μ/π Separation and the New Dirc

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Outline

- How well does BaBar do now?
- Effect of TOF
- The Fast Focussing Dirc (fDirc)
- Conclusions

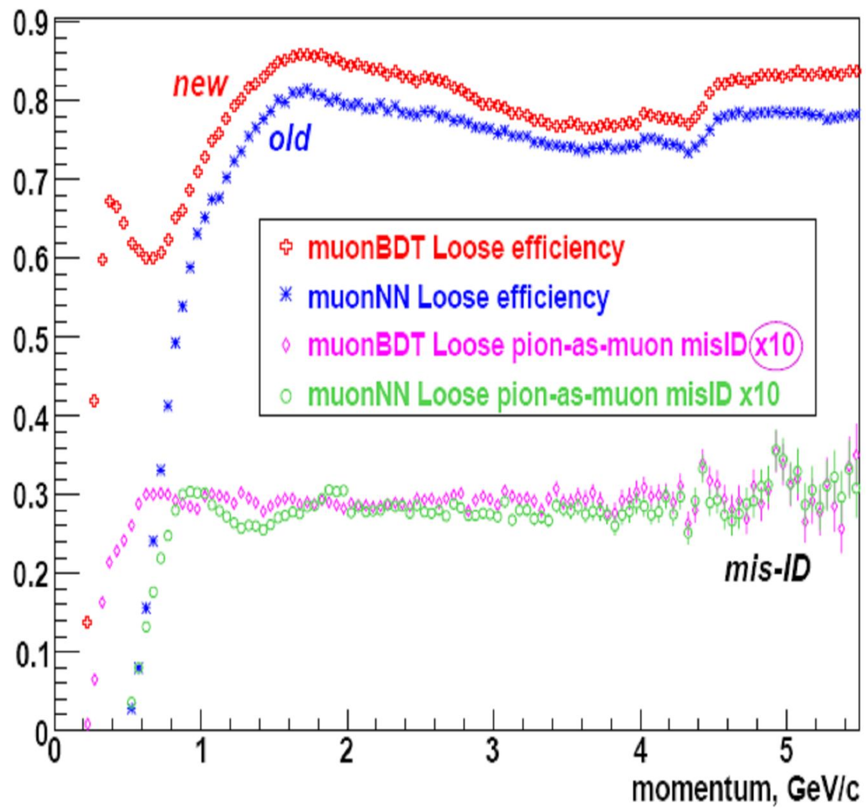
Introduction

- These are (pre-simulation) thoughts and observations relating to the effect of time-of-flight (TOF) measurements on the efficiency of the new detector for the study of $B \rightarrow X_s\mu^+\mu^-$ decays.
- These decays require good identification of μ's in the momentum range below 1 GeV/c
- It may be that the fDirc upgrade, if it goes ahead, will provide much of what we need in this respect.
- It is anticipated that TOF in a forward PID will help this decay mode considerably.

  (Achille will follow with a physics case for forward PID)

