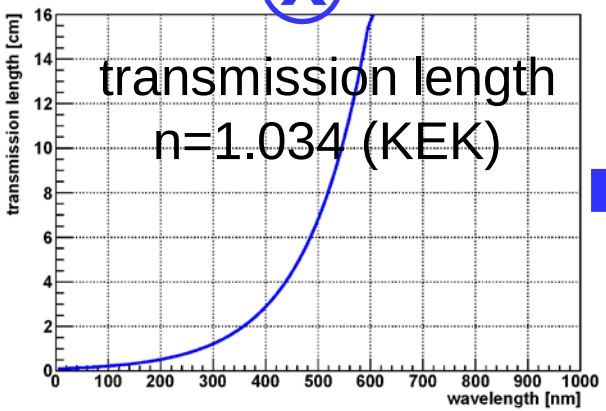
- Aerogel (**t2cm**)
- PMT
- clear fiber x100 (ϕ1mm, single clad)
- WLS (ELJEN EJ-299-27, **t1mm**)



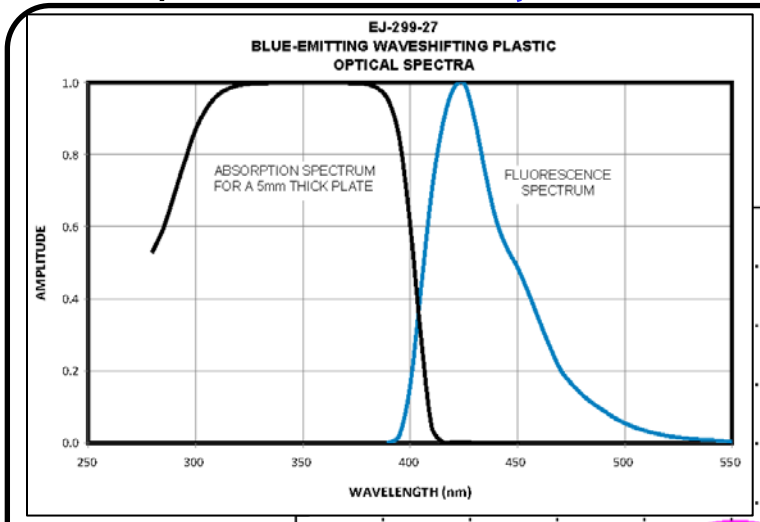


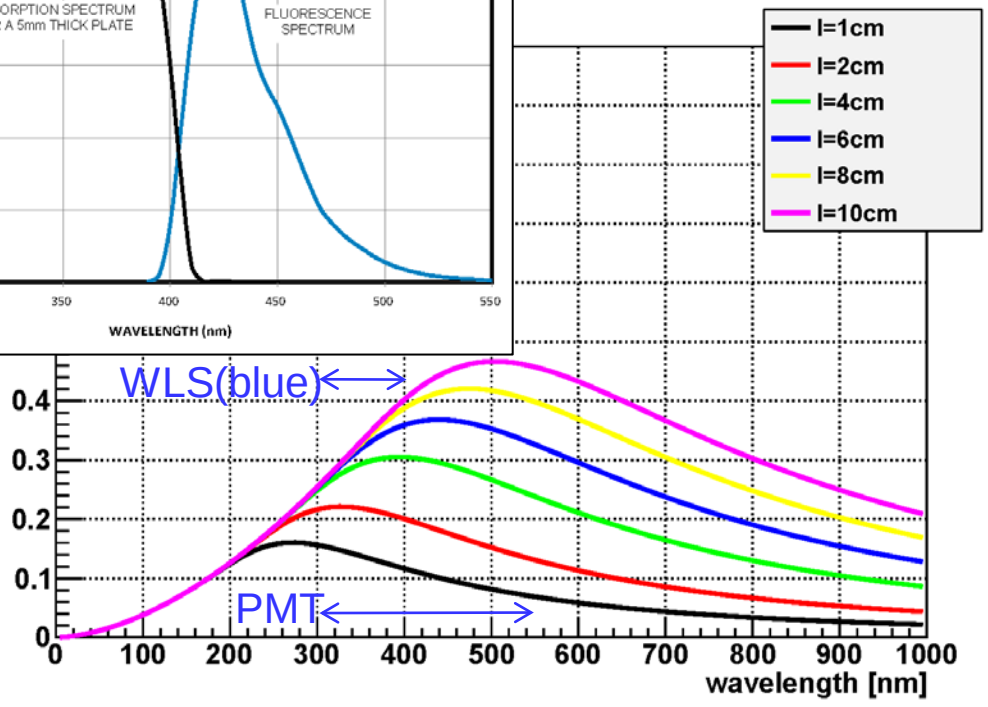
expected # of photon
@ 1GeV/c π & n=1.034

X

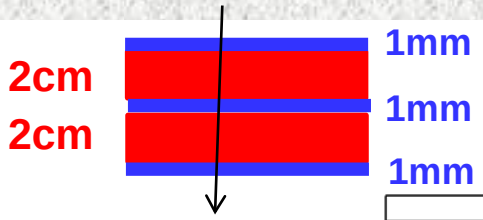


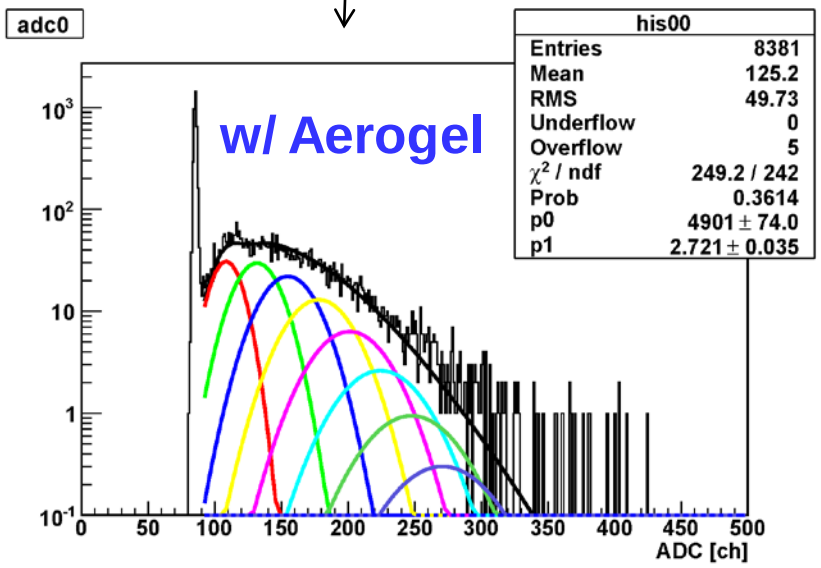
transmission length
n=1.034 (KEK)

