# Report of
# Forward PID Taskforce

Members:
C. Hearty, H. Jawahery, P. Lubrano, B. Meadow & M. Rama

Representatives of proponents:
J. Va'vra (TOF), E.A. Kravchenko (FARICH), N. Arnaud, A. Stocchi (fTOF)

*XVII Super B Workshop*
*Elba*
*June 1, 2011*

*Hassan Jawahery*
*University of Maryland*

# The charge

## Charge to the SuperB Detector Geometry Selection Task Forces.

**BR+FF, July 1, 2010**

Several of the options described for the SuperB detector in the Conceptual Design Report of 2007 have now been resolved. However, as indicated in the Detector Progress Report of June 30, 2010, two major options remain that have a large impact on the overall detector system geometry, and therefore prevent us from defining final subsystem envelopes. Specifically, these open options are:

1. whether to include a hadronic PID detector in the forward region, and
2. whether to include an EMC in the backward region

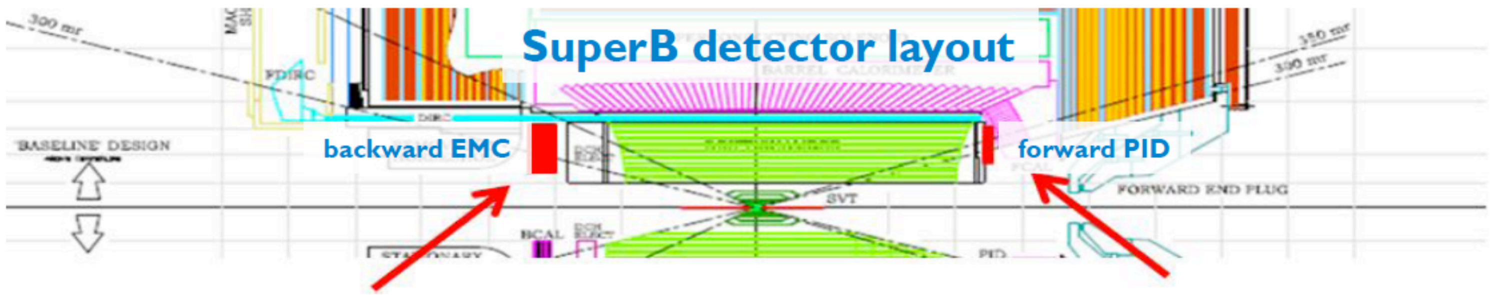
As we believe it is crucial to be able to define these regions soon, and in any case before the TDR, we have decided to appoint two Geometry Selection Task Forces (one for the forward region and one for the backward region) to broadly investigate all issues involved and provide recommendations to the Techboard for final decisions.

These Task Force committees are called (1) The Forward Geometry Selection Task Force, led by Hassan Jawahery, and (2) The Backward Geometry Selection Task Force, led by Bill Wisniewski. Other committee members are ………

The committees should make their recommendations based on a wise balance between all competing factors. These factors include, but are not limited to:

1. an evaluation of the physics impact of the inclusion of the device;
2. the impact of the material of the device on the performance of other subdetectors;
3. an evaluation of the technical performance of suggested devices, their maturity, the related risks, and the need for further R&D;
4. the impact on the overall detector structure and assembly procedures,
5. the cost of the device
6. the manpower needs and group strengths.

# FPID- Geometry




Forward PID angular acceptance:

$\theta = 17^o - 26^o$ (~5% CM of all tracks (if isotropic in CM))

Other geometry related considerations

Length of DCH

Material & its distribution in front of Forward EMC

Proposed Candidate Technologies:

Focusing RICH (FARICH)

DIRC-like TOF (fTOF) (TOF resolution ~40 ps)

Pixalated TOF (TOF resolution of ~100 ps)

