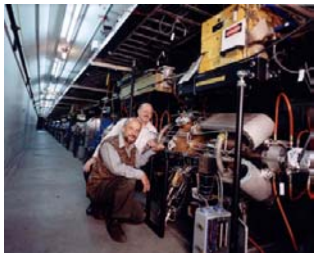
B Physics in Berkeley

BaBar and CDF

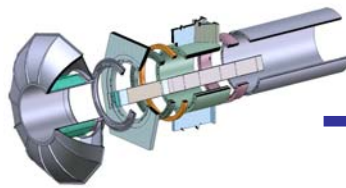
R. Cahn

HEPAP, March 6, 2003

LBNL: Doing the Physics From Start to Finish



Conception

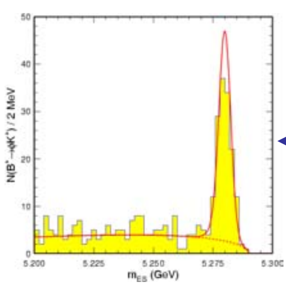


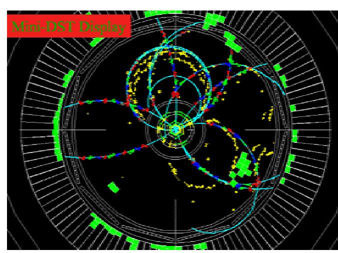
Design

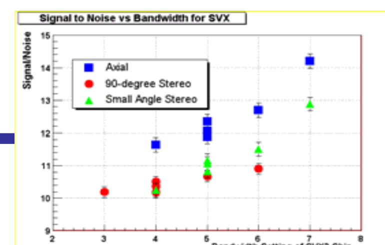
BaBar team - LBNL
XBD9902-00245-07

Fabrication

upgrade







Commissioning

Analysis

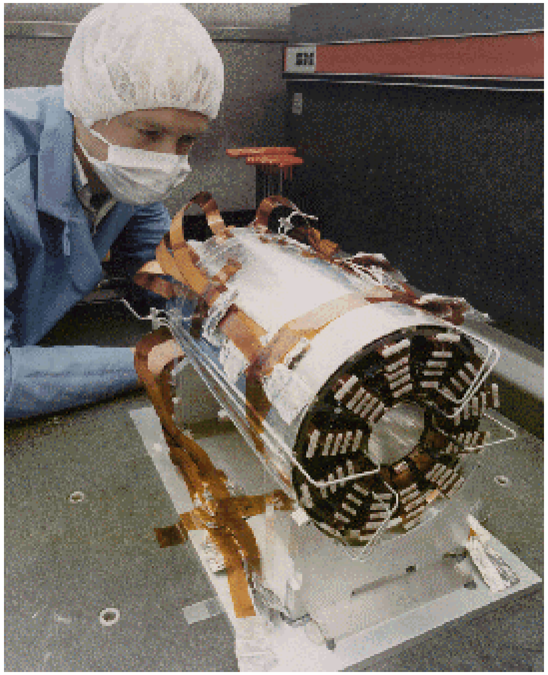
Reco/
Simulation

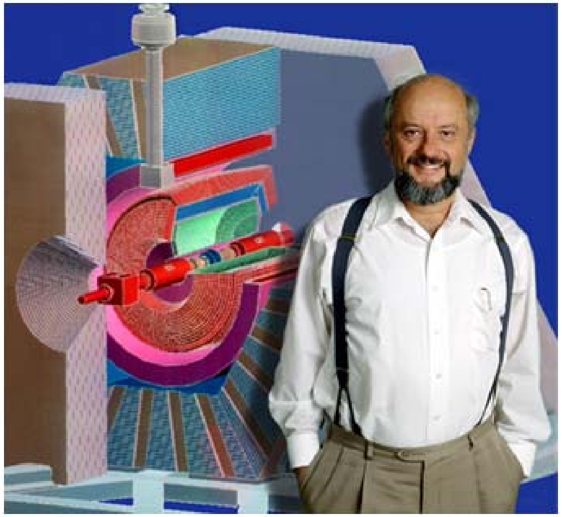
Operations/
Calibration

Performance optimization

Conception

Silicon vertex detector can work in hadron collider



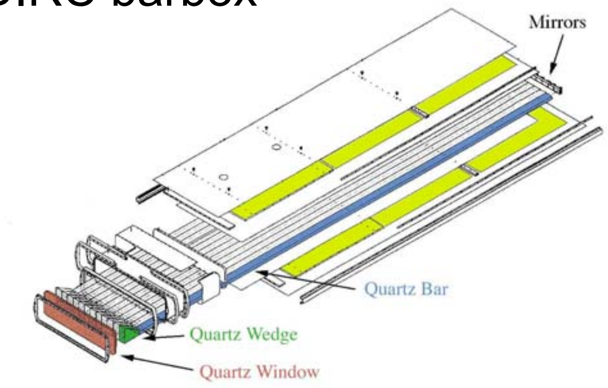


Pier Oddone with B-Factory at SLAC
XBD9703-00952

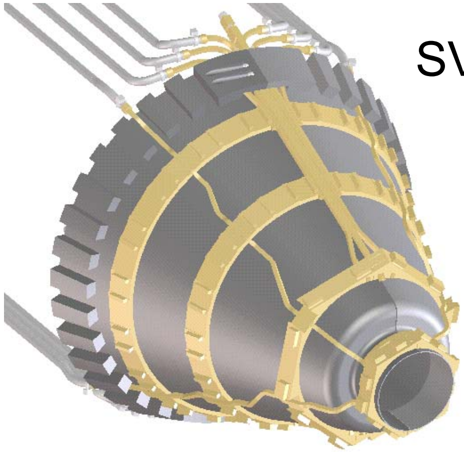
Oddone: *Asymmetric B-factory can study CP*

