CP violation and related issues

Course at UB, May 2005

Part 15: Super B-factories

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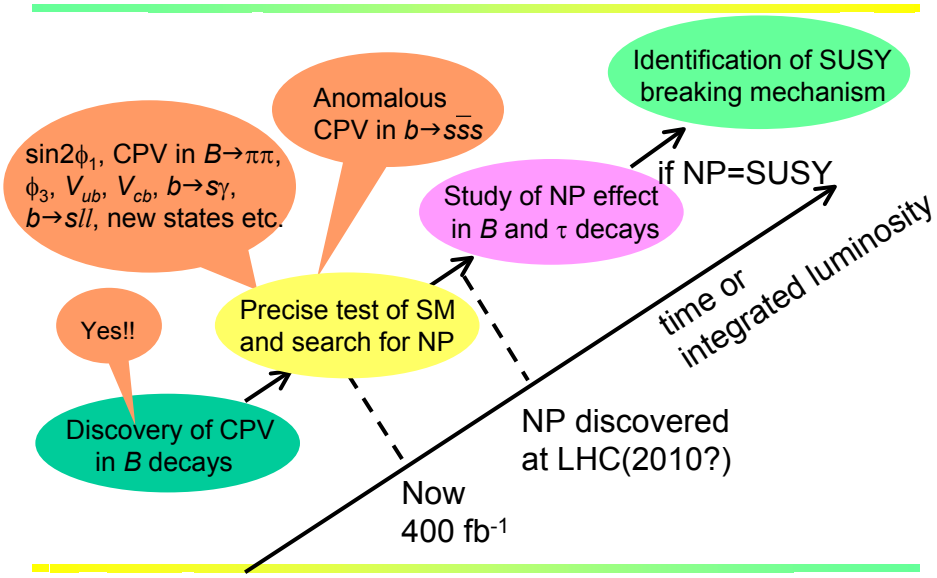
Contents

Why? - Roadmap of B Physics



Motivations for Super KEKB

1. Possible anomalies observed in B decays

- TCPV in $b\to sss \neq b\to ccs$: 3.8σ
- Polarization in penguin dominated $B\to VV$ decays
- $A_{CP}(B^{\pm}\to K^{\pm}\pi^0) \neq A_{CP}(B^0\to K^{\pm}\pi^{\mp})$

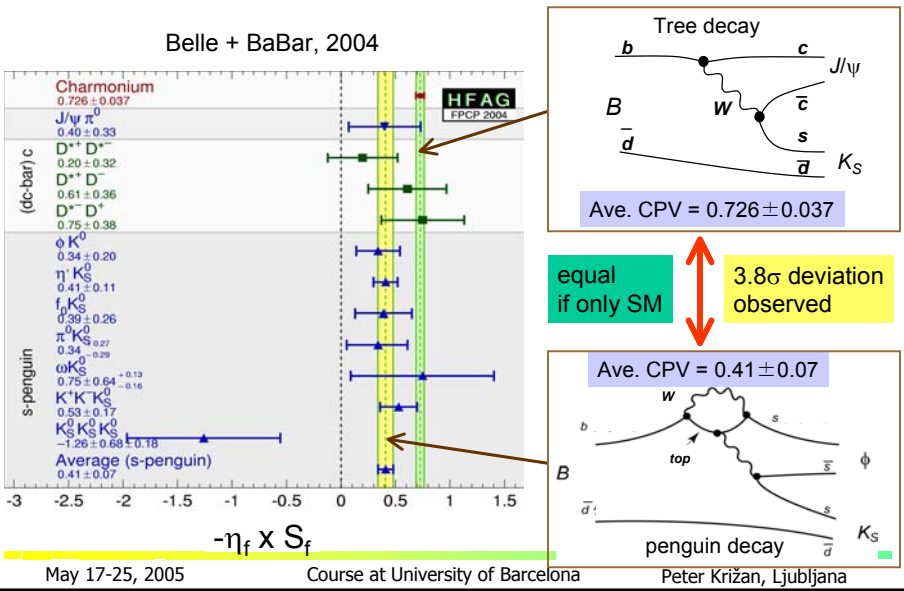
These MUST be clarified.