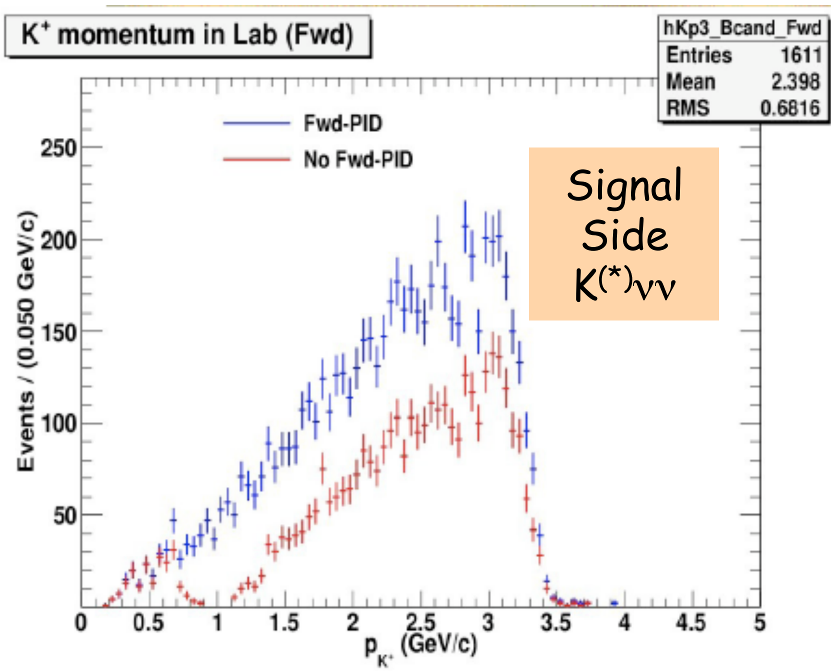
# Physics Impact

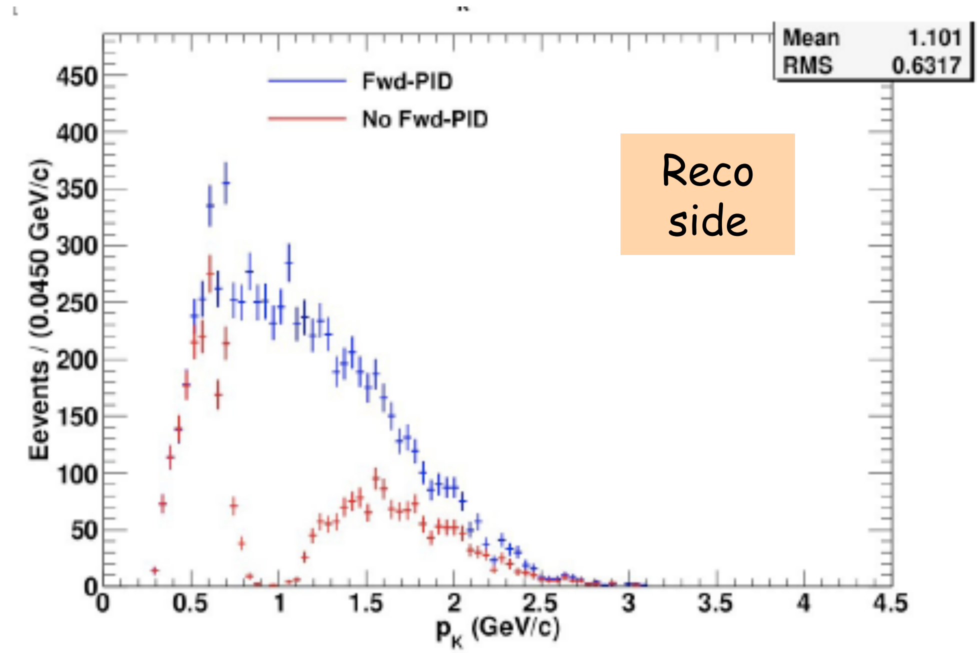
- The main physics gain is expected to be in improved $K/\pi$ separation.

- Physics Gain evaluated using the benchmark modes:
  - $B \to K^{*0}(\to K^-\pi^+)\nu\nu$ + Reconstruction of other B
  - $B \to \tau\nu$ + Reconstruction of other B
  - Other processes, including charmless B, tau and charm decays will benefit, but most are not statistic starved.

- Must also evaluate the adverse impact:
  - Performance of Forward EMC, due to the increased material in front.
    - Evaluated in terms of efficiency and resolution for $\gamma$ & $\pi^0$
  - Performance of DCH due to the shorter length in the forward section of the detector
    - Evaluated in terms of impact on momentum resolution

# Physics Impact (Results)




## Conclusions for fwd TOF

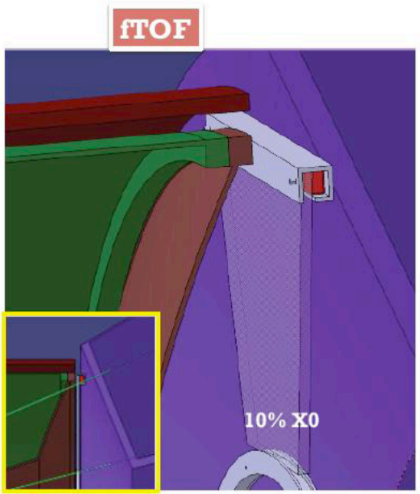
E. Manoni
A. Perez

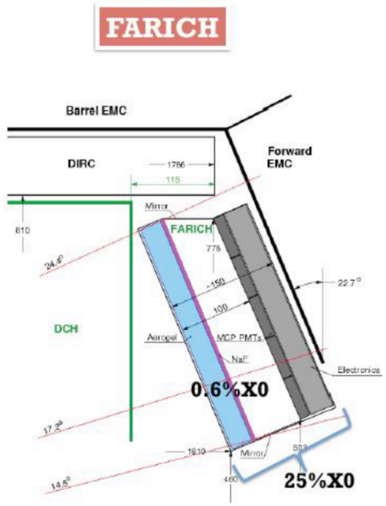
- The results of the hadronic and SL analyses are overall consistent
- 2.0-2.5% efficiency gain per identified $K^{\pm}$
  - The efficiency of signal plus Breco tag increases by ~4.5% (~2.5%) when there is (not) a $K^{\pm}$ in the signal final state
  - The Breco tag background increases as well (~2.5%)
  - S/sqrt(S+B) increases by ~1-4 % depending on the mode

# Physics – Impact on EMC

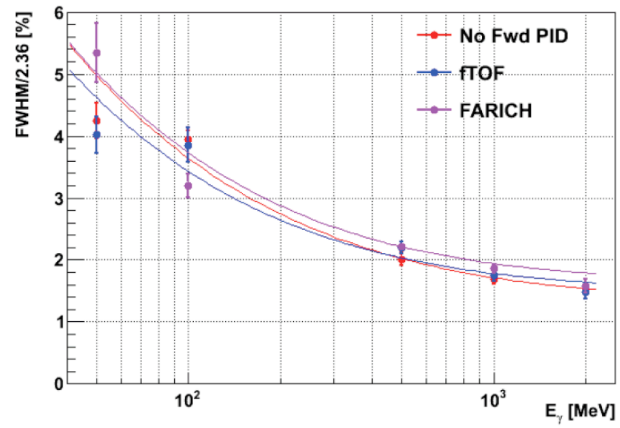
S. Germani

## Fwd PID geometry options

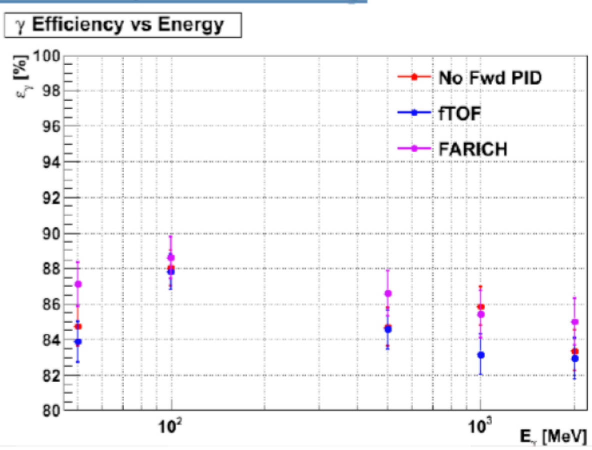



## Fwd EMC Energy Resolution




## Fwd EMC $\gamma$ Efficiency




eff(FARICH)>eff(fTOF) (but single points are stat. compatible)

can it be due to different placement of fTOF compai to FARICH?