BaBar Design

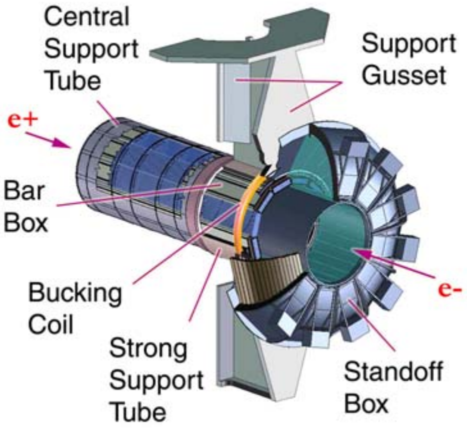
DIRC barbox



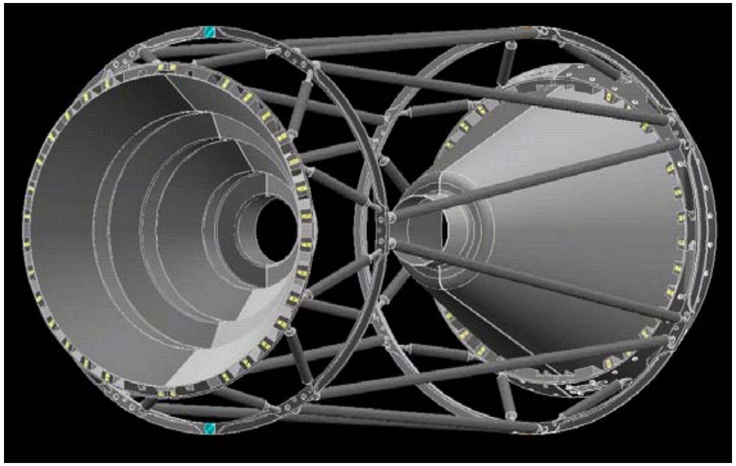
SVT cone



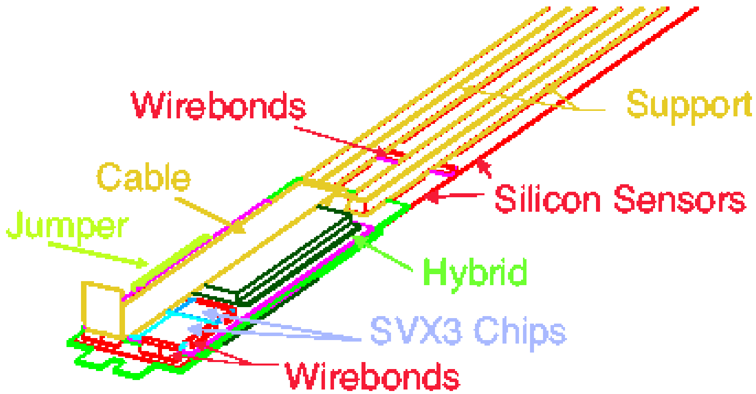
DIRC structure



SVT space frame

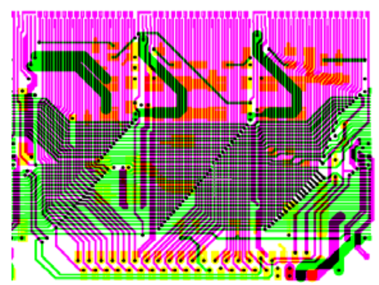


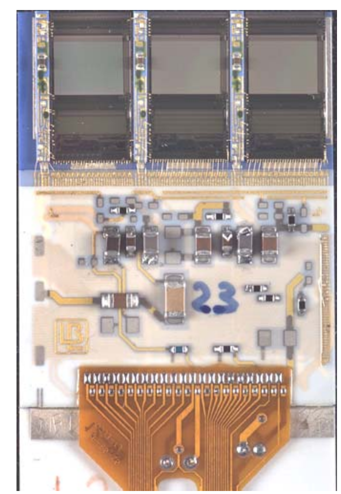
CDF Design

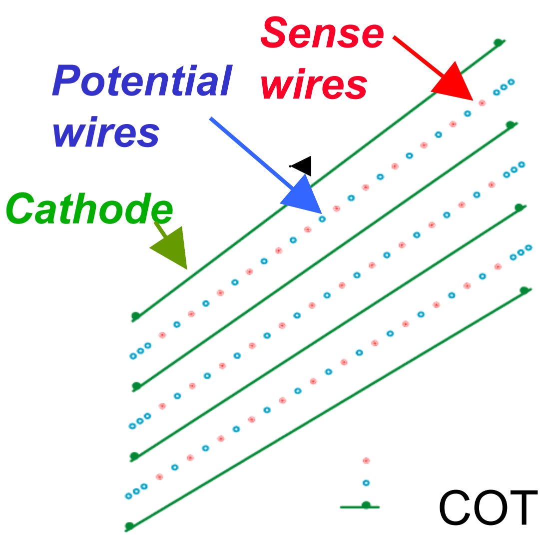