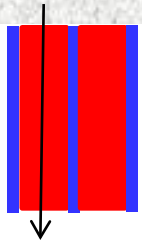


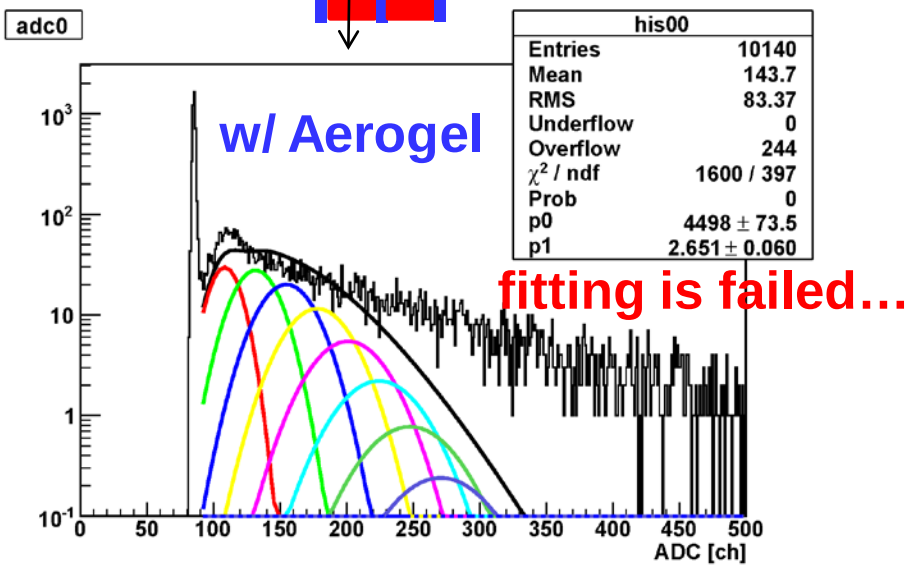


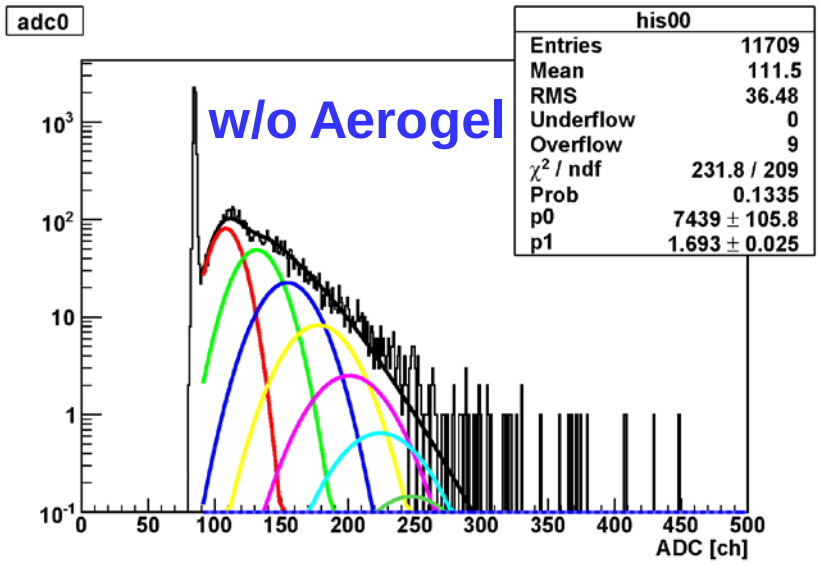
WLS (Cont'd)

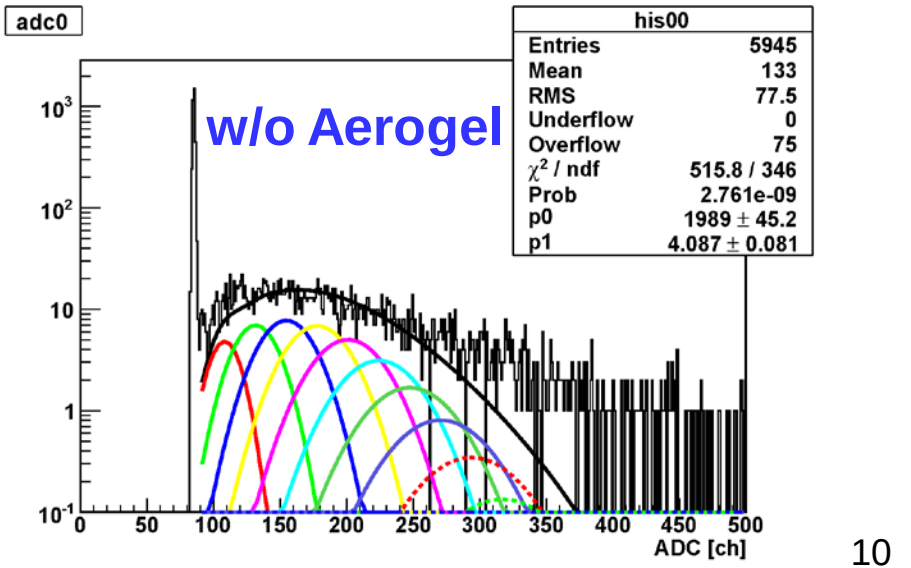

2cm
2cm
1mm
1mm
1mm


adc0
his00
Entries 8381
Mean 125.2
RMS 49.73
Underflow 0
Overflow 5
χ² / ndf 249.2 / 242
Prob 0.3614
p0 4901 ± 74.0
p1 2.721 ± 0.035
w/ Aerogel
ADC [ch]




adc0
his00
Entries 10140
Mean 143.7
RMS 83.37
Underflow 0
Overflow 244
χ² / ndf 1600 / 397
Prob 0
p0 4498 ± 73.5
p1 2.651 ± 0.060
w/ Aerogel
fitting is failed…
ADC [ch]


adc0
his00
Entries 11709
Mean 111.5
RMS 36.48
Underflow 0
Overflow 9
χ² / ndf 231.8 / 209
Prob 0.1335
p0 7439 ± 105.8
p1 1.693 ± 0.025
w/o Aerogel
ADC [ch]


adc0
his00
Entries 5945
Mean 133
RMS 77.5
Underflow 0
Overflow 75
χ² / ndf 515.8 / 346
Prob 2.761e-09
p0 1989 ± 45.2
p1 4.087 ± 0.081
w/o Aerogel
ADC [ch]

WLS (Cont'd)

--- What we have learned ---

- WLS (blue, t1mm) emits several photons with charged particles

  → We cannot install a large amount of WLS in detector acceptance

- present method of WLS+fiber readout cannot collect Cherenkov light from the Aerogel

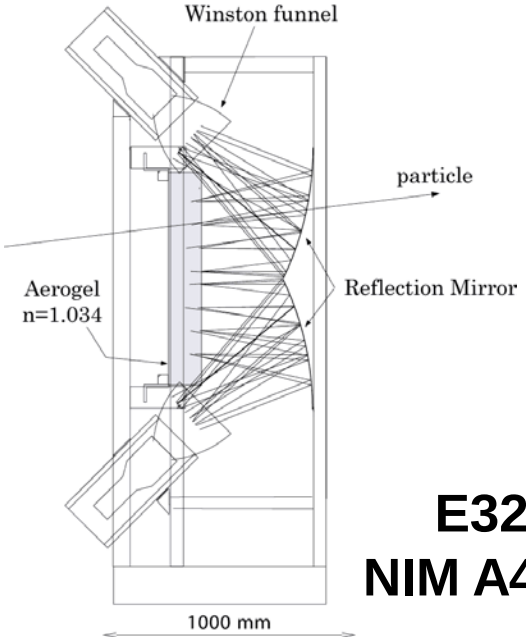
--- What we have to do ---

- reconsider the configuration of the Aerogel and WLS
  - increase the fibers?
  - usage of blue and green WLS?