2. New physics will be found soon at LHC.

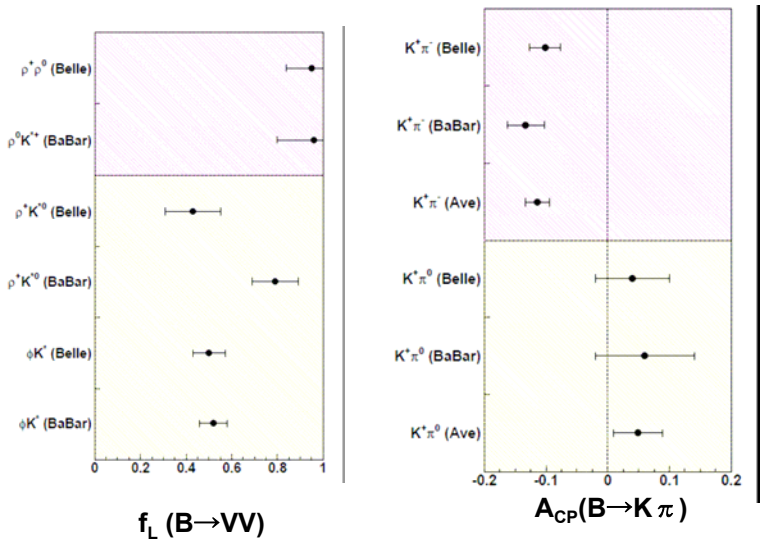
- Once New Physics is discovered and its mass scale is determined, next is to study its flavor structure and CP violation, where B physics can play a unique role.

3. e^+e^- B factory with L=3.5$\times10^{35}$ is competitive with LHCb.

Anomalous CPV hints new physics?



Other Evidences for New Physics



Comparison with LHCb

Observable	Belle 2003 (0.14ab^{-1})	SuperKEKB (5 ab^{-1})	SuperKEKB (50 ab^{-1})	LHCb (0.002ab^{-1})
$\Delta S_{\phi K^0_S}$	0.51	0.079	0.031	0.2 [390]
$\Delta S_{K^+K^-K^0_S}$	$^{+0.32}_{-0.26}$	0.056	0.026	
$\Delta S_{\eta' K^0_S}$	0.27	0.049	0.024	×
$\Delta S_{K^0_S K^0_S K^0_S}$	NA	0.14	0.04	×
$\Delta S_{\pi^0 K^0_S}$	NA	0.10	0.03	×
$\sin 2\chi$ $(B_s \to J/\psi\phi)$	×	×	×	0.058
$S_{K^{*0}\gamma}$	NA	0.14	0.04	×
$\mathcal{B}(B \to X_s\gamma)$	26% (5.8 fb^{-1})	5%	5%	×
$A_{CP}(B \to X_s\gamma)$	0.004	0.011	5×10^{-3}	×
C_9 from $\overline{A}_{FB}(B \to K^*\ell^+\ell^-)$	NA	32%	10%	
C_{10} from $\overline{A}_{FB}(B \to K^*\ell^+\ell^-)$	NA	44%	14%	
$\mathcal{B}(B_s \to \mu^+\mu^-)$	×	×	×	4σ (3 years) [392]
$\mathcal{B}(B^+ \to K^+\nu\nu)$	NA		5.1σ	×
$\mathcal{B}(B^+ \to D\tau\nu)$	NA	12.7σ	40.3σ	×
$\mathcal{B}(B^0 \to D\tau\nu)$	NA	3.5σ	11.0σ	×
$\sin 2\phi_1$	0.06	0.019	0.014	0.022
ϕ_2 ($\pi\pi$ isospin)	NA	3.9°	1.2°	×
ϕ_2 ($\rho\pi$)	NA	2.9°	0.9°	×
ϕ_3 ($DK^{(*)}$)	20°	4°	1.2°	8°
ϕ_3 ($B_s \to KK$)	×	×	×	5°
ϕ_3 ($B_s \to D_sK$)	×	×	×	14°
$\lvert V_{ub}\rvert$ (inclusive)	16%	5.8%	4.4%	×
$\mathcal{B}(\tau \to \mu\gamma)$	$< 3.1 \times 10^{-7}$	$< 1.8 \times 10^{-8}$		
$\mathcal{B}(\tau \to \mu(e)\eta)$	$< 3.4(6.9) \times 10^{-7}$	$< 5 \times 10^{-9}$		
$\mathcal{B}(\tau \to \ell\ell\ell)$	$< 1.4\text{-}3.1 \times 10^{-7}$	$< 5 \times 10^{-9}$		

SuperKEKB LoI
hep-ex/0406071

SuperKEKB Parameters

Stored current:
1.27/1.7 A (KEKB)
→ 4.1/9.4 A (SuperKEKB)