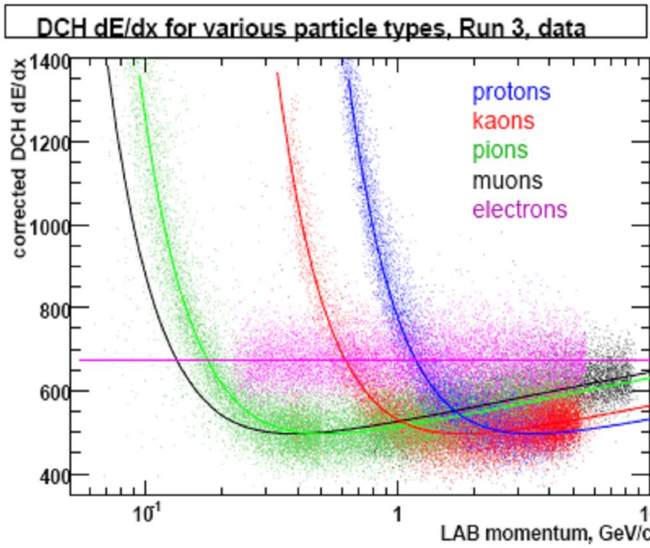
μ Identification in BaBar

- Babar selectors combine dE/dx, Dirc, IFR (and EMC) information to identify μ with reasonable efficiency except for a "gap" below ~ 1 GeV/c where the IFR dominates.
- Recent improvements in dE/dx calibration have prevented disastrous performance in this region
- The Dirc separates μ/π quite well in the low momentum part of this range, BUT
  - it is rather inefficient below 400 MeV/c.
  - Track momentum uncertainty feeds significantly into the Cherenkov angle error
  - ALSO, μ's in this range tend to decay, or to be decay products of π's and K's.
- μ/π separation is good over entire range above 1 GeV/c.
- The Dirc is inefficient at low momentum because μ's do not have sufficient transverse momentum to hit it.
  - A case for forward PID may be made on this basis.