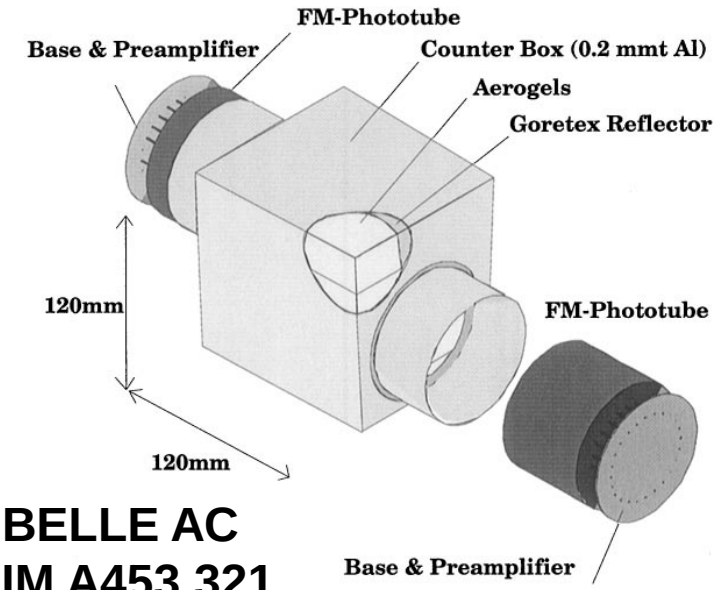
Other Ways …

- development of a “normal type” Aerogel Cherenkov Counter with finemesh-PMTs such as BELLE AC.

- **development of a “reflection type” Aerogel Cherenkov Counter with optical mirrors such as E325 AC.**



E325 AC
NIM A457, 581



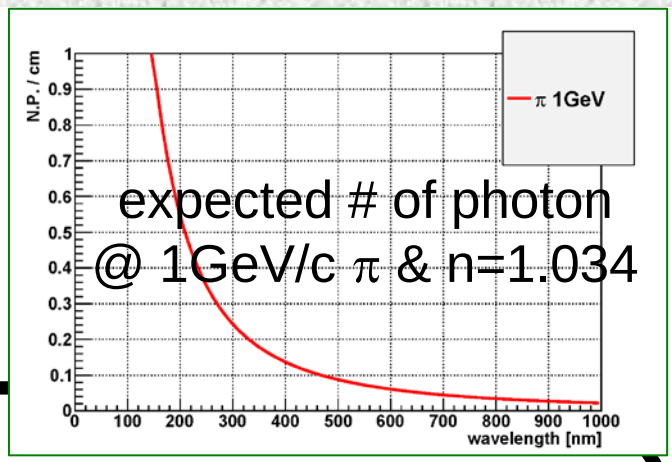
BELLE AC
NIM A453,321

Summary

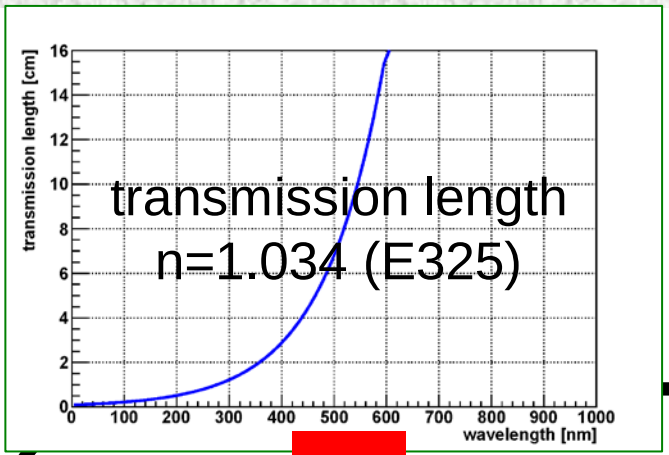
- We have been developing an Aerogel Cherenkov Counter for the E16 upgrade in order to measure K^+K^- pair.

- Development of WLS+fiber readout has been started, but we have to adjust the configuration of AC+WLS+fiber. Further study is required…