Beam-beam parameter:
0.057 (KEKB)
→ 0.17 (SuperKEKB)

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

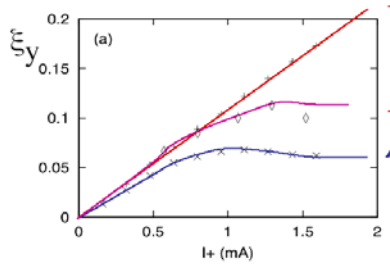
Lorentz factor
Classical electron radius
Beam size ratio
Geometrical reduction factors due to crossing angle and hour-glass effect

Luminosity:
0.15×10^{35} cm^{-2}s^{-1} (KEKB)
3.5×10^{35} cm^{-2}s^{-1} (SuperKEKB)

Vertical β at the IP:
5.2/6.5 mm (KEKB)
→ 3.0/3.0 mm (SuperKEKB)

Crab Cavity

- Crab crossing will boost the beam-beam parameter up to 0.17!



(Strong-weak simulation)

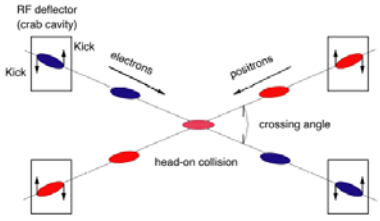
K. Ohmi

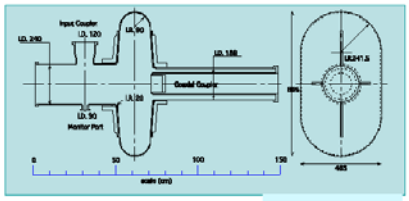
Head-on(crab)

(Strong-strong simulation)

crossing angle 22 mrad

- Superconducting crab cavities are under development, will be installed in KEKB in early 2006.





K. Hosoyama, et al

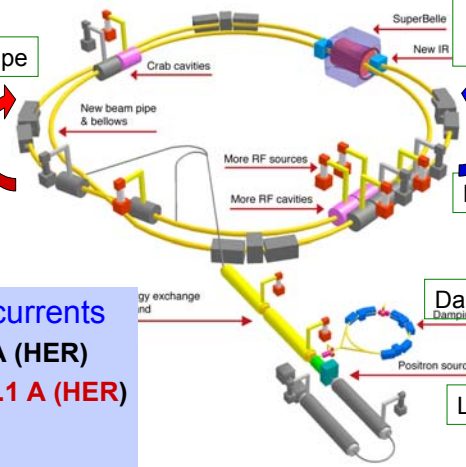
SuperKEKB Design

Interaction Region
Crab crossing
θ=30mrad.
βy*=3mm
New QCS

New Beam pipe

8GeV (e+, 4.1A)

3.5GeV (e-, 9.6A)



More RF power

Damping ring

Linac upgrade

$$L \approx \frac{\gamma_\pm}{2er_e}\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\frac{R_L}{R_y}$$

Increase beam currents
- **1.6 A (LER) / 1.2 A (HER)**
  → **9.6 A (LER) / 4.1 A (HER)**

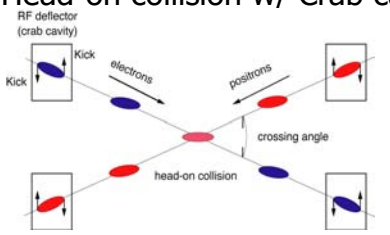
Smaller β_y^*
- **6 mm→3 mm**

Increase ξ_y
- **0.05→0.28(W-S)**

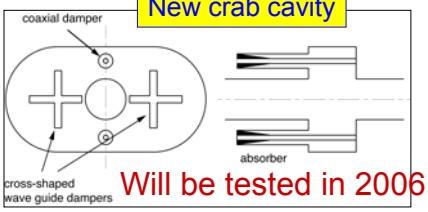
$L=3.5\times10^{35}cm^{-2}s^{-1}$

Super-KEKB (cont'd)