- Fwd PID Effects on EMC
  - $\gamma$
    - fTOF and FARICH effects on photons energy resolution are negligible
    - FARICH effects on photon detection efficiency is negligible
    - fTOF effect on photon detection efficiency is very small
  - $\pi^0$
    - fTOF and FARICH effects on pions mass resolution are negligible
    - fTOF and FARICH effects on pions detection efficiency is small

# Physics- Impact on DCH

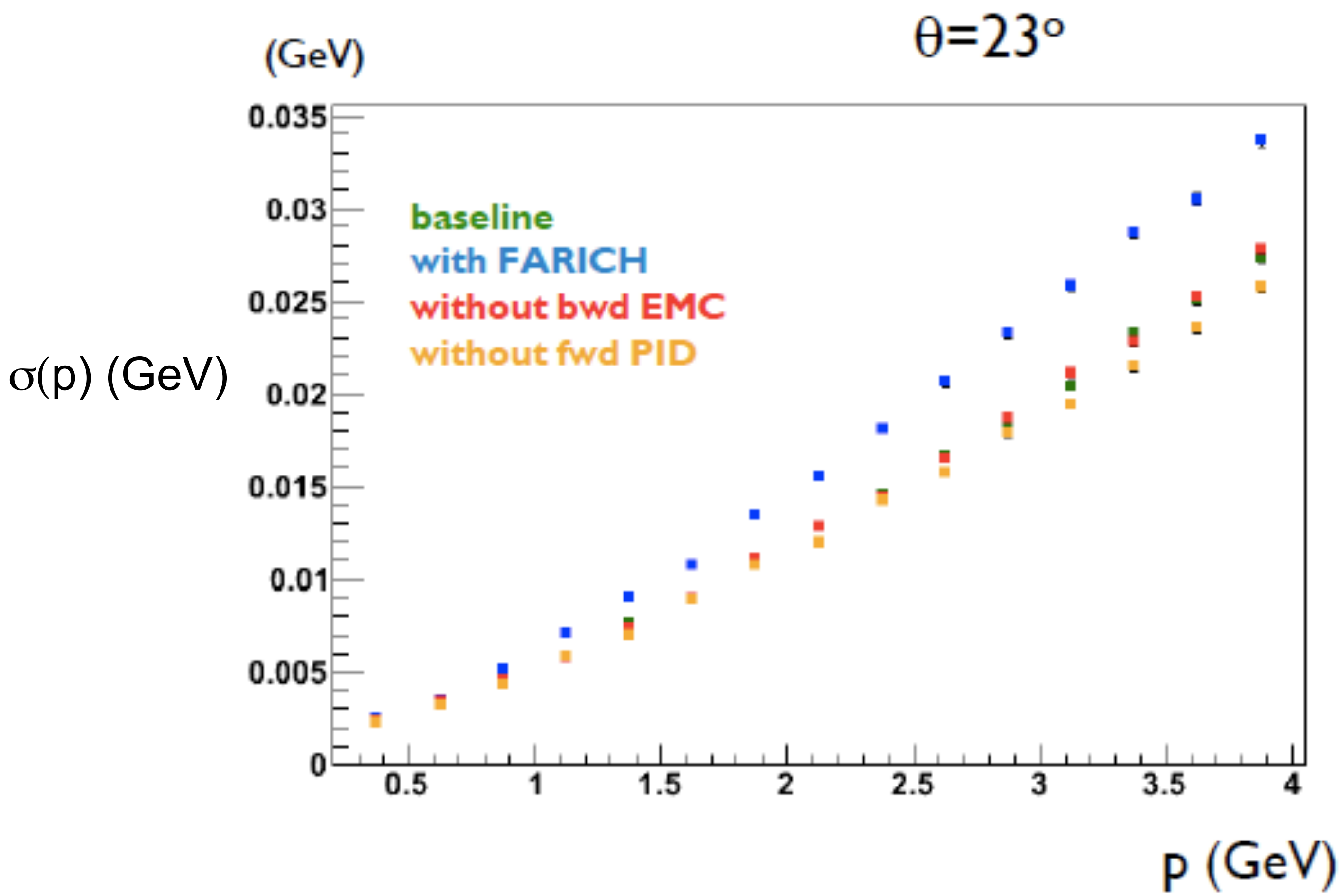
M. Rama

Impact of the change in DCH length on momentum resolution

Degradation of momentum resolution for tracks in FPID region

[FARICH ( -17 cm): 17%   &  fTOF ( -5 cm): 5%]