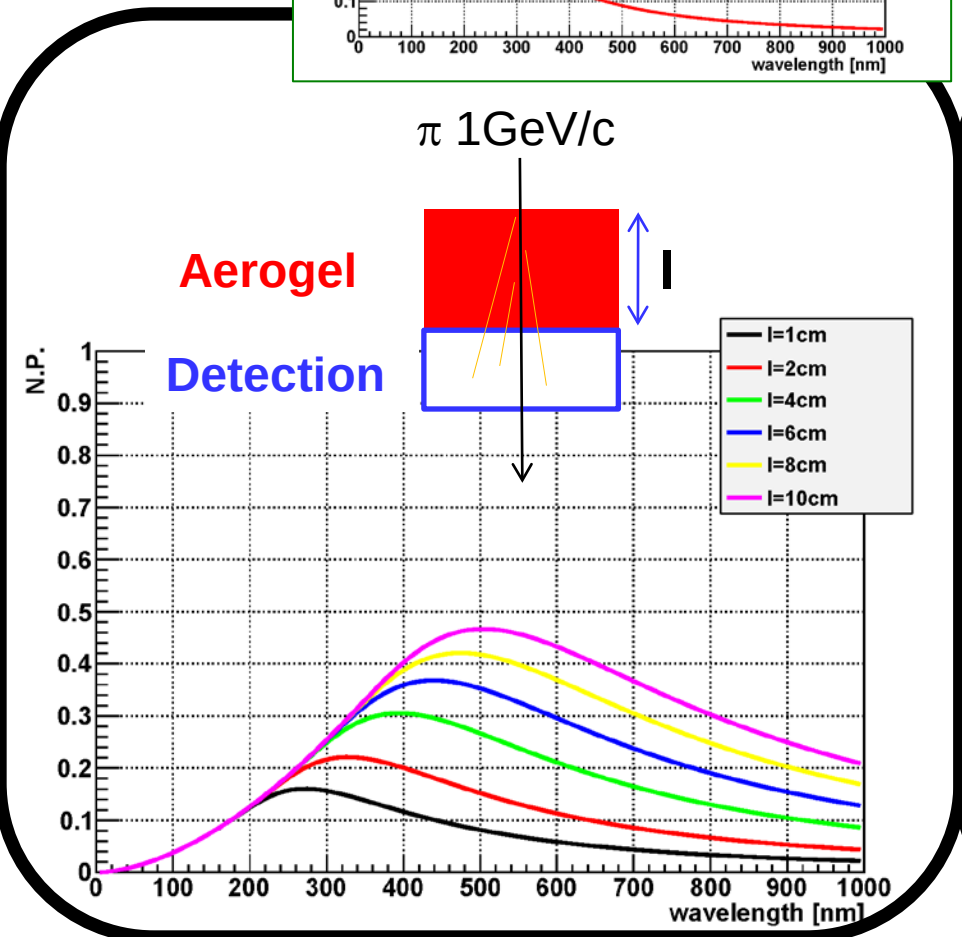
Expected Photon Spectra

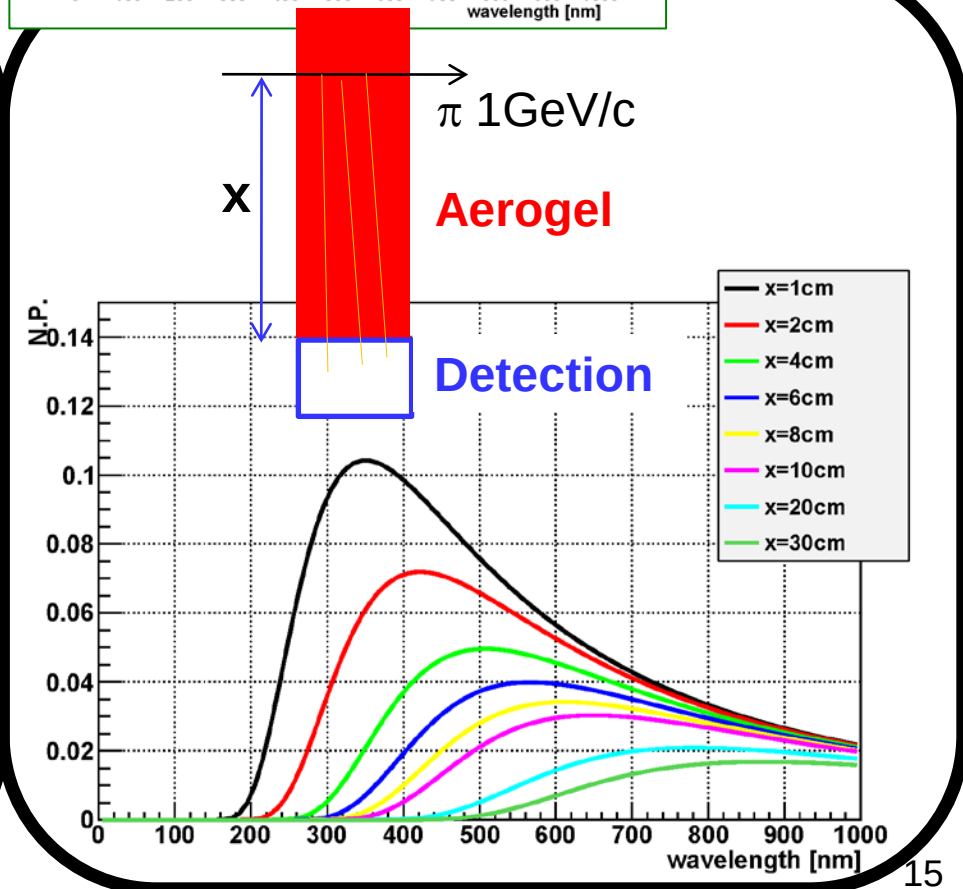


expected # of photon
@ 1GeV/c π & n=1.034

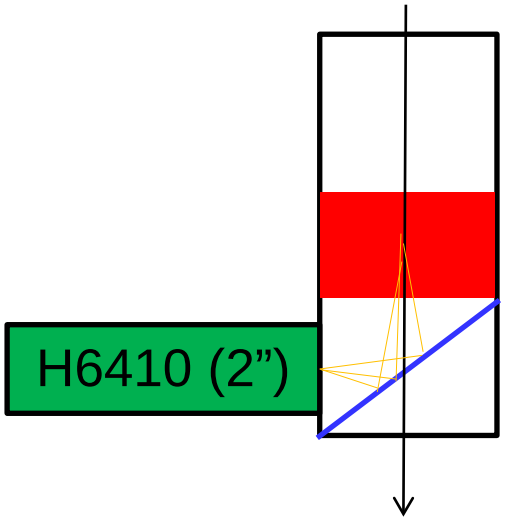


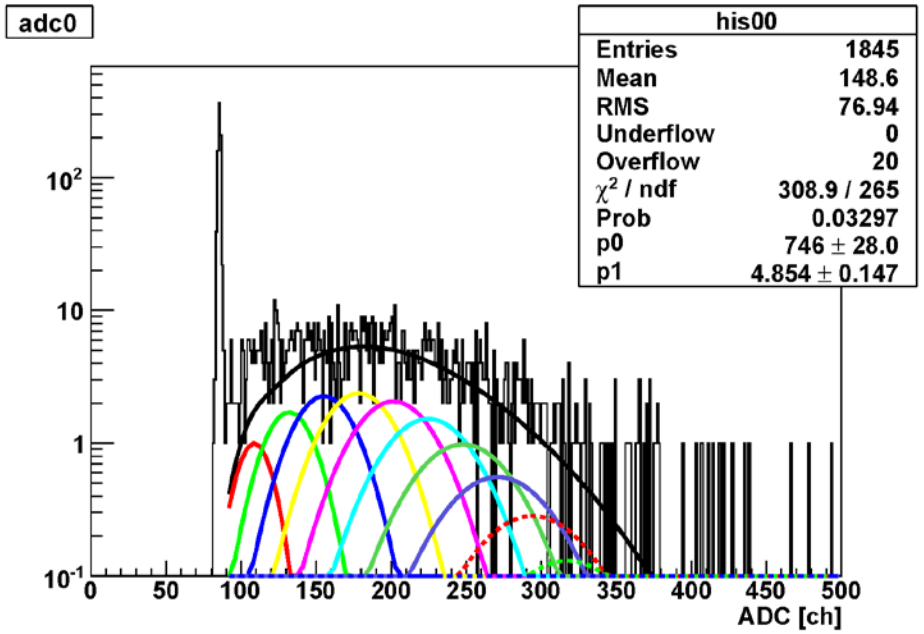
transmission length
n=1.034 (E325)

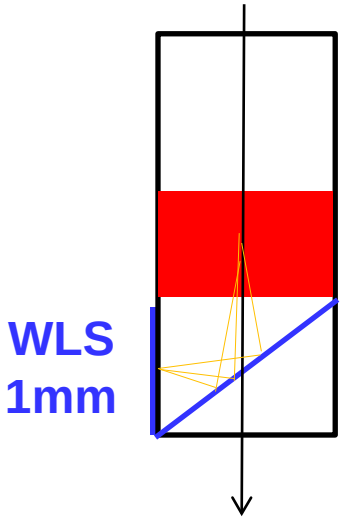


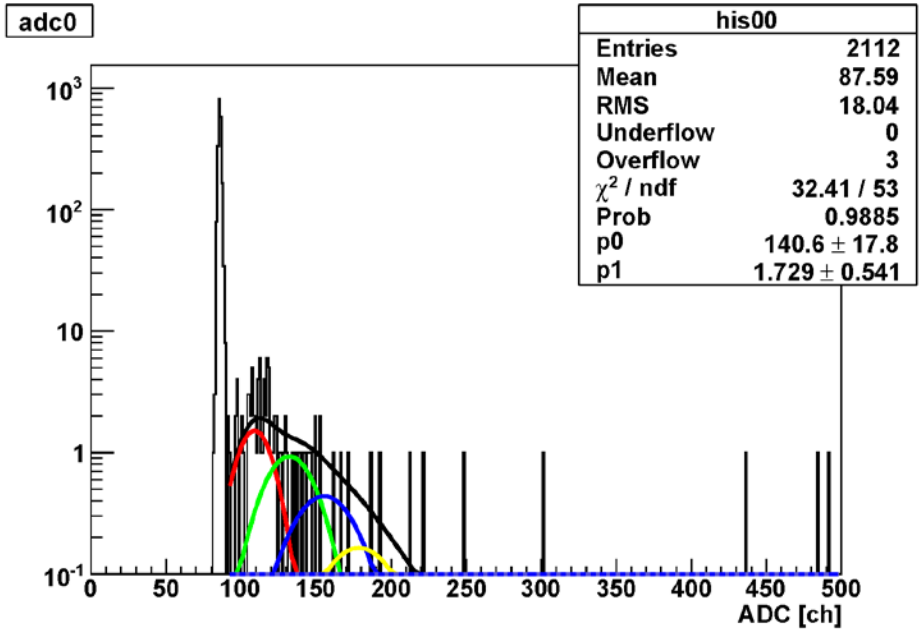


WLS (Cont'd)