- Head-on collision w/ Crab cavity

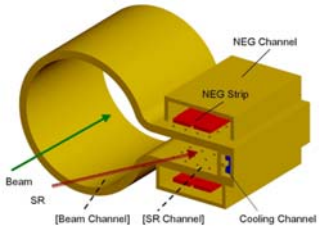


New crab cavity



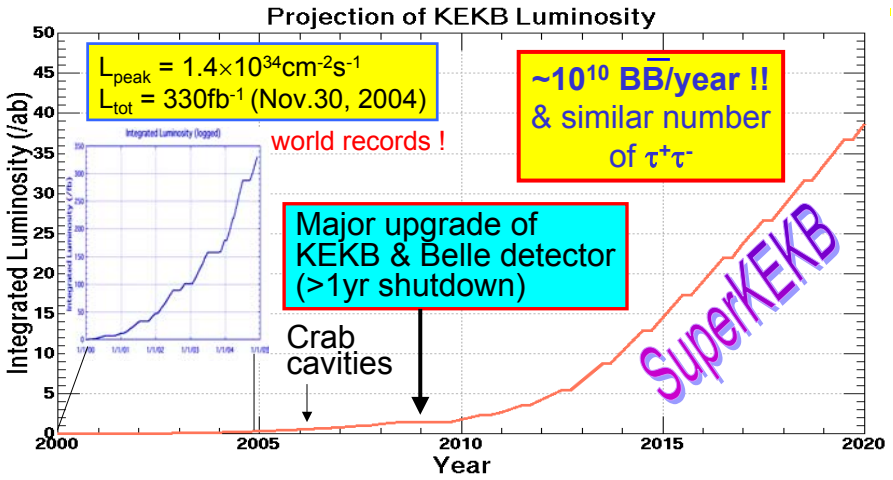
Will be tested in 2006.