~1% degradation/cm



# Proposed Detector Technologies

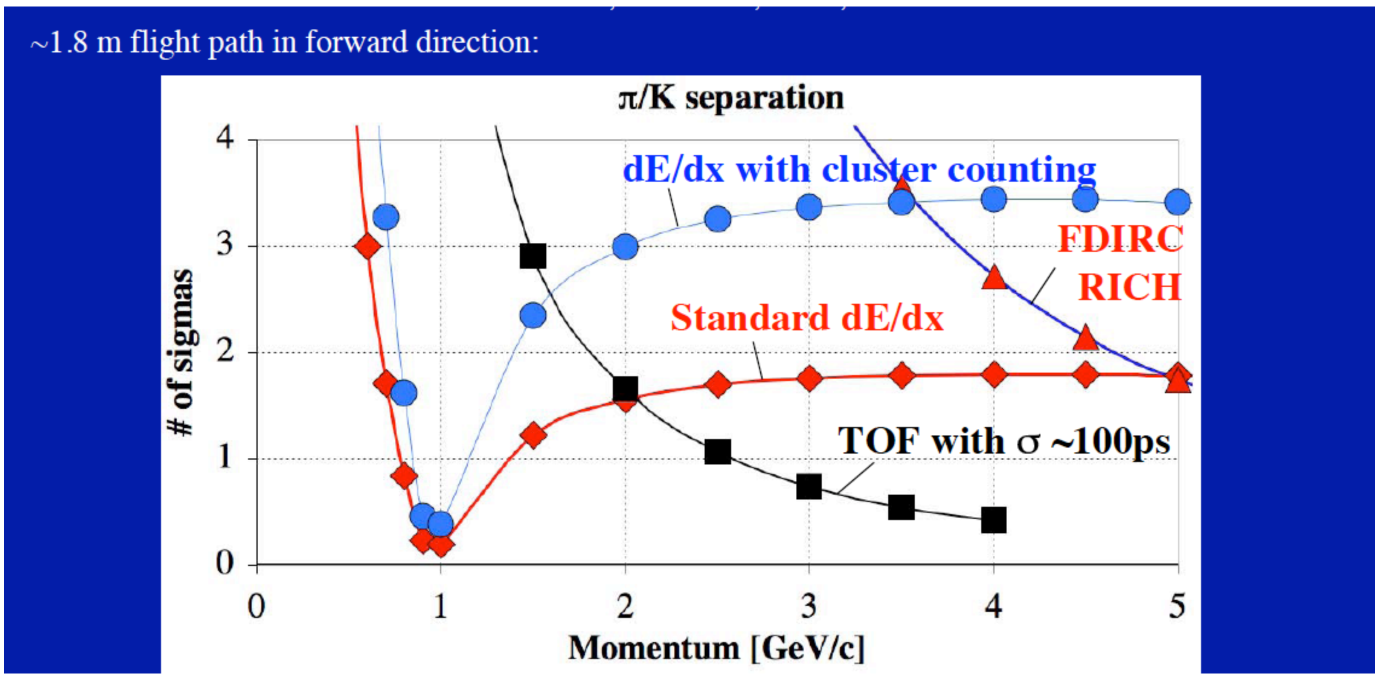
# Technology Evaluation parameters

- Proof-Of-Principle for each of the proposed technologies- at least with cosmic- ray tests, and if possible with beam tests. Issues common to all devices are:
  - Performance in presence of background.
  - The effect of magnetic field on photo-detectors and the overall performance of the device.
  - Aging of the photo-detectors
- Reliable estimates of cost, required manpower, and construction schedule for each of the proposed technologies. This includes, information on the availability of components on the time scale of SuperB construction schedule
- Integration

# Pixelated TOF Option

- The Idea is to use the LYSO crystals of the FEMC as TOF counters- read out with G-APD

- At 100 ps resolutions- this technique provides >3 sigma K/pi separation up to ~1.5 GeV- coverage in dE/dx hole (p~ 1 GeV) & complement dE/dx elsewhere



# Pixelated TOF performance

Jerry Va'vra: CR Studies performed at SLAC with 4x4 G-APD arrays

## Conclusion

- **Results so far:**

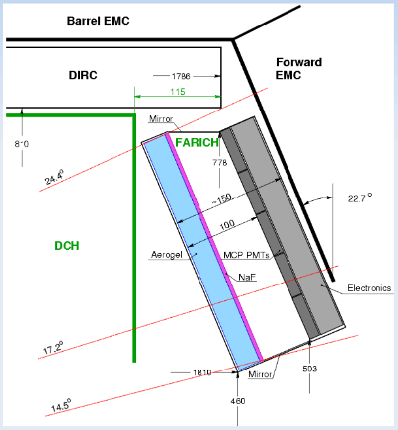
| Test | Radiator | Detector | Particle | Resolution |
|---|---|---|---|---|
| SLAC | Small LYSO 17mm x 17mm x 17mm | MCP-PMT | CRT μ's | 109 & 159 ps |
| SLAC | Small LYSO 17mm x 17mm x 17mm | G-APD array | CRT μ's | ~ 140 ps |
| SLAC | Small scint. 17mm x 17mm x 17mm | G-APD array | CRT μ's | ~ 136 ps |
| SLAC | Long LYSO 25mm x 25mm x 200mm | G-APD array | CRT μ's | ~ 220 ps |
| Fermilab | Tiny LYSO 3mm x 3mm x 7mm | $3mm^2$ G-APD | γ's from $Co^{60}$ | ~ 155 ps |
| Pisa | Tiny LYSO 3mm x 3mm x 10mm | $3mm^2$ G-APD | 2γ's from $Na^{22}$ | ~ 107 ps |

- Still one more test is planned in CRT, but things do not look hopeful to me that we can achieve σ ~ 100ps. But would like to go at it once more.

# Focusing RICH(FARICH) Option

E. Kravchenkov

## FARICH layout

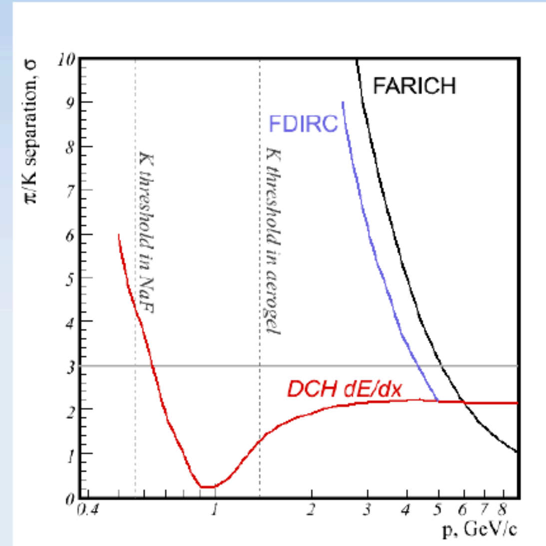



- MCP PMT photodetectors - Photonis XP85012
- Radiator - Focusing Aerogel + NaF

| layer | marerial | n(400nm) | t, mm |
|---|---|---|---|
| 1 | aerogel | 1.039 | 16.2 |
| 2 | aerogel | 1.050 | 13.8 |
| 3 | NaF | 1.332 | 5.0 |

