Status of FARICH


presented by Sergey Kononov
Budker INP

XIII SuperB PID meeting, Isola d'Elba
May 31, 2010
Focusing Aerogel + NaF

- We need some high index radiator media to positively identify low momentum particles ($p_K < 1.3$ GeV/c).
- Water was initially proposed but it entails a container issue.
- Sodium fluoride (NaF) crystal has index of refraction $n=1.33$ about the same as water, downside: $X_0$(NaF) = 11.7 cm – 3 times less than water.
- NaF-RICH was used in CAPRICE (balloon borne experiment flew in 1994) NaF and aerogel based RICH installed in AMS-02. We studied it earlier (A.Yu.Barnyakov et al., NIMA 581(2007)410).
- NaF price from Crystran Co. dated 2006
  NaF polished plate 138mm x 127mm x 10mm 1pce US$2000 $11/cm$^2$, small comparing to ~$200/cm^2$ for Photonis MCP PMT
FARICH for SuperB

- Expansion gap ~180 mm
- Photonis MCP PMT with 8x8 anode pads of 6x6mm
- 3-layer focusing aerogel $n_{\text{max}} = 1.07$, 40mm thickness
- NaF 5mm thickness
- $X/X_0 = 4\%$ (aerogel) + $4\%$ (NaF) + $10\%$ (MCP PMT) + $8\%$ (?? support, electronics, cables) = $26\%$
- BaBar DIRC: $19\%$ $X_0$ at $\theta = 90^\circ$, $43\%$ $X_0$ at $\theta = 26^\circ$
Photonis MCP PMT

XP85012

- Chevron MCP configuration
- 8x8 anode pads with 6.5mm pitch
- Bialkali photocathode, QE(400nm)=29%
- Gain \( \sim 5 \cdot 10^5 \)
- 25\(\mu\)m pores, need 10\(\mu\)m to work in 1.5T field with gain \( \geq 10^5 \)
- MCP open area ratio \( \sim 70 \% \)
- Size □59 mm
- Effective area fraction 81%
- excellent timing \( \sim 40\)ps single photon

J. Va'vra

\( \text{QE}(\lambda) \)
Layout of PMTs

- 12 sectors in phi
- 26 PMTs in each sector, 88% fill factor
- active/total area ~70%
- 312 PMTs in all
- 19,968 channels
Monte Carlo simulation

Simulation

- Standalone, based on Geant4.
- Geometry: radiator and detection planes are parallel, full photon acceptance.
- Radiator's layers can be configured with a great amount of freedom. Single-ring focusing aerogel is calculated for a given thickness and a number of layers.
- Photon detector is homogeneous with equidistant square pixels, defined by PDE(\(\lambda\)), pixel size and fill factor.
- Effects: Rayleigh scattering and absorption in aerogel, dispersion of refractive index, multiple scattering, magnetic field.

Reconstruction

- Track parameters are taken from simulation.
- Scattered and reflected photons are killed.
- Hit position as center of a pixel (primary particle position randomized in XY over a pixel period).
- Observable: radius (angle) of a hit relative to track position (angle).
- Dependence of the average radius (angle) on particle velocity is calibrated and used to reconstruct velocity and derive \(\sigma_\beta\).
- For inclined tracks calibration is phi-wise.
- Separation: \[
\frac{2(\beta_\pi - \beta_K)}{\sigma_\pi + \sigma_K}
\]
Monte Carlo simulation

kaon @ 4 GeV/c

May 31, 2010

Sergey Kononov, Budker INP
FARICH: Npe and $\sigma_\beta$

$D=180\text{mm}$, Photonis MCP PMT with 6mm pixels

$Npe = 16+17$

$\sigma_\beta \geq 8 \cdot 10^{-4}$
FARICH: PID

D=180mm, Photonis MCP PMT with 6mm pixel

Excellent PID level. There is an overlap with DCH dE/dx PID
Background consideration

- Only background from radiative Bhabha has been considered (showers in IR elements penetrating tungsten shielding).
- The electron momentum spectrum in Forward TOF (1cm quartz) was taken from the Leonid's presentation in Annecy.
- Simulate the response of RICH to electrons when shoot directly to NaF (10 mm), multiple scattering and B-field is taken into account: 0.7 p.e. per particle.
- 8 electrons in average per bunch crossing (Leonid's presentation): 6 p.e. per bunch crossing.
- Occupancy from Bhabha events (~80kHz) is negligible.
Background consideration

- **Pile-up noise**
  Time resolution <1ns
  Occupancy: 6p.e./20000ch = $3 \cdot 10^{-4}$ → less than one background hit within area of the rings – negligible for the ring reconstruction.