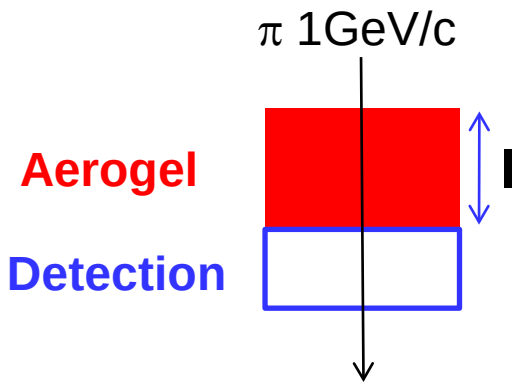

H6410 (2")
Aerogel
6cm

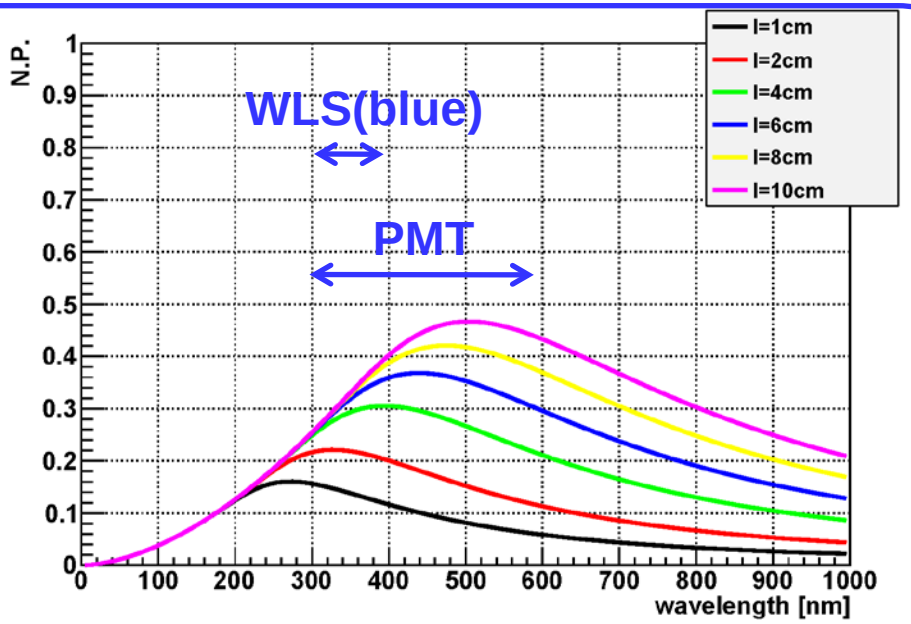

adc0
his00
Entries 1845
Mean 148.6
RMS 76.94
Underflow 0
Overflow 20
χ² / ndf 308.9 / 265
Prob 0.03297
p0 746 ± 28.0
p1 4.854 ± 0.147
ADC [ch]

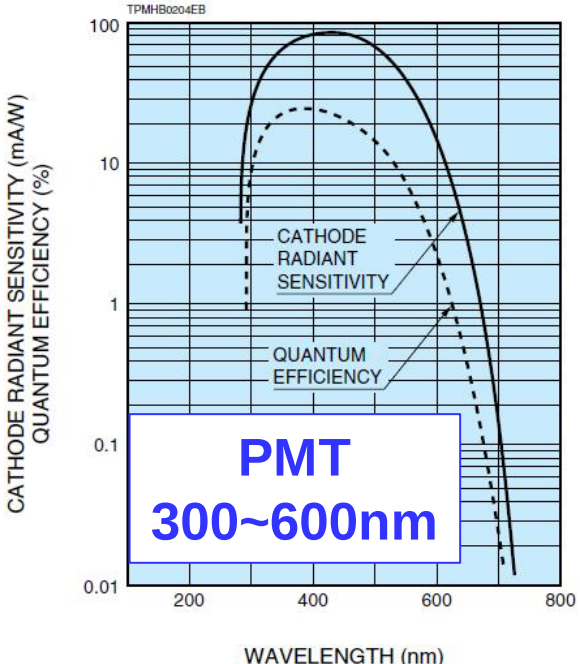

WLS
1mm
Aerogel
6cm

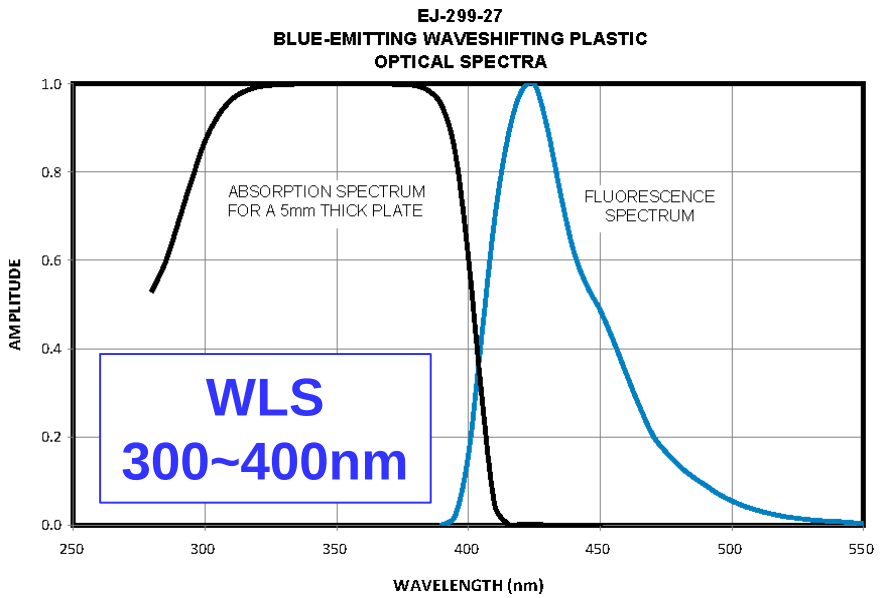

adc0
his00
Entries 2112
Mean 87.59
RMS 18.04
Underflow 0
Overflow 3
χ² / ndf 32.41 / 53
Prob 0.9885
p0 140.6 ± 17.8
p1 1.729 ± 0.541
ADC [ch]

WLS (Cont'd)