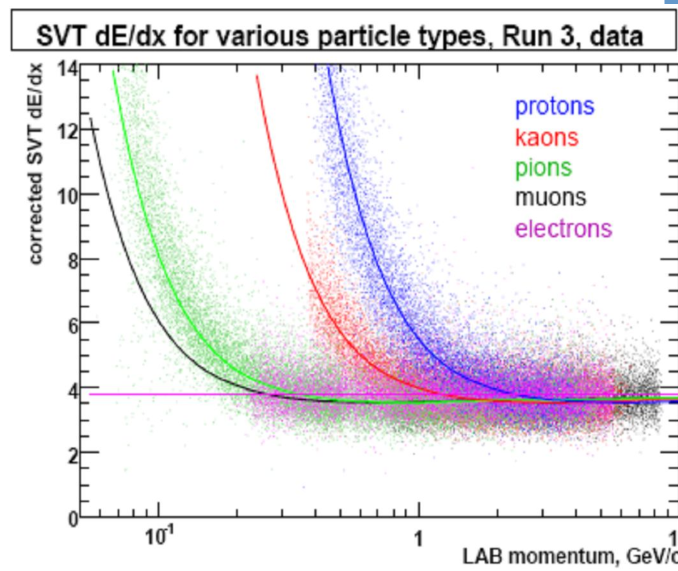


from S. Telnov, April 9, 2008

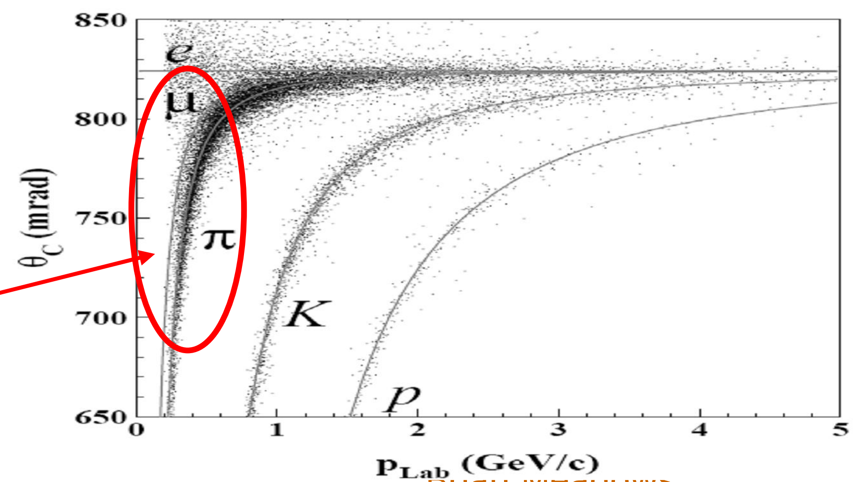
Dirc and dE/dx Information



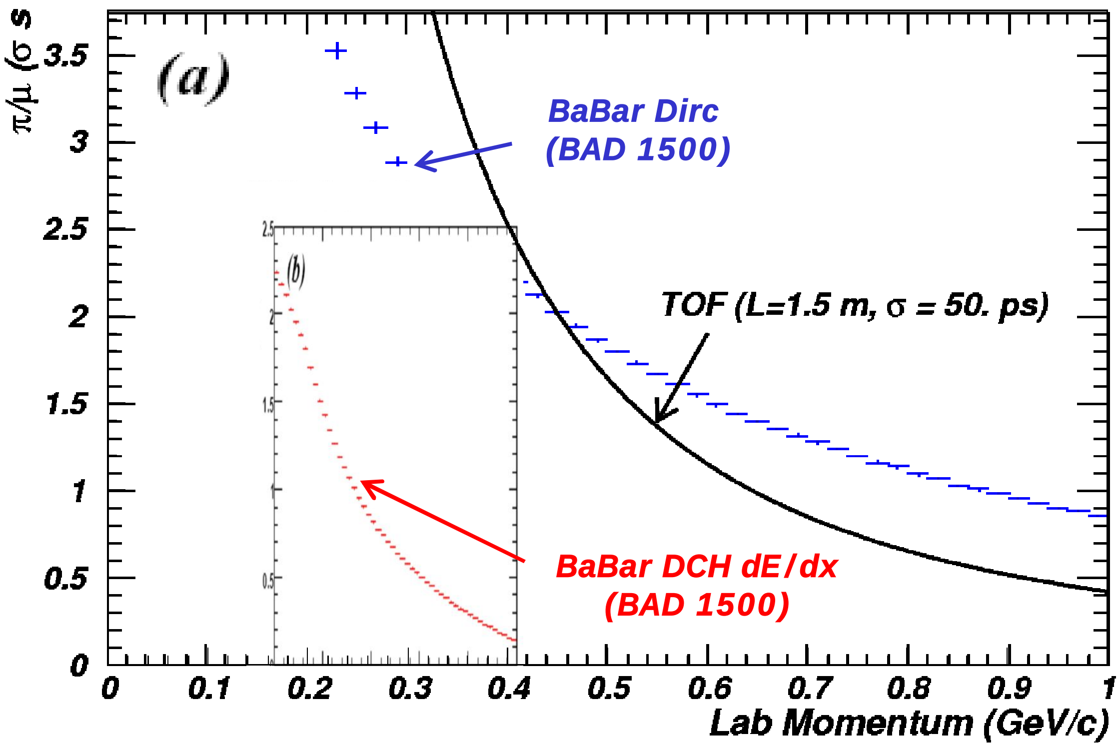
up to 2.0σ π/K separation



Steep dependence of θ_c on $|p_\mu|$



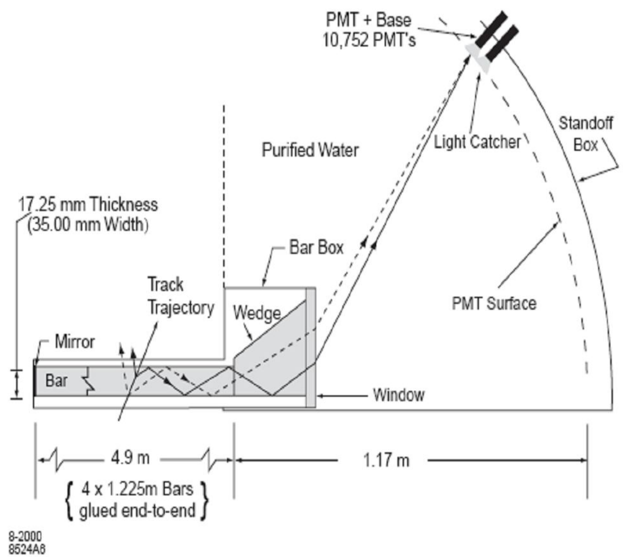
TOF in Low Momentum Region

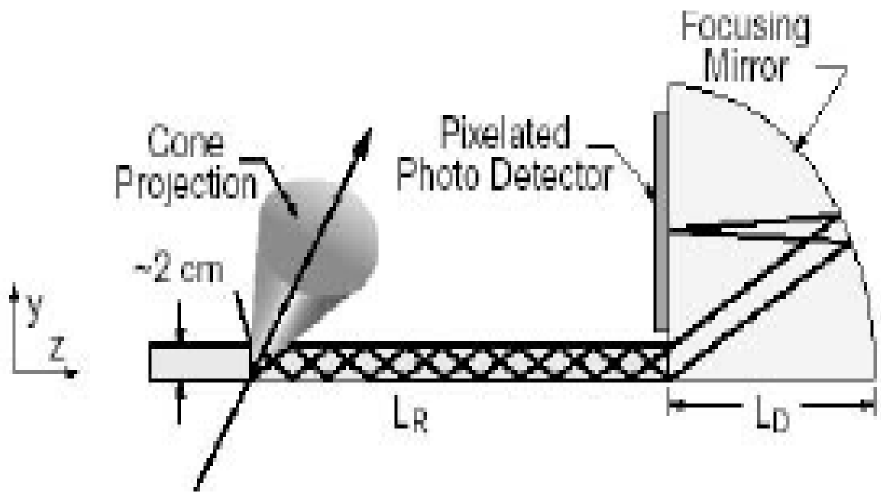


TOF does better than Dirc at low momentum where:

- **Dirc efficiency falls off AND**
- **Difference between μ and π depends more critically on measurement of $|p_\mu|$**

Rudiments of the fDirc





- Conventional PMT's
  - τ resolution ~1.6 ns
- Water stand-off box
- No focussing
  - Size of PMT window and cross-section of bar introduce uncertainties in photon direction

- PMT array (Hamamatsu H-8500 Flat-panel MaPMT
  - τ resolution ~ 140 ps
- Oil (or quartz ??) SOB
- Focussing mirror (f~0.5 m) maps a direction onto a "point" in the detector plane.

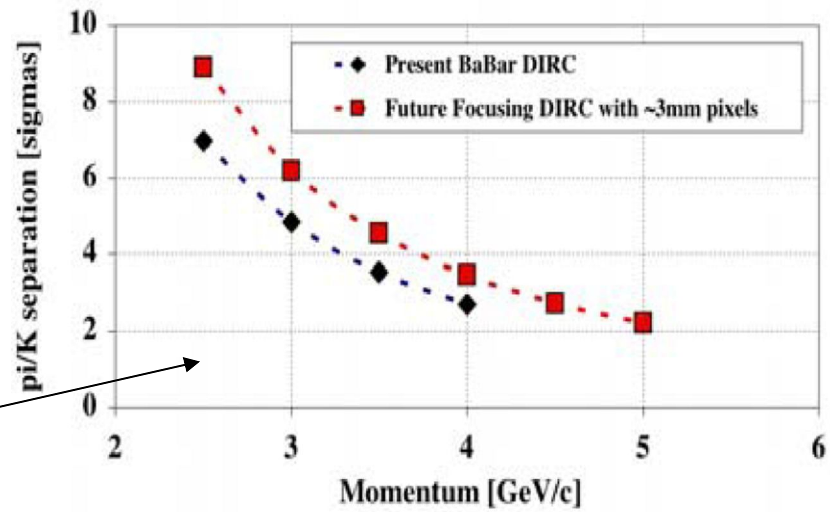
Rudiments of the fDirc

- Two main accomplishments:
  - Reduces chromatic error (dispersion in bar)
  - Reduces geometric error arising from finite cross-section of bar and diameter of PMT photo-cathode.

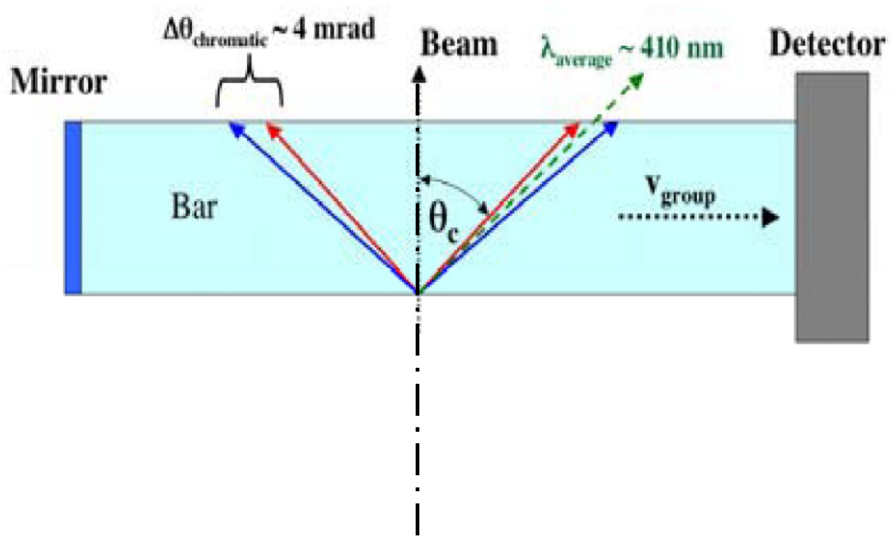
Contribution to Cherenkov angle resolution [mrads]	Present BaBar	Focusing DIRC prototype	Ultimate DIRC of the future
$\Delta\theta_{track}$	~1	~1	~1
$\Delta\theta_{chromatic}$	~5.4	~1	~1
$\Delta\theta_{transport\ along\ the\ bar}$	2-3	2-3	~1
$\Delta\theta_{bar\ thickness}$	~4.1	~1	~1
$\Delta\theta_{PMT\ pixel\ size}$	~5.5	~4	~1
$\Delta\theta_c^{track}$	~2.4	~1.5	~1
Total $\Delta\theta_c^{photon}$	~9.6	~4.8	2-3