- X/X0 = 2.4%(aerogel) + 4.3%(NaF) + 10%(PMT) + ~ 8% (support,FEE,cooling) ≈ 25%

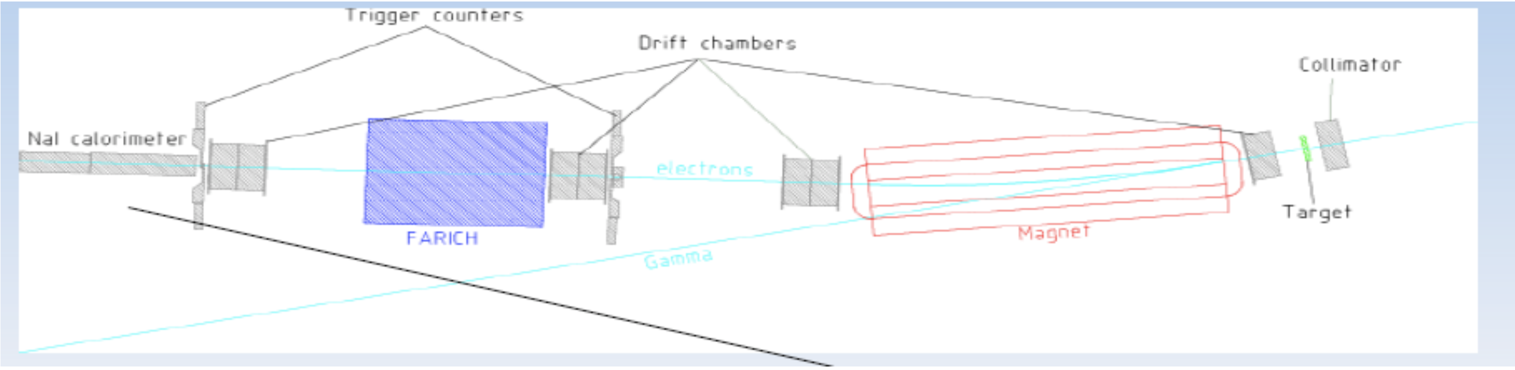
04.04.11 E.A.Kravchenko

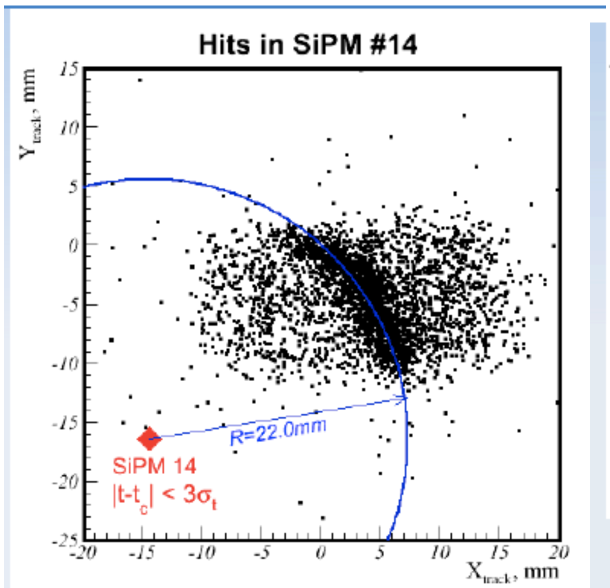


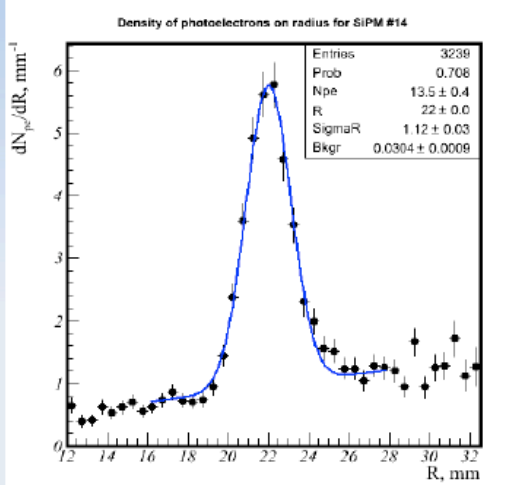

**π/K separation of FARICH in comparison with FDIRC and DCH**

- Superior PID performance over other options
- Robust with respect to background hits
  - less than 1 hit/ Cherenkov ring
  - PMT lifetime >7 yrs (at gain~5x10$^5$ (?))
- Down side:
  - Needs to cut ~17 cm from DCH is ~17 cm.
    - 17% degradation of momentum resolution.
  - material in front of EMC (25% $X_0$ )
  - Cost ~3.5 M Euro [dominated by PMT]
    - Some uncertainties in availability of MCP-PMT's (10 μm hole)