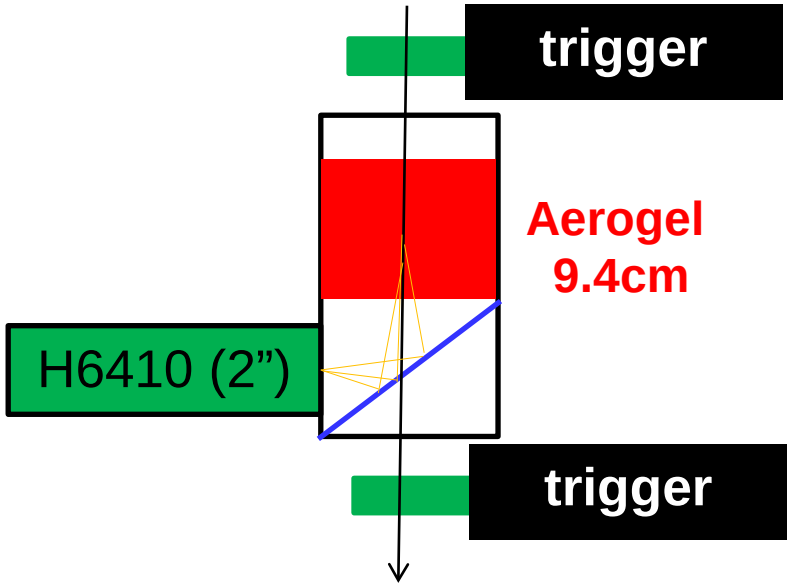

π 1GeV/c
Aerogel
Detection
l

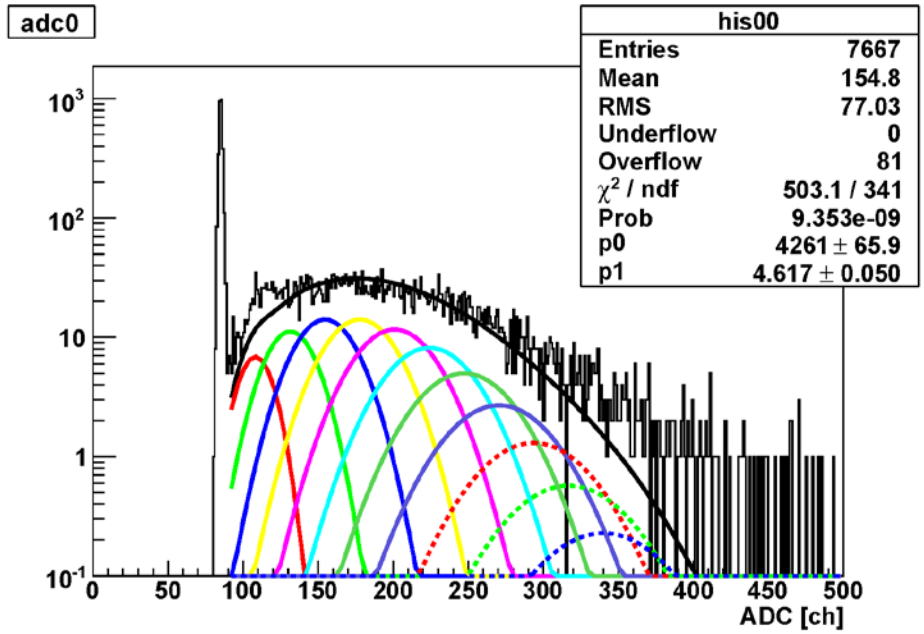

N.P.
WLS(blue)
PMT
l=1cm
l=2cm
l=4cm
l=6cm
l=8cm
l=10cm
wavelength [nm]

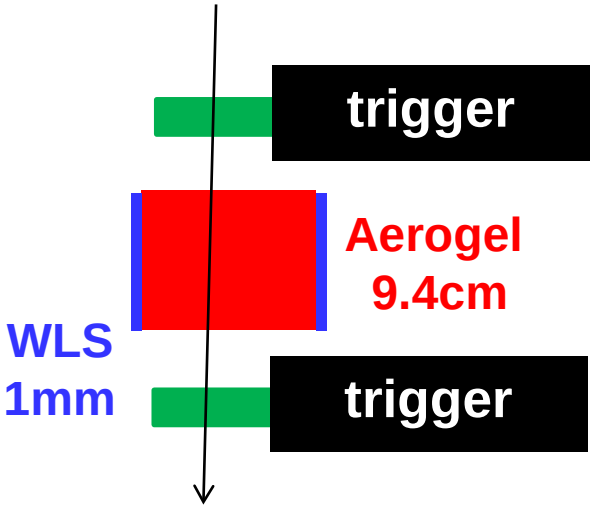

TPMHB0204EB
CATHODE RADIANT SENSITIVITY (mA/W)
QUANTUM EFFICIENCY (%)
CATHODE RADIANT SENSITIVITY
QUANTUM EFFICIENCY
PMT
300~600nm
WAVELENGTH (nm)

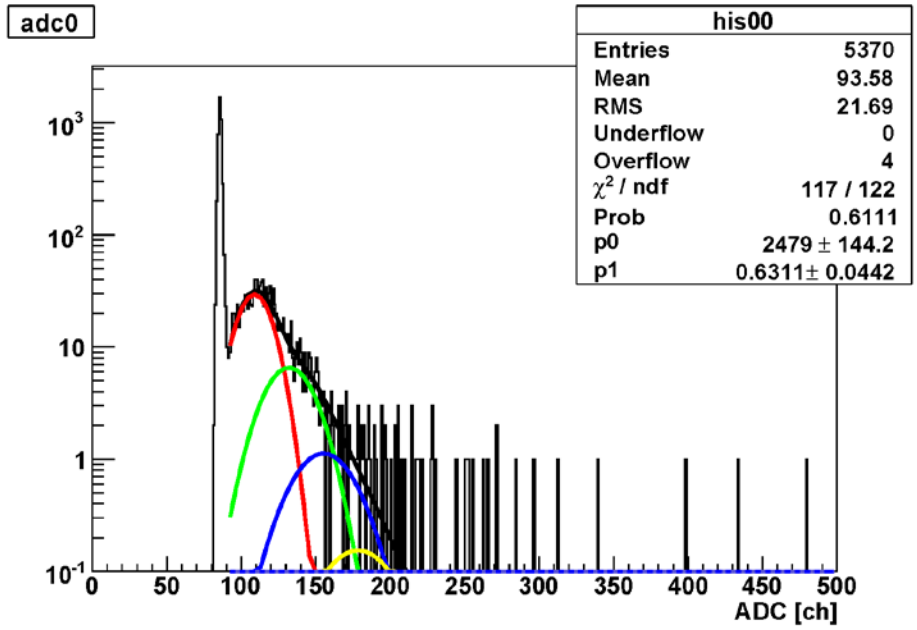

EJ-299-27
BLUE-EMITTING WAVESHIFTING PLASTIC
OPTICAL SPECTRA
ABSORPTION SPECTRUM
FOR A 5mm THICK PLATE
FLUORESCENCE
SPECTRUM
AMPLITUDE
WLS
300~400nm
WAVELENGTH (nm)

WLS (Cont'd)


trigger
Aerogel
9.4cm
H6410 (2")
trigger


adc0
his00
Entries 7667
Mean 154.8
RMS 77.03
Underflow 0
Overflow 81
χ² / ndf 503.1 / 341
Prob 9.353e-09
p0 4261 ± 65.9
p1 4.617 ± 0.050
ADC [ch]


trigger
Aerogel
9.4cm
WLS
1mm
trigger


adc0
his00
Entries 5370
Mean 93.58
RMS 21.69
Underflow 0
Overflow 4
χ² / ndf 117 / 122
Prob 0.6111
p0 2479 ± 144.2
p1 0.6311± 0.0442
ADC [ch]

Photon Fitting

$$f(x) = C\sum_{n} \frac{\lambda^{n}\exp(-\lambda)}{n!} \times \frac{1}{\sqrt{2\pi n\sigma_1}} \exp\left(-\frac{\left(x-\left(p_0+np_1\right)\right)^2}{2n\sigma_1^2}\right)$$

Poisson **Gaussian**

C : normalized factor ← **parameter**

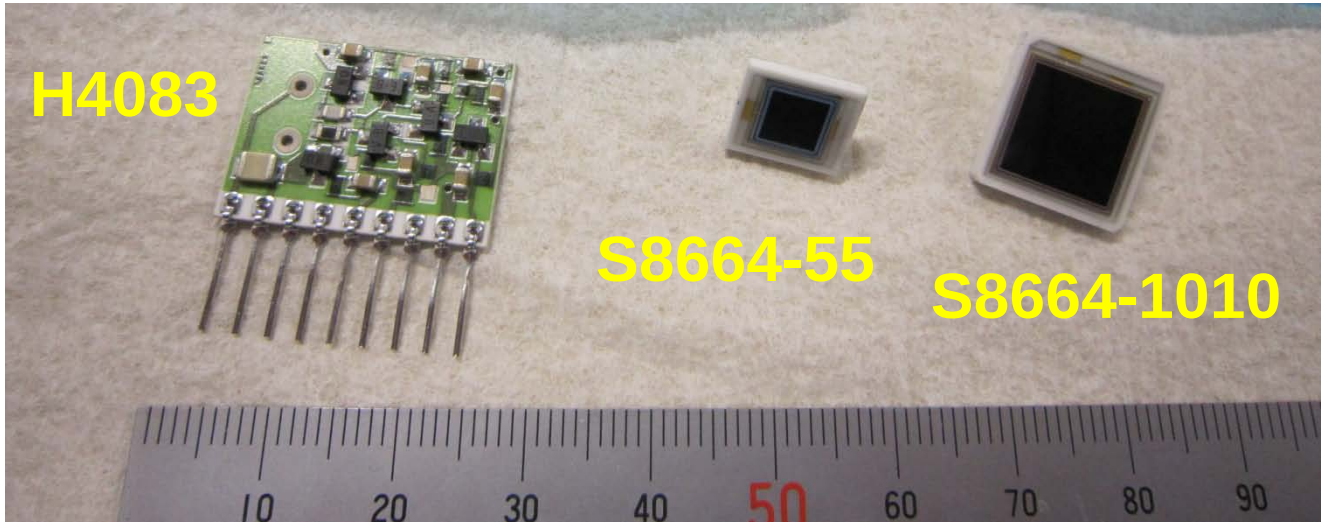
λ : mean value of photoelectron ← **parameter**