- **MCP PMT aging**
  Gain: $10^5$
  Integrated anode charge:
  \[6 \times 200 \times 10^6 \times 10^5 \times 3 \times 10^7 \times 1.6 \times 10^{-19} / (312 \times 5.3^2) = 0.07 \text{ C/cm}^2/\text{year}\]
  P. Krizan et al. poster at RICH2010:
  10% QE drop at 400mC/cm$^2$ (25μm version) ~6 years of SuperB
  Aging tests of 10μm version are ongoing (P.Krizan)

- **MCP PMT gain stability**
  Time between collisions: 5ns
  Rate: $6 \times 200 \times 10^6 / (312 \times 5.3^2) = 140 \text{ kHz/cm}^2$ – no gain drop.
Front-end electronics

- We have started consultations with Dominique: Can use FE ASICs similar to FDIRC
- 100 ps TDC timing resolution would provide a strong suppression of backgrounds.
- Good time-of-flight measurement is expected as well. Simple estimation: $\sigma_{\text{TOF}} \sim 50\text{ps}$ for 1GeV/c kaons.
- Need a conceptual design that would enable to fit FEE in the small space 3-4cm behind the PMTs.
Cost estimation

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost, k€</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photonis MCP PMT, 6.5k€/unit*</td>
<td>2,300</td>
</tr>
<tr>
<td>3-layer aerogel, 3k€/tile</td>
<td>400</td>
</tr>
<tr>
<td>NaF, 2k€/tile</td>
<td>200</td>
</tr>
<tr>
<td>Electronics (scaled from FDIRC)</td>
<td>300</td>
</tr>
<tr>
<td>Mechanical structure (?)</td>
<td>100</td>
</tr>
<tr>
<td>R&amp;D (FARICH prototype)</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>3,400</td>
</tr>
</tbody>
</table>

*Price for MCP PMT with 25μm pores. 10μm version is under development and price is unknown.
Aerogel-only option

D=180mm, Photonis MCP PMT with 6mm pixels

- No NaF – 4% $X_0$ less material
- No positive kaon ID below $P=1.3$ GeV/c => we can work in yes-no mode
- Less robust relative to backgrounds
- Cost ~3.2 M€
**NaF-only option**

D=180mm, Photonis MCP PMT with 12mm pixels (four 6mm-pixels joined)

- $\pi/K$ up to 4 GeV/c
- 4 times less channels (5'000 channels) => cheaper, less material
- No aerogel => cheaper
- Less robust performance
- Cost ~2.8 M€

Ring (R~30cm) will be clipped if side mirrors are not used => need 10mm thickness to retain Npe>10.
FARICH prototype

- box designed for radiator-PD distance from 50 to 700 mm
- 32 MRS-APDs (SiPMs) as photon detectors
- custom made discriminator boards
- CAEN V1190B 64 channel multihitTDC
Prototype's status

- Most of SiPMs are tested for amplification, noise rate
- TDC readout with SiPMs and discriminators is tested
- Assembly is in progress
Electron beam of several GeV (< 5 GeV)
Moving converter in the beam halo to produce Bremsstrahlung gammas
Gammas are converted to electron-positron pairs in the target
Magnet is used to select electrons (positrons) with the required energy
The components are being assembled and tested
First runs planned for October-November 2010
Conclusion and outlook

- The Forward PID system based on FARICH with an excellent performance is suggested: $\pi/K$ better than $8\sigma$ (MC) in the range $0.6-4$ GeV/c.
- Pile-up noise from radiative Bhabha is small.
- Accumulated anode charge of MCP PMT is estimated at 70 mC/cm$^2$/year – only minor aging of photocathode is expected during the SuperB lifetime.
- The cost of the FARICH is estimated at 3.4 M€.
- The first beam test with the FARICH prototype is to be carried out until the end of 2010.
- Front-end electronics conceptual design should be created.
## Planacon XP85012 material budget

Calculated basing on information from Emile Schyns (Photonis)

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness, cm</th>
<th>$X_0$, g/cm²</th>
<th>$\rho$, g/cm³</th>
<th>Weight, g</th>
<th>$X/X_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Window</strong></td>
<td>Borosilicate glass</td>
<td>0.2</td>
<td>28.2</td>
<td>2.23</td>
<td>14.9</td>
</tr>
<tr>
<td><strong>Endplate</strong></td>
<td>$Al_2O_3$ ceramics</td>
<td>0.1</td>
<td>27.9</td>
<td>3.9</td>
<td>13.1</td>
</tr>
<tr>
<td><strong>Two MCPs</strong></td>
<td>Lead glass (65% porosity)</td>
<td>0.2</td>
<td>9.6</td>
<td>4.0</td>
<td>8.0</td>
</tr>
<tr>
<td><strong>Anode pads</strong></td>
<td>Fe</td>
<td>0.01</td>
<td>13.8</td>
<td>7.87</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Contacts</strong></td>
<td>Fe</td>
<td>0.46</td>
<td>13.8</td>
<td>7.87</td>
<td>18.7</td>
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<tr>
<td><strong>Isolators</strong></td>
<td>$Al_2O_3$ ceramics</td>
<td>0.56</td>
<td>27.9</td>
<td>3.9</td>
<td>11.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68.0</td>
</tr>
</tbody>
</table>

Supposedly
Monte Carlo simulation
additional effects

Degradation of resolution
π @ 0.7 GeV/c (βγ=5)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No field, MS on</td>
<td>4%</td>
</tr>
<tr>
<td>B=1.5T from IP, MS off</td>
<td>14%</td>
</tr>
<tr>
<td>B=1.5T from IP, MS on</td>
<td>21%</td>
</tr>
</tbody>
</table>

π @ 0.7 GeV/c
B=1.5T, MS on
Occupancy (NaF+Aerogel)
NaF-RICH
Compact NaF-RICH idea

NaF-RICH can be made thinner if use mirrors with PMTs flipped.
Test beam at VEPP-4M Novosibirsk
Gain in magnetic field

Photonis XP85012 (25 μm)

Photonis Prototype (10 μm)

Hamamatsu R10754-00-L4 (10 μm)

A. Lehman (PANDA Coll.), RICH2010
MCP PMT rate stability

A. Lehman (PANDA Coll.), RICH2010