SVXII ladder design

CDF SVX-II Layer-1
Phi Layout & Hybrid
side-by-side



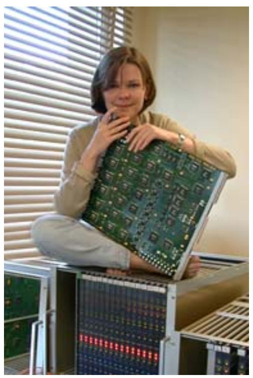




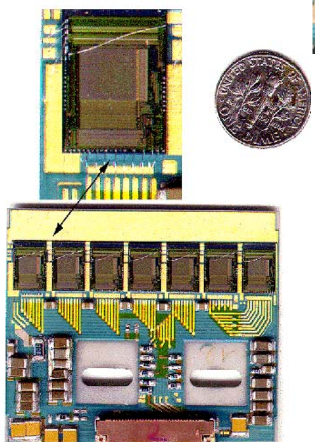
COT cell

BaBar Fabrication

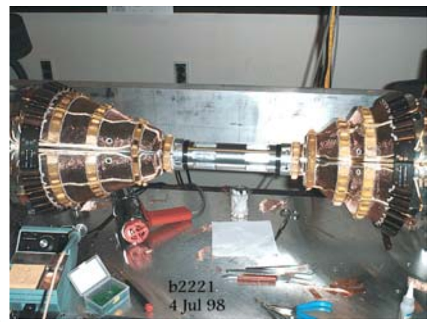
Working with LBNL's Engineering Division we developed critical instrumentation for BaBar and CDF