- Ante-chamber /solenoid for reduction of electron clouds



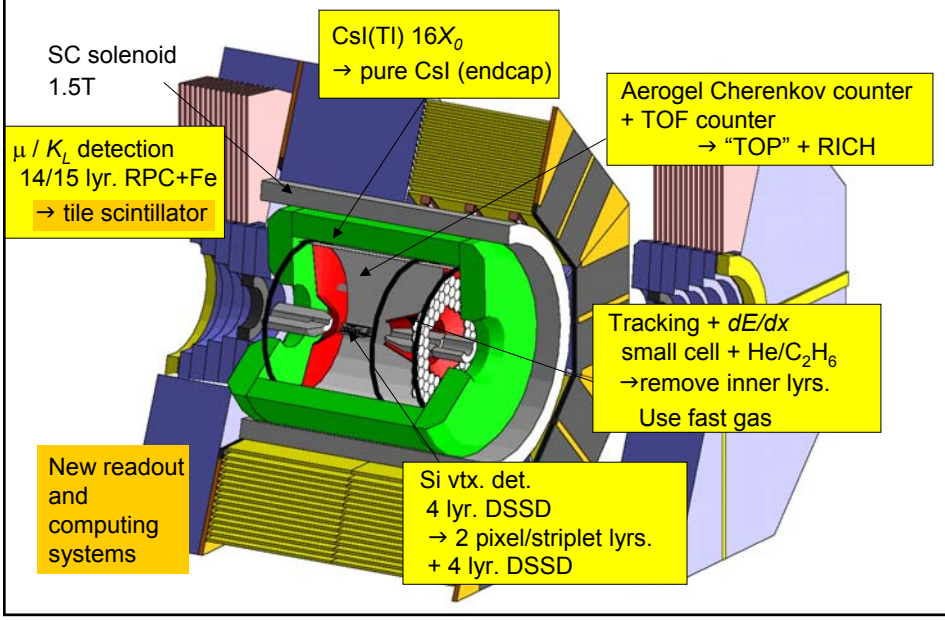
Ante-chamber
with solenoid field

KEKB Upgrade Scenario

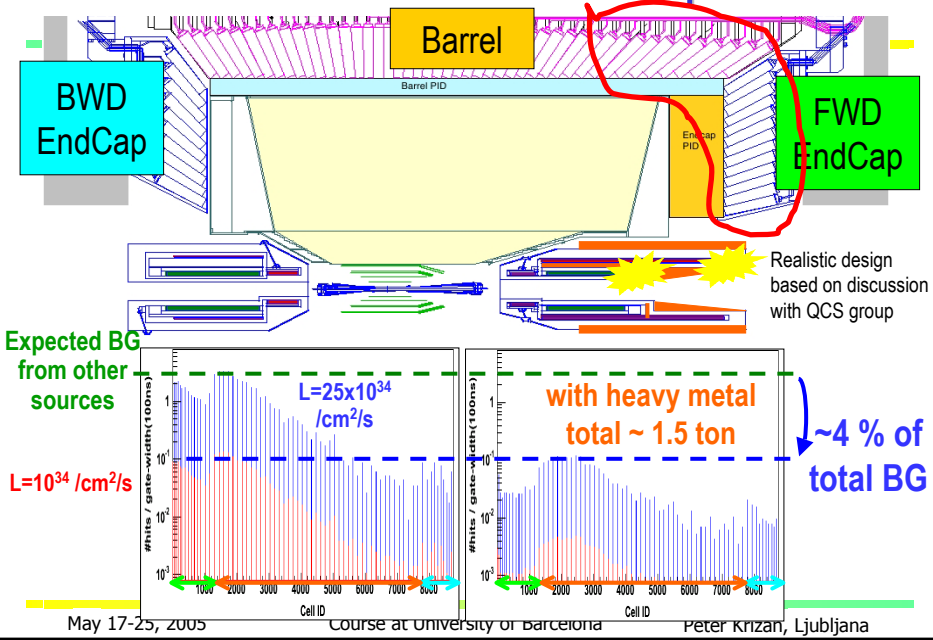


L_{peak} (cm^{-2}s^{-1})	1.4x10^{34}	5x10^{34}	5x10^{35}
L_{int}	330 fb^{-1}	~1 ab^{-1}	~10 ab^{-1}

Belle Upgrade



Rad. Bhabha BG sim. for Super-KEKB

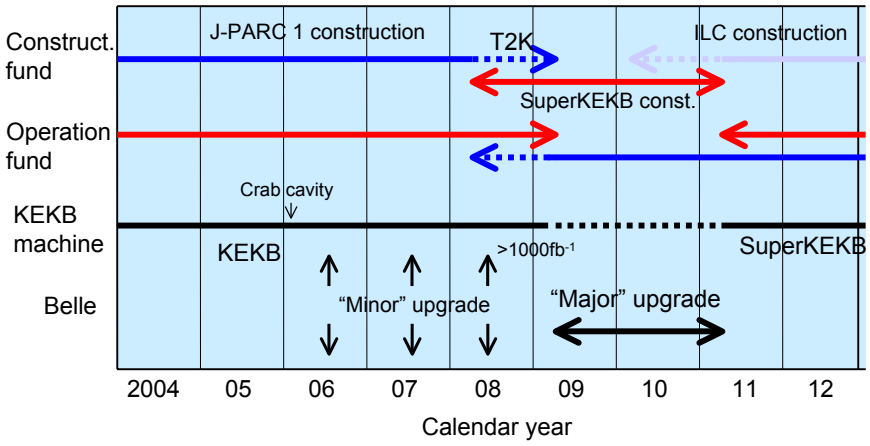


Baseline Design of SuperBelle

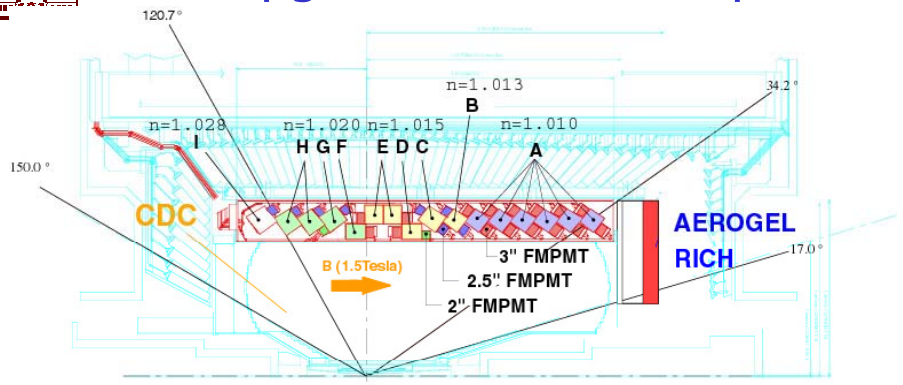
- Vertexing detector: “striplet” + APV25 or pixel
- Central drift chamber: small cell + faster gas
- PID device: TOP(B) + Aerogel RICH(E)
- EM calorimeter: Pure CsI + tetrode (E)
- Scintillator K_L and μ detector (KLM) <– no RPCs
- Pipelined DAQ
- Much bigger computing system

→ Issue

Proposed Schedule



PID upgrade in the endcap



improve K/π separation in the forward (high mom.) region for few-body decays of B's