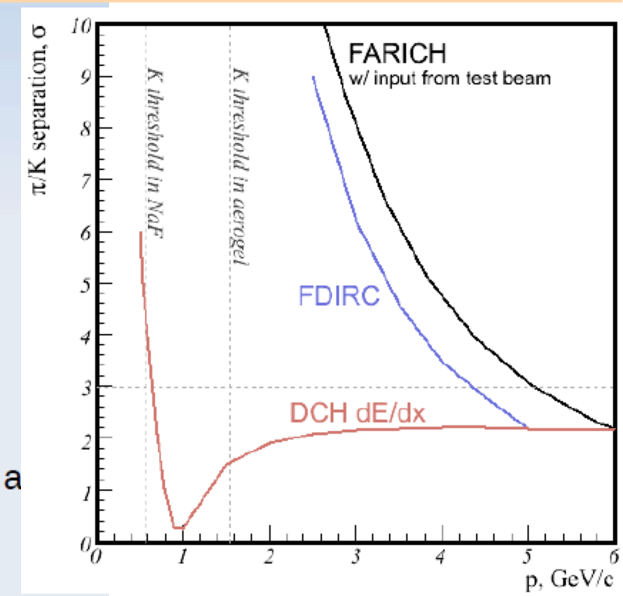
# FARICH- beam test



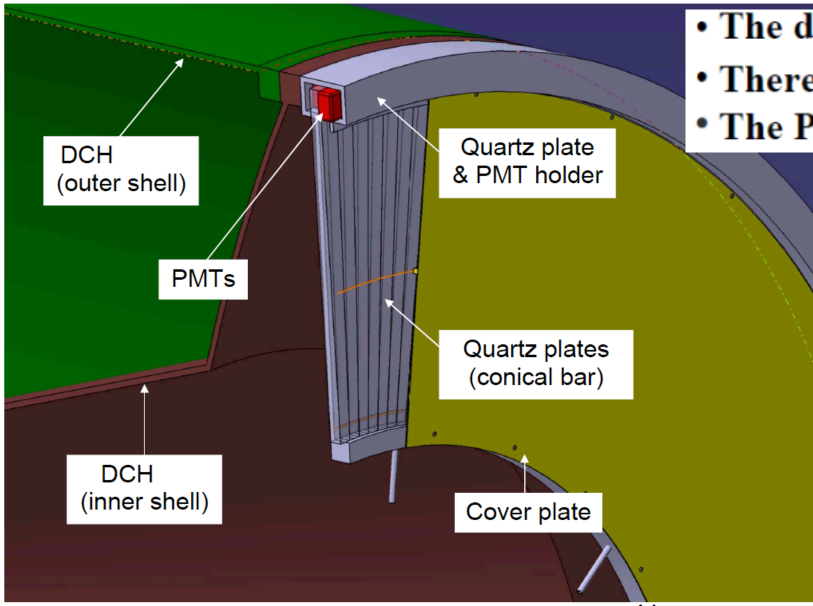

Recalculation of performance with beam test results




- Pure Gaussian + flat background (from randome coincedence with G-APD noise) a least in ±5σ region.
- $\sigma_r^2 = \sigma_{aerogel}^2 + \sigma_{pixel}^2 + \sigma_{track}^2$
- $\sigma'_{aerogel} = \mathrm{sqrt}(\sigma_r^2 - \sigma_{pixel}^2)$

  $= \mathrm{sqrt}(1.09^2 - 2.1^2/12) = 0.91$ mm

# Focusing TOF (DIRC-like TOF) Option

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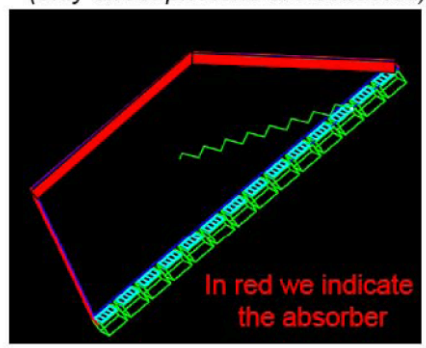
- **The detector is made of 1.5cm thick (12% $X_0$) quartz sectors,**
- **There are 12 sectors (30 degree in $\phi$) covering $15 < \theta < 25$ degrees**
- **The PMT's are attached to the sector outer radius (14 PMT's / sector)**

Two possibilities have been considered for the photon collections

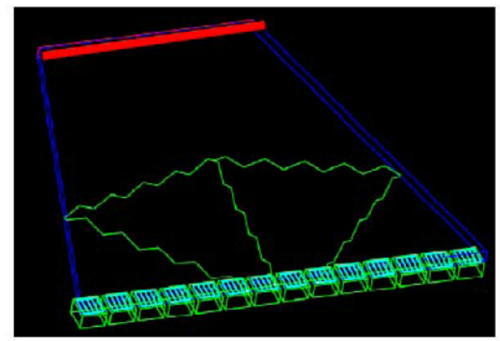
**"simple geometry – with absorber"**

*(only direct photons are collected)*

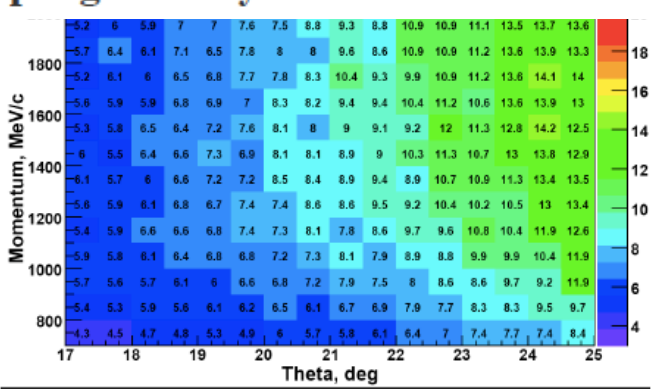



**"without absorber"**

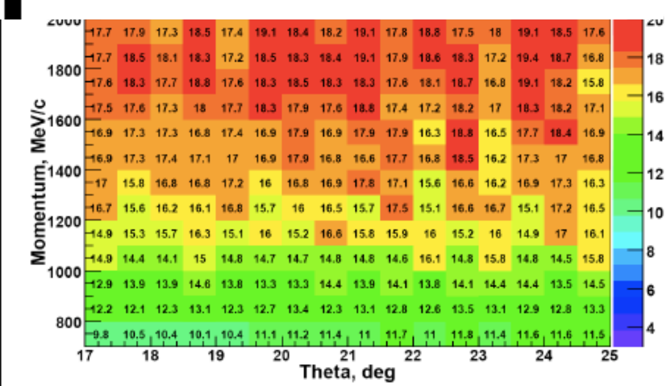
*(photons with different paths are collected)*