- Beam tests at ESA show that the idea works.

Projected performance



Chromatic Dispersion



See: NIM A533 (2005) 96-106
and: NIMA595 (2008) 104-107

- Cherenkov angle depends on photon wavelength λ because *n* does

  $$\cos\theta_c(\lambda) = 1/[\beta n(\lambda)]$$

  → Gives ~ 4 mrad spread in θ_c

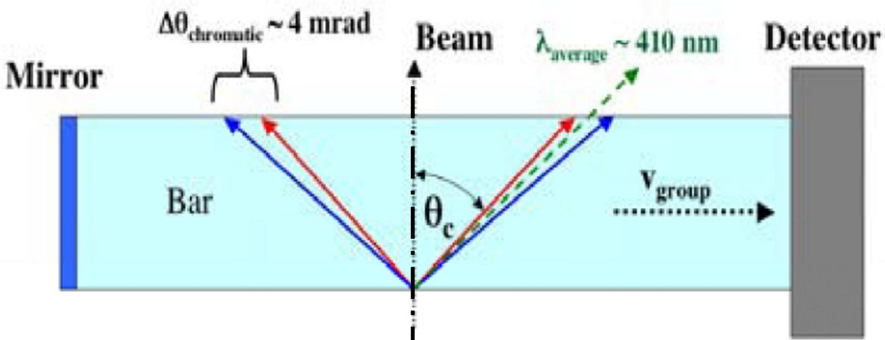
- Photons propagate distance L_{drift} in bar at group velocity v_{group}:

  $$v_{\text{group}} = c/[n(\lambda) - \lambda dn(\lambda)/d\lambda]$$

  → Gives spread in drift time t_{drift} of several 100's of ps.

- Precise measurements of t_{drift} improve resolution of θ_c

More Precisely ...



TOF Constraint: β **same for all photons for track.**

T_0 constraint: Same value for all tracks

- TOF resolution is not simply $150/\sqrt{N_\gamma}$ ps

  (May well be < 50 ps though)

- We do not simply measure θ_c either.

- What we really measure is:

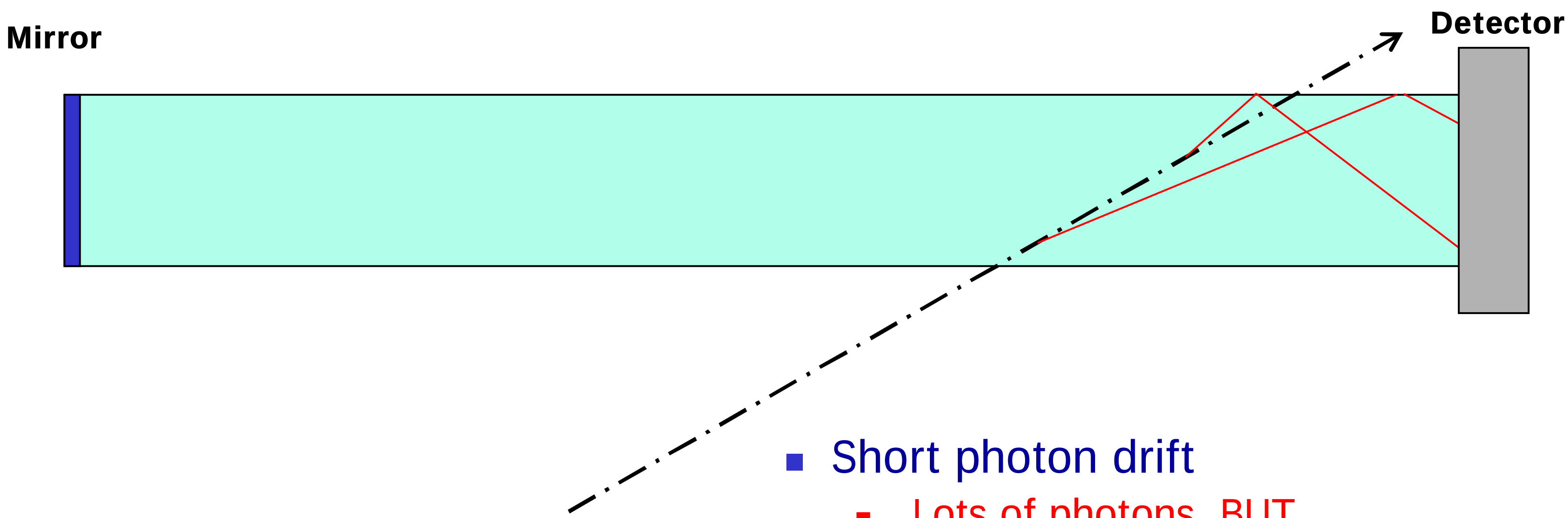
  $T_{TOT} = T_0 + TOF(\beta) + T_{drift}(\beta)$

- A fit, with constraints, can solve for β and for T_0.

This leads to an interesting interplay between TOF and θ_c !

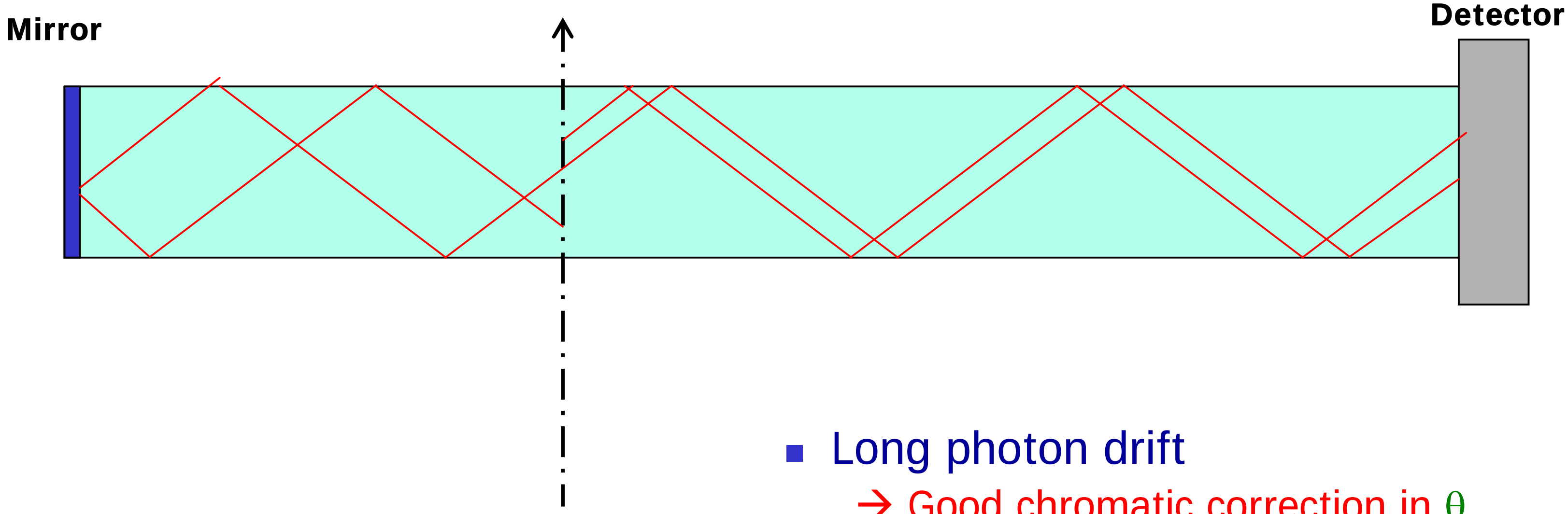
Brian Meadows, Feb 16, 2009

Forward Tracks (TOF Better, θ_c worse)