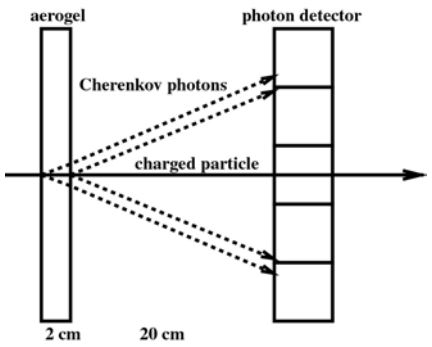
good K/π separation for b -> dγ , b -> sγ

improve purity in fully reconstructed B decays

low momentum (<1GeV/c) e/μ/π separation (B ->Kll)

keep high the efficiency for tagging kaons

Proximity focusing RICH in the forward region



K/π separation at 4 GeV/c

$\theta_c(\pi)$ ~ 308 mrad (n = 1.05)

$\theta_c(\pi) - \theta_c(K)$ ~ 23 mrad

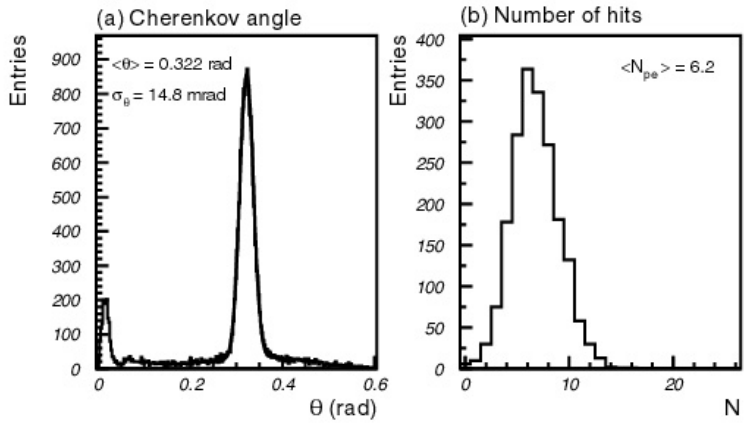
$d\theta_c$(meas.) = σ_0 ~ 13 mrad

With 20mm thick aerogel and 6mm PMT pad size

→ 6σ separation with N_{pe}~10

Beam test: Cherenkov angle resolution and number of photons

Beam test results with 2cm thick aerogel tiles:
>4σ K/π separation

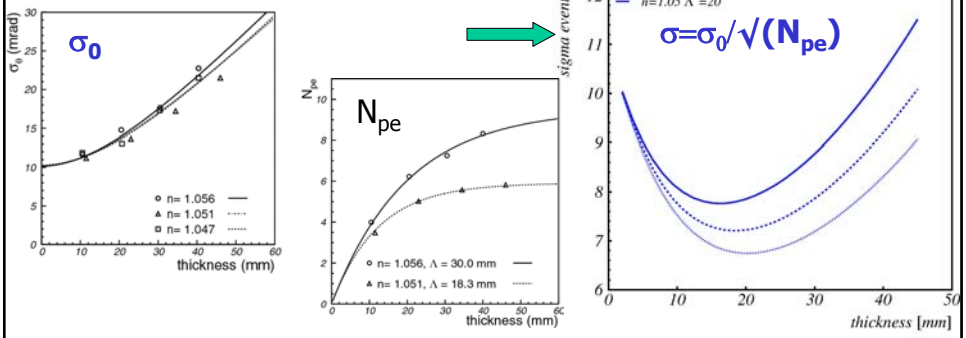


-> Number of photons has to be increased.

How to increase the number of photons?

What is the optimal radiator thickness?

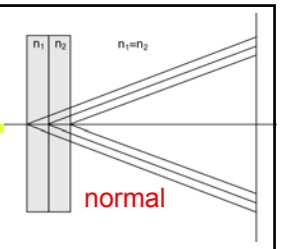
Use beam test data on σ_0 and N_{pe}



Minimize the error per track: $\sigma=\sigma_0/\sqrt{(N_{pe})}$

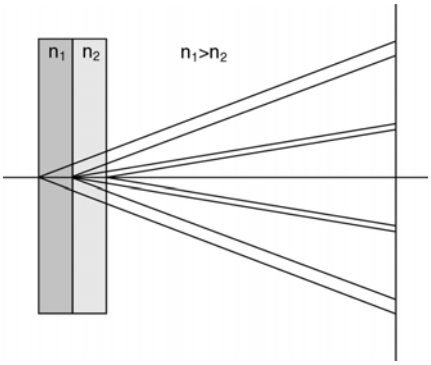
Optimum is close to 2 cm

Radiator with multiple refractive indices

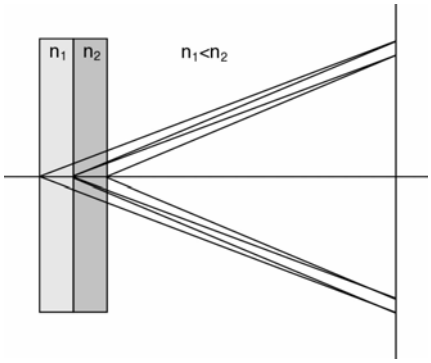


How to increase the number of photons without degrading the resolution?