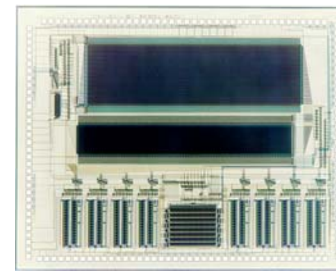
Trigger
Track Segment Finder



AToM



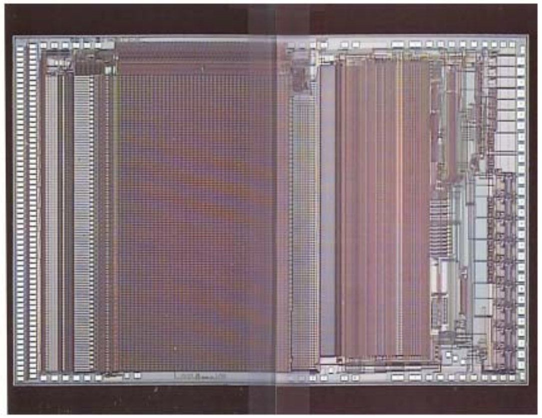
SVT mechanical



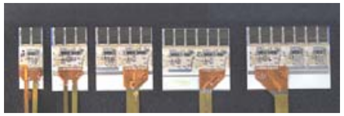
Drift Chamber Readout

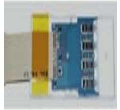
DIRC barrel

CDF Fabrication



SVX-3d chip

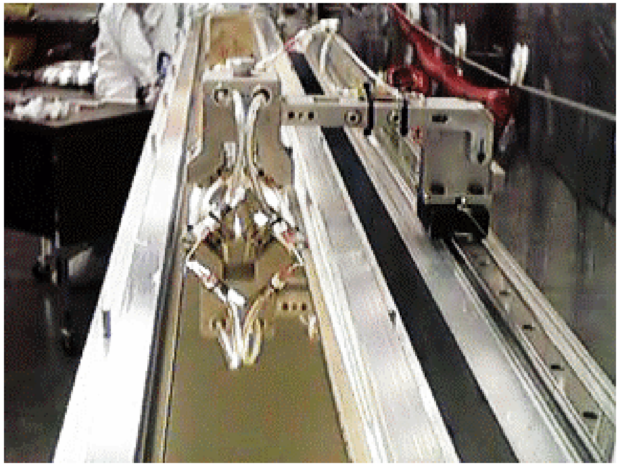




SVX hybrids

Assembly of Central OuterTracker

Fabrication of field sheets for COT at LBL



Commissioning

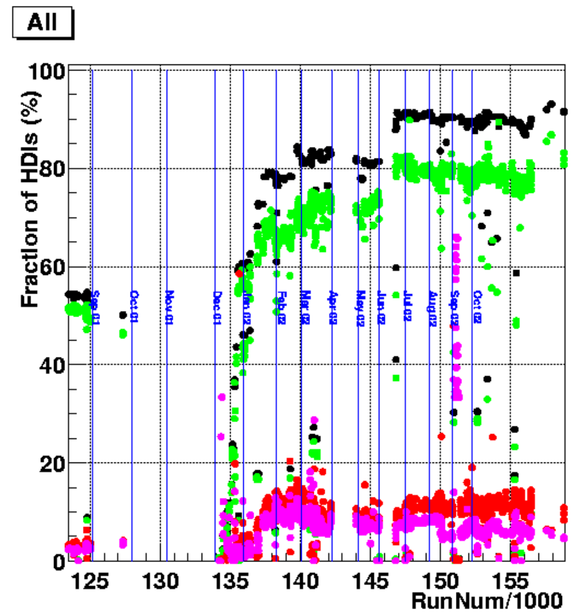
CDF

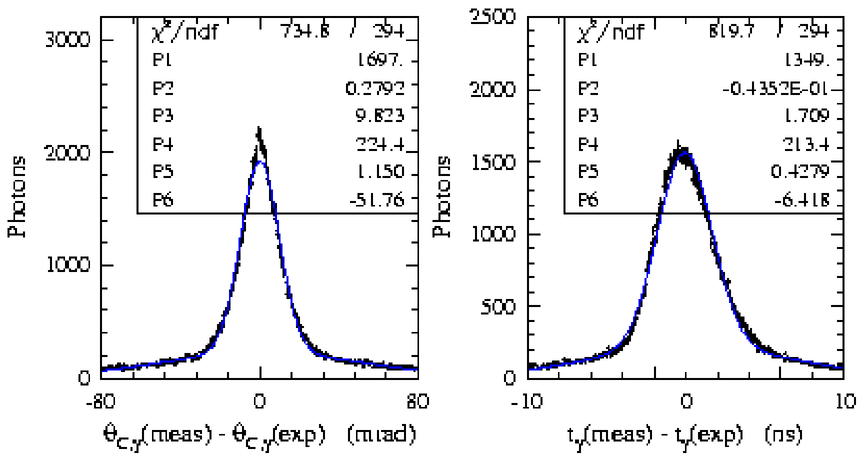
92.5% of ladders are operating

~85 % collect good data

7.5% bad ladders (ISL cooling)