**"simple geometry – with absorber"**



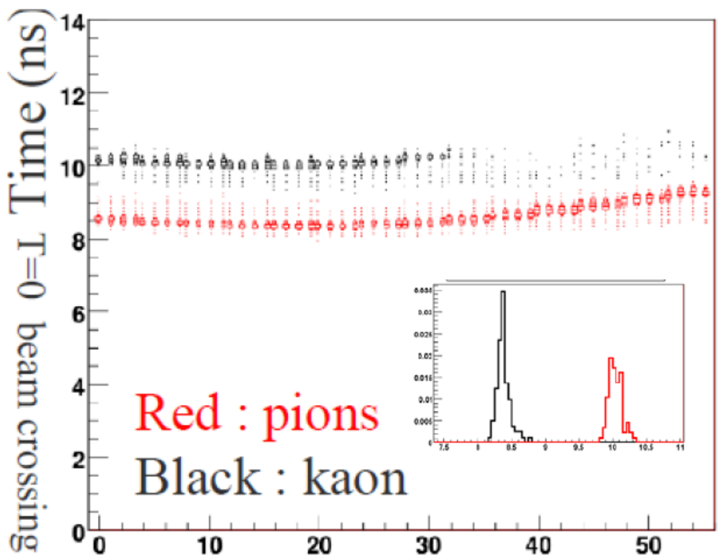

**"without absorber"**



# fTOF - expected performance

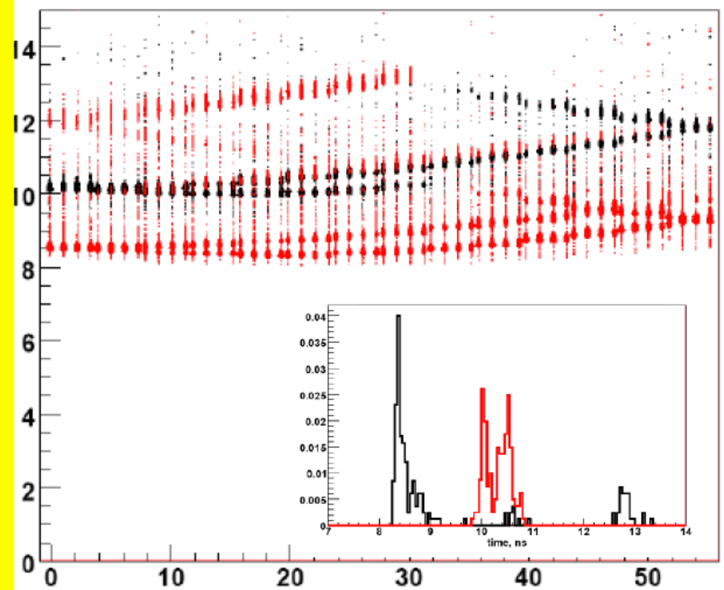
**Photoelectron timing using tracks with P=700Mev , theta=17, phi=0**

**"simple geometry – with absorber"**




Channel number of the PMT hit

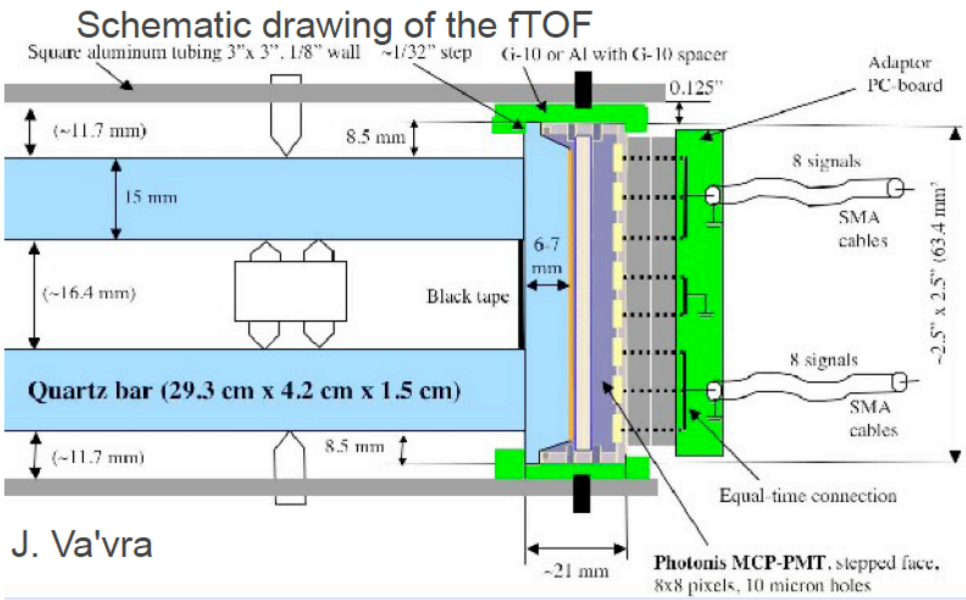
**"without absorber"**



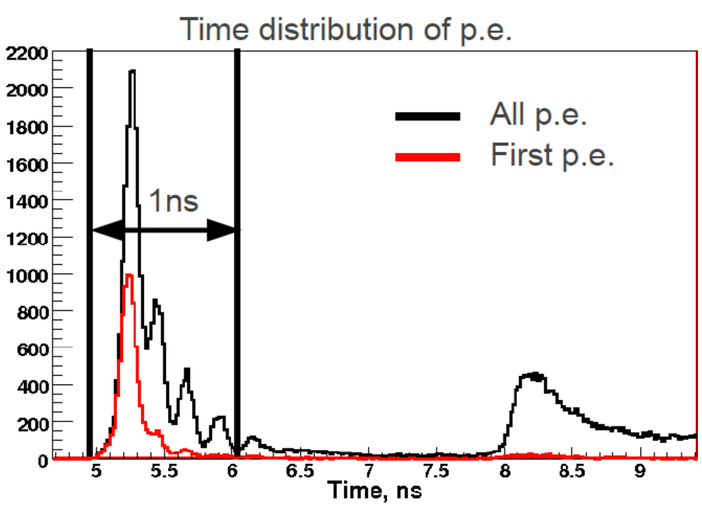
More photons collected but time algorithm more difficult.

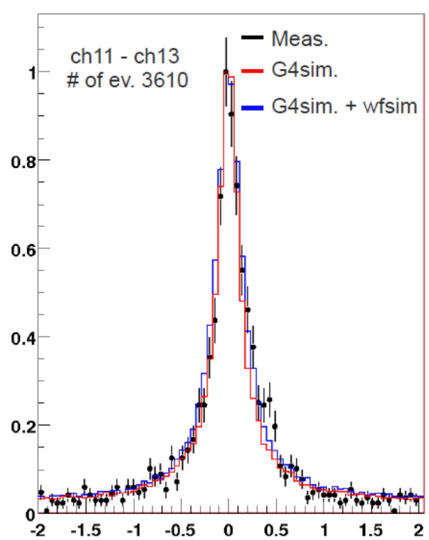
FTOF is a 2D device because it measures time vs position

# fTOF performance at SLAC Cosmic Ray set up




- Two quartz bars connected to one Photonis MCP-PMT (8x8 channels, stepped face, 10 micron holes).
- Tube operate at -2.7kV (gain ~ $7.0 \times 10^5$)
- 16 channels connected to the USBWC electronics developed by LAL electronics team
- Amplifiers (40dB)
- Filters (600MHz bandwidth )
- Another quartz counter used as trigger




- The narrow part of the distributions provides a measure of time resolution
  - ~90 ps/hit
- Results reproduced in simulation, validating other simulation predictions
- At >10 p.e. they expect better than 40 ps resolution/track