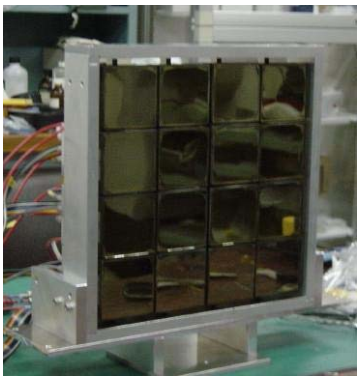
. measure two separate rings
"defocusing" configuration



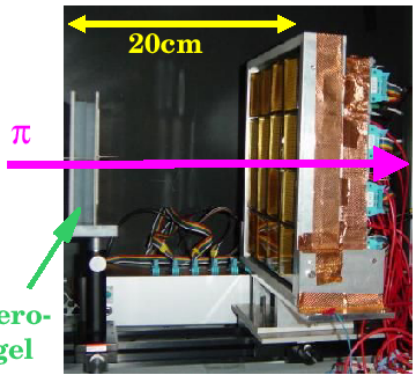
. measure overlaping rings
"focusing" configuration



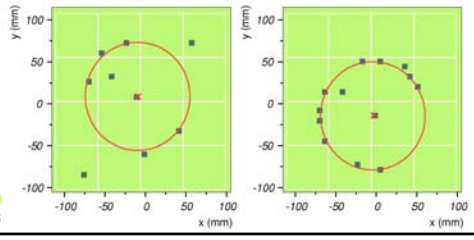
Beam tests



Photon detector: array of 16 H8500 PMTs

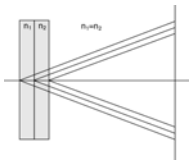


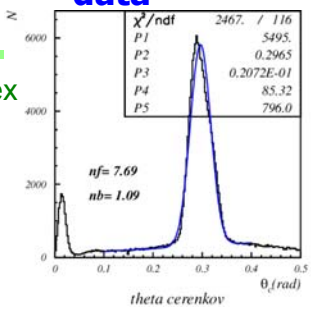
Clear rings, little background



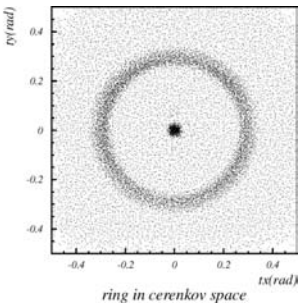
FOCUSING CONFIGURATION - data

4cm aerogel single index



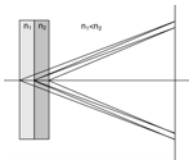


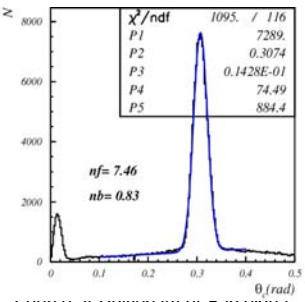
theta cerenkov

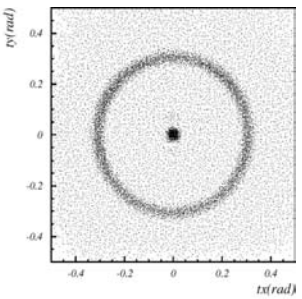


ring in cerenkov space

2+2cm aerogel







Aerogel production R&D

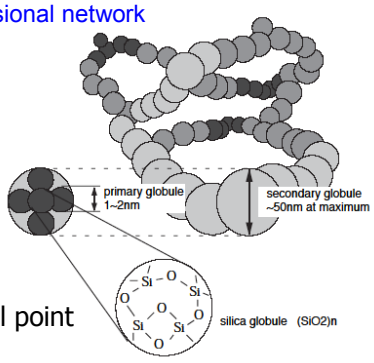
- Colloidal formation

$n\mathrm{Si(OR)_4} + 4n\mathrm{H_2O} \rightarrow n\mathrm{Si(OH)_4} + 4n\mathrm{H_2O}$ hydrolysis