p_0 : pedestal peak ← constant

p_1 : distance of pedestal to single-photon ← constant

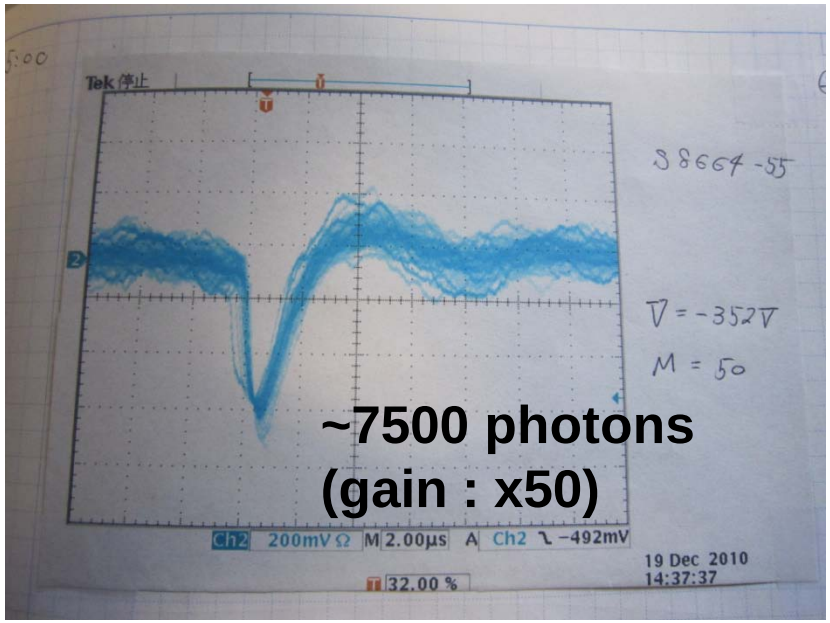
σ_1 : PMT resolution for single-photon ← constant

SiAPD



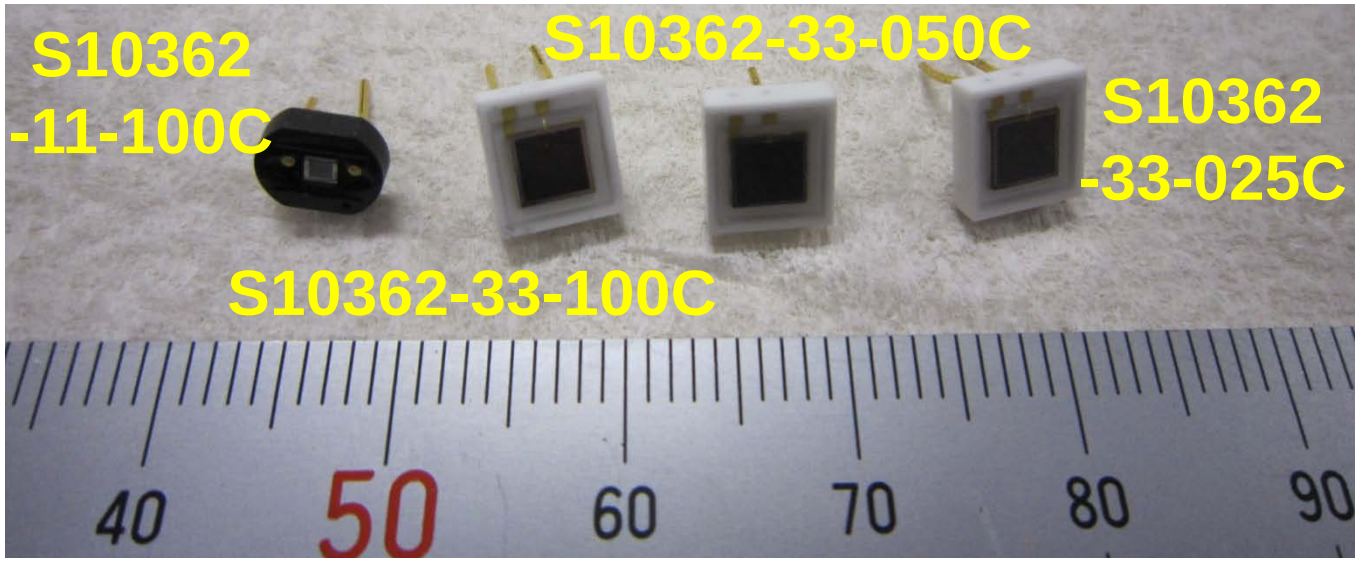
We purchased and tested SiAPDs.

But we **CANNOT** see the signal of a few photons on SiAPD, because of read-out electronics noise!



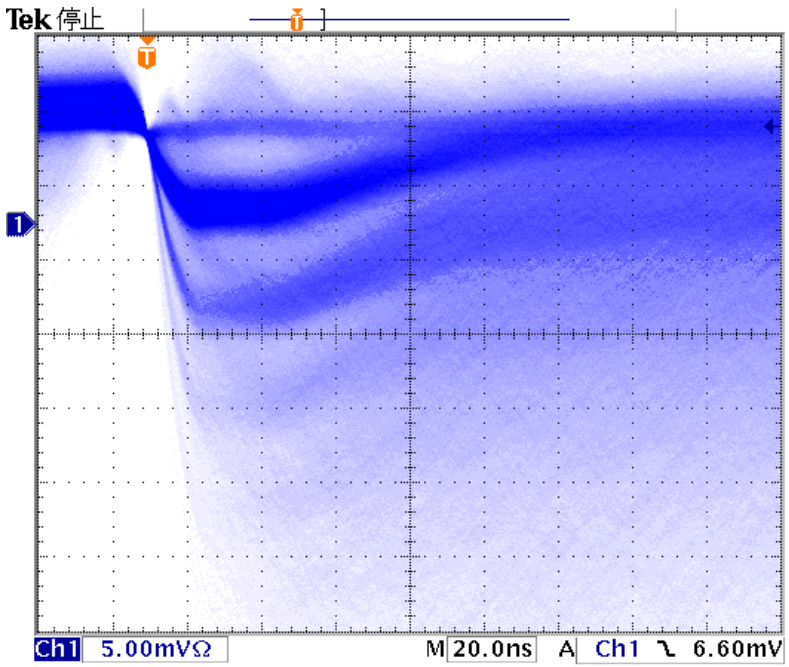
what we have learned is …
“using low-gain devices for Cherenkov detection is awful difficult!”