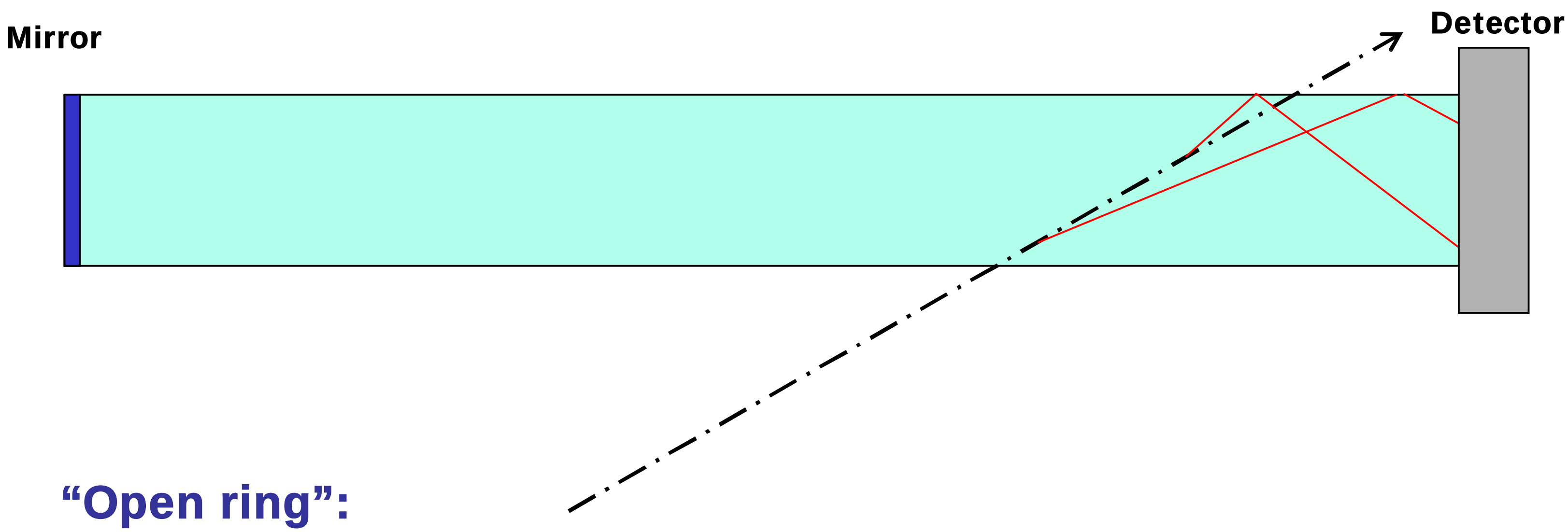
- Short photon drift
  - Lots of photons, BUT
  - → Poor chromatic correction in θ_c
- Long track:
  - Also, lots of photons
  - Δ_{TOF} (uncertainties in TOF from origin of photons along path in the Dirc bar) anti-correlate with those of photons drift times $\Delta_{dri\phi_t}$

Tracks with no Dip (TOF Poorest)



- Long photon drift
  - → Good chromatic correction in θ_c
- Relatively poor TOF measurement:
  - Lots of photons and long tracks
  - Δ_{Drift}~0 while Δ_{TOF} is same fraction as at other dip angles.

The "Open Ring Problem"



"Open ring":

Forward tracks have most Photons on one side of track.

"Problem":

If a forward track scatters, The scatter affects θ_c for All photons in the same direction.

Measurement of β from TOF

- **Almost unaffected by the scatter.**
- **Is relatively good wrt θ_c for such tracks anyway.**

Conclusions

- It appears that the fDirc should bring good improvements to all PID, especially in μID in the low momentum region.
- Forward PID will increase efficiency for low momentum muons that typically miss the barrel Dirc.
  - A TOF measurement in this momentum range is quite effective.
- A simulation, within the FastSim framework, is needed to make a quantitative evaluation of any gains there may be from fDirc and forward TOF.

(See also Nicolas Arnaud's talk this morning:

http://agenda.infn.it/getFile.py/access?contribId=99&sessionId=17&resId=0&materialId=slides&confId=959)