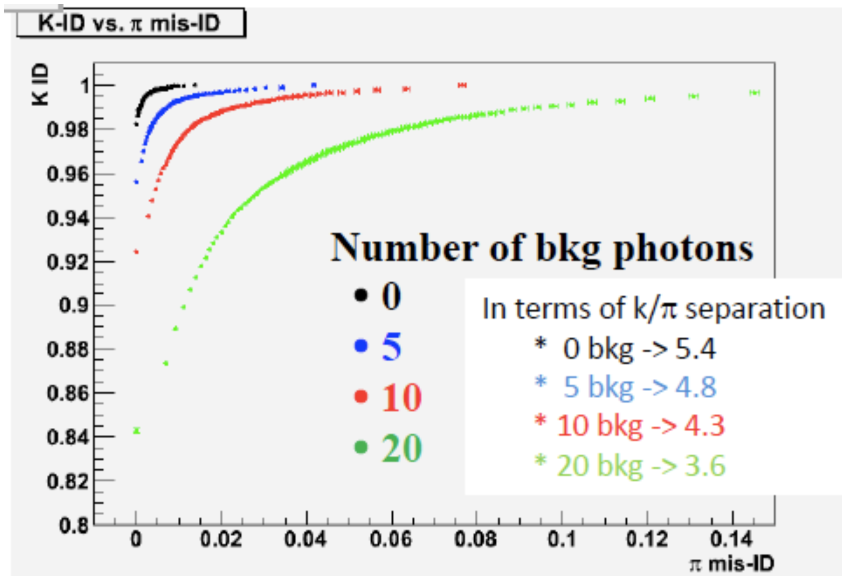
# fTOF performance (with BKG.)

Simulation of radiative Bhabhas & fTOF with Bruno

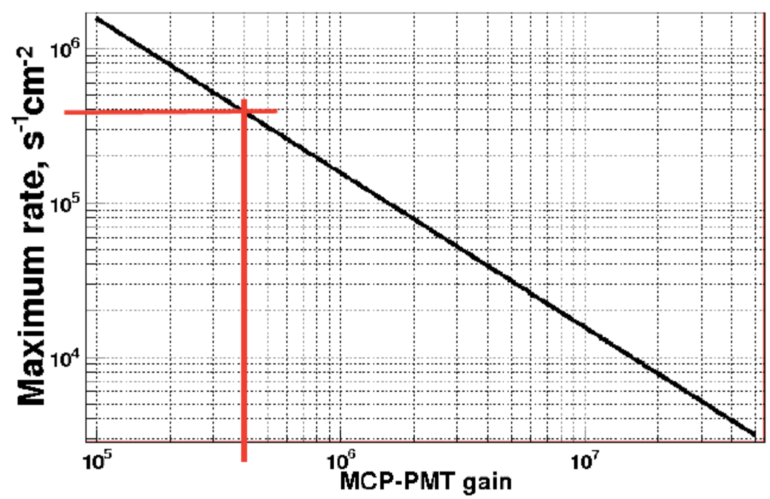
L.Bumistrov

| | | |
|---|---|---|
| Elba 2011 | Most precise description of the machine | 460kHz/cm$^2$ |

➔1.8 p.e in fTOF/bunch crossing




MCP-PMT life time




We can run tubes @ gain 4 *10$^5$
The study of the TTS of the SL10 at low gain is in progress at LAL test bunch.

**Maximum integrated anode charge for SL10-XM0027 : 2.5 C* (QE drop by 20%)**

Need verification in a full prototype

5 yrs PMT lifetime at 2.5 C maximum charge
The maximum may be 1 C- needs further investigation

# Other factors

- Cost:
  - fTOF ~2 M Euro [1.2 M for PMT]
  - FARICH ~3.5 M Euro [2.3 M for PMT]

  For comparison: Barrel focusing DIRC at ~ 10 M$

- Integration:
  - These devices weigh ~100 Kg or less
    - Could be supported on Forward EMC (at ~4 Ton) or DCH
  - No serious work done on how to take services in and signals out.

# Summary/Recommendation: Physics

- The gain from FPID is around 4-5% for best performance; Roughly 2%/Kaon. No physics channel with higher gain has been identified.

- Impact on EMC:
  - The results based on simulation and beam test [electrons at 1 GeV] show no significant degradation of resolution & efficiency for $\gamma$ & $\pi^0$

- Impact on Tracking resolution due to shortened Drift chamber:

  ~1% degradation in momentum resolution/cm cut from DCH

# Summary/Recommendations: FARICH

- On the whole this technology is likely to yield the most powerful PID performance- and robust- extending well above the nominal 4 GeV for the B decays. The expected performance is also verified by impressive beam test results. [However, we have not identified any physics channel that would significantly gain from the extended performance.]

- The required cut of ~17 cm to DCH length significantly degrades momentum resolution in this angular region. This, in the opinion of the taskforces members, is an unacceptably large negative impact on the detector performance and too severe constraint on the tracking system. Hence, the taskforce does not see this technology appropriate for Forward PID in the SuperB detector.

# Summary/Recommendations: Pixalated TOF

- This technique, due to its potential minimal disturbance on the rest of the detector and likely modest cost, was deemed very attractive. At the aimed resolution of ~100 ps, it would complement the dE/dx measurements for $\pi$/K coverage below 2 GeV. However, with the obtained time resolution for a full size LYSO in CR tests at ~230 ps, the proponent (Jerry) & taskforce have concluded that this technique will not deliver the required performance for this task.

# Summary/Recommendations: Focusing TOF

- Simulation studies & cosmic ray tests have demonstrated that key aspects of this technique can be attained- including time resolution of ~90 ps/hit.

- There remains significant uncertainties on the expected background level and its impact on PMT lifetime.

- The taskforce believes this technique could be appropriate for the Forward PID system provided:
  - Background issues are understood- which may require further studies of the IR design and shielding
  - A full prototype of the system is developed and tested, to verify the expected performance, in particular the pattern recognition in presence of background hits.

# Summary/Recommendations

- The importance of hermeticity [and redundancy] in PID coverage will increase as we approach systematic dominated era in the SuperB physics program.  Hence, the taskforce members believe- independently of the outcome of the current technology evaluation- that there is physics merit to allowing a gap in the forward region for a Forward PID device as an upgrade option.