MPPC



We purchased and tested MPPCs.

The dark count signals of ~Mcps were confirmed as written in the product specification.



It seems that **usage of the MPPCs for a single-photon detector is too hard!**
Several tens of photons are required.

Vector Meson, ϕ

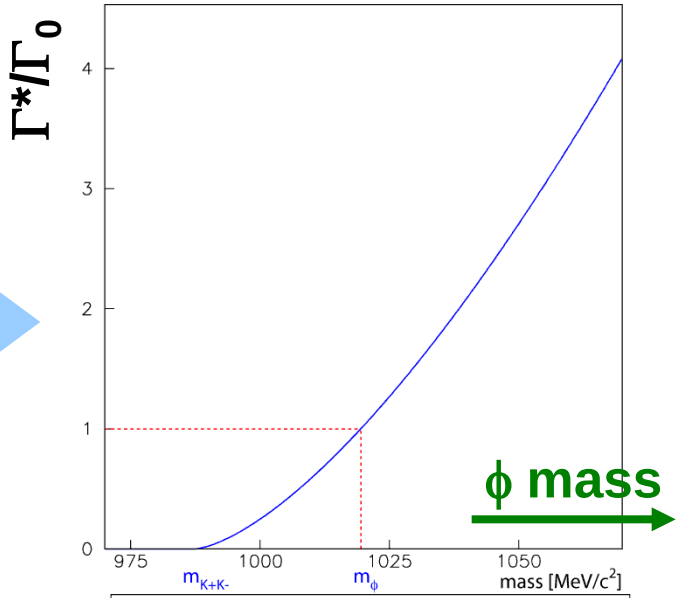
J.D.Jackson, Nuovo Cimento 34, 1644 (1964).

m_ϕが変化

$$\Gamma^* / \Gamma_0 = (q/q_0)^3 (m_0/m^*)$$

$$q = \sqrt{m^{*2}/4 - m_K^2}$$

$$q_0 = \sqrt{m_0^2/4 - m_K^2}$$

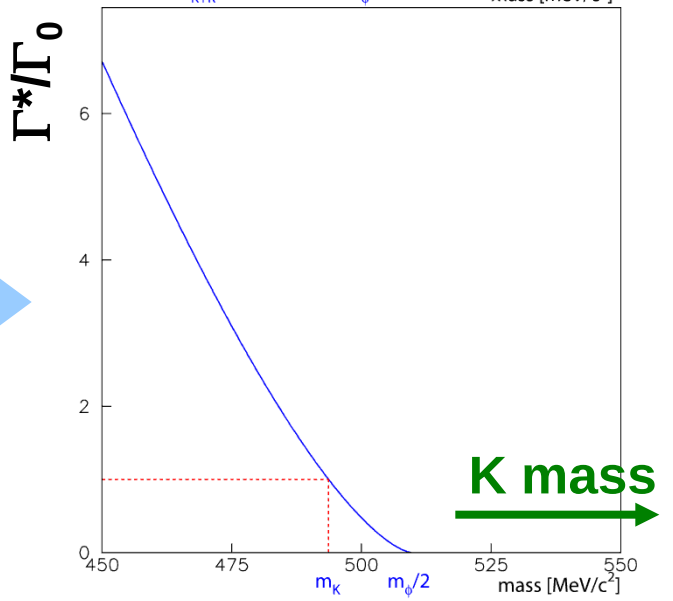


m_Kが変化

$$\Gamma^* / \Gamma_0 = (q/q_0)^3$$

$$q = \sqrt{m_0^2/4 - m_K^{*2}}$$

$$q_0 = \sqrt{m_0^2/4 - m_K^2}$$

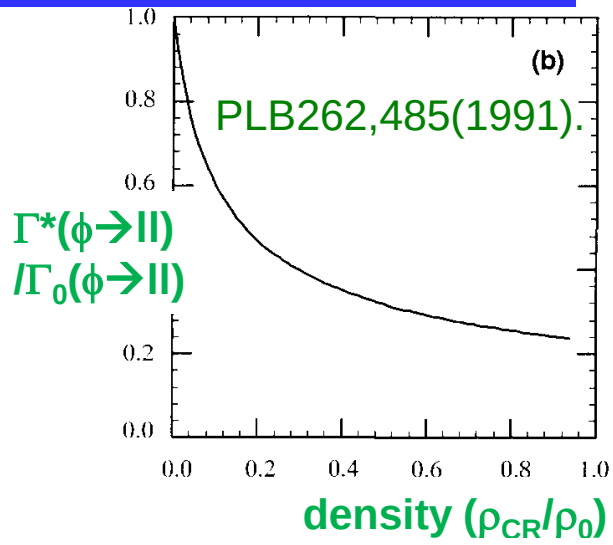


φ Puzzle

核物質中でのφまたはKのスペクトラル関数の変化によって、φ→ll/KKの崩壊幅が変化するのではないか?

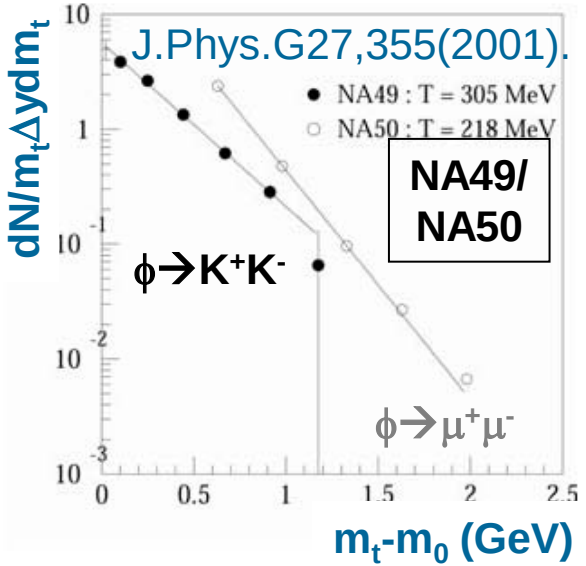
●theoretical predictions

- D.Lissauer and V.Shuryak, PLB253,15(1991).
  Γ(φ→KK)/Γ*(φ→ll) の増加*
- P.-Z. Bi and J.Rafelski, PLB262,485(1991).
  Γ(φ→KK)/Γ*(φ→ll) の増加*
- J.P.Blaziot and R.M.Galain, PLB271,32(1991).
  Γ(φ→KK)/Γ*(φ→ll) の減少*
- etc.



●NA49/NA50@CERN-SPS

– PLB491,59(2000).; PLB555,147(2003).;
J.Phys,G27,355(2001).
– $\phi \rightarrow K^+K^-/\mu^+\mu^-$, 158AGeV Pb+Pb
– production CS's are ***inconsistent***



ϕ Meson Measurements

Hot Matter

- **CERES(NA45)@CERN-SPS**
  - PRL96,152301(2006).
  - $\phi \rightarrow e^+e^-/K^+K^-$, 158AGeV Pb+Au
  - production CS's are ***consistent***
- **PHENIX@BNL-RHIC**
  - EPJ,A31,836(2007).
  - $\phi \rightarrow e^+e^-/K^+K^-$, sqrt($s_{NN}$)=200GeV Au+Au
  - production CS's are ***consistent***
- **NA60@CERN-SPS**
  - NPA830,753c(2009).
  - $\phi \rightarrow \mu^+\mu^-/K^+K^-$, 158AGeV In+In
  - production CS's are ***consistent***

Cold Matter

- **E325@KEK-PS**
  - PRL98, 152302(2007).
  - $\phi \rightarrow e^+e^-/K^+K^-$, 12GeV p+C/Cu