$n\mathrm{Si(OH)_4} \rightarrow (\mathrm{SiO_2})_n + 2n\mathrm{H_2O}$ condensation

ammonia alcohol

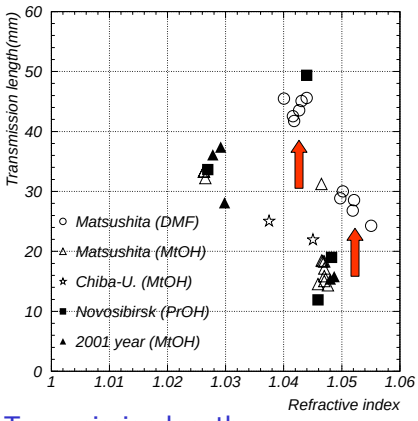
3-dimensional network



- Treatment for hydrophobic
- Supercritical drying
  - Use CO_2 extraction
  - Safer due to low supercritical point
    - 31degree & 7.5MPa

cf: methanol: 240degree & 8.1MPa

Aerogel production R&D



Transmission length vs refractive index

Reported last year: better optical quality for n~1.05 hydrophobic aerogel

a new solvent (Di-Methyl-Formamide instead of Methyl-alcohol)

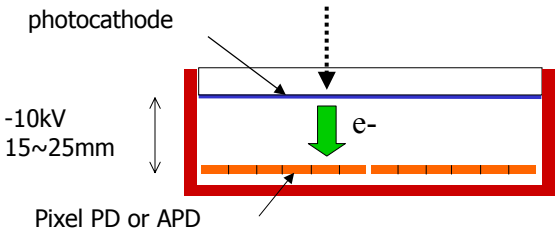
precursor (Methyl-silicate-51) from a different supplier

-> considerable improvement

100x100x20mm^3 n=1.050

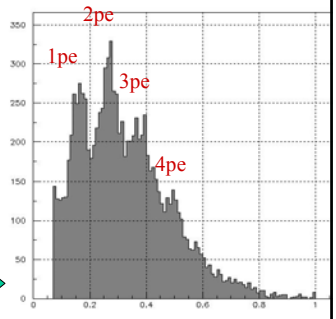
Development and testing of photon detectors for 1.5 T

- Has to work inside magnetic field of the spectrometer = 1.5 T
- Baseline: large area HPD of the proximity focusing type
- Backup: MCP-PMT



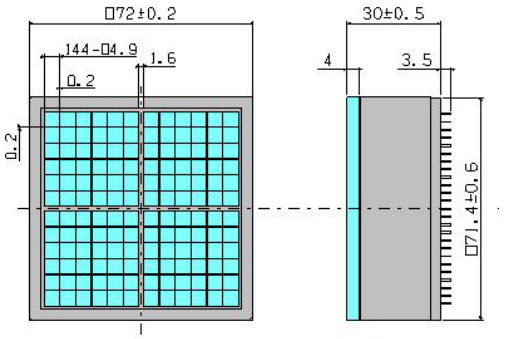
R&D project in collaboration with Hamamatsu

Tests with single channel and 3x3 channel devices look very promissing.



HPD development

59mm x 59mm active area (65%),
12x12 channels



Ceramic HPD box

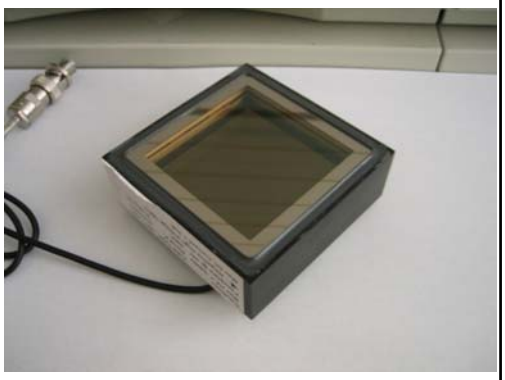
First tests carried out. Problems with sealing the tube at the window-ceramic box interface.

Waiting for the next batch in September.

Photon detector R&D – one of the options: Burle MCP-PMT

BURLE 85011 MCP-PMT:

- multi-anode PMT with 2 MCPs
- 25 μm pores
- bialkali photocathode
- gain ~ 0.6 x 10^6
- collection efficiency ~ 60%
- box dimensions ~ 71mm square
- 64(8x8) anode pads
- pitch ~ 6.45mm, gap ~ 0.5mm
- active area fraction ~ 52%



Burle MCP PMT beam test

- **BURLE MCP-PMT** mounted together with an array of 12(6x2) **Hamamatsu R5900-M16 PMTs** at 30mm pitch (reference counter)