~ 7% error rate





BaBar

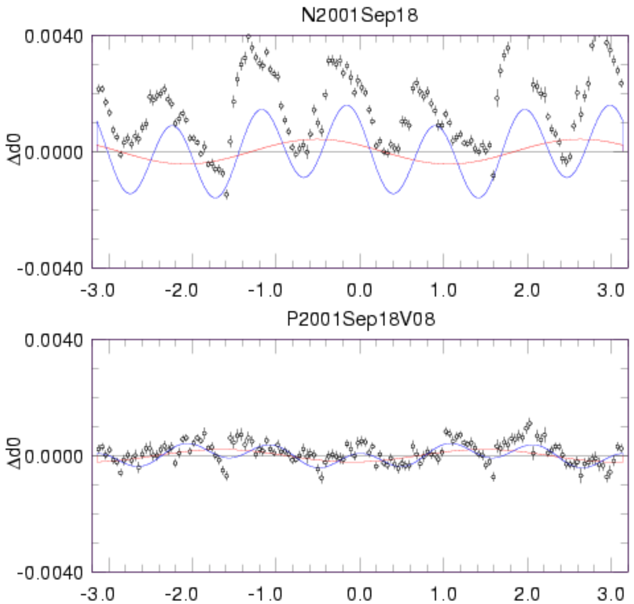
DIRC angular and time resolutions

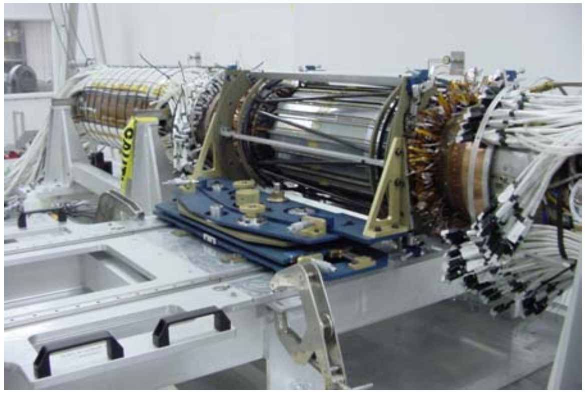
Shelkov

Operations & Calibration at BaBar

Residuals of SVT alignment showed strong azimuthal variation. Mini-DST made it possible to use enough tracks to remove most of it.

Gritsan





SVT removed for access in Summer 2002. Most of few dead modules resuscitated by fixing connections. Valuable experience gained in preparation for major refurbishing in Summer 2005.

Kerth

BaBar Reco/Simulations

- R. Jacobsen: Reconstruction Manager/ Offline Computing Co-ordinator (1995-2000)
  - Sub-system code: DIRC, SVT, trigger,tracking,alignment
- D. Quarrie (NERSC) led database development
  - On-line configuration database
  - Off-line conditions database
  - Event store
- G. Abrams led on-line computing
  - Detector control
  - Calibration

Performance Optimization

- B physics is precision physics

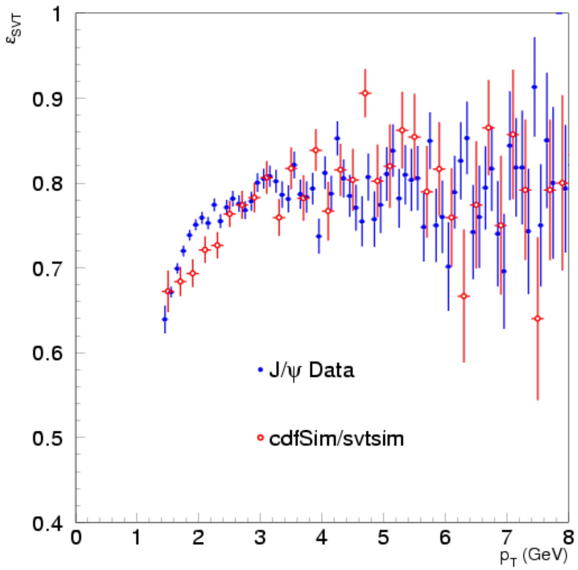
- Continual improvements in hardware and software are essential

- Inevitably, those who design and build the detector are in the best position to propose and implement improvements

Development of the "Mini" DST for BaBar

- David Brown leads team with NERSC computing professionals
- Mini-DST replaces 20 times larger version
- Mini provides access event details
- New computing model's central component
- Already improved calibrations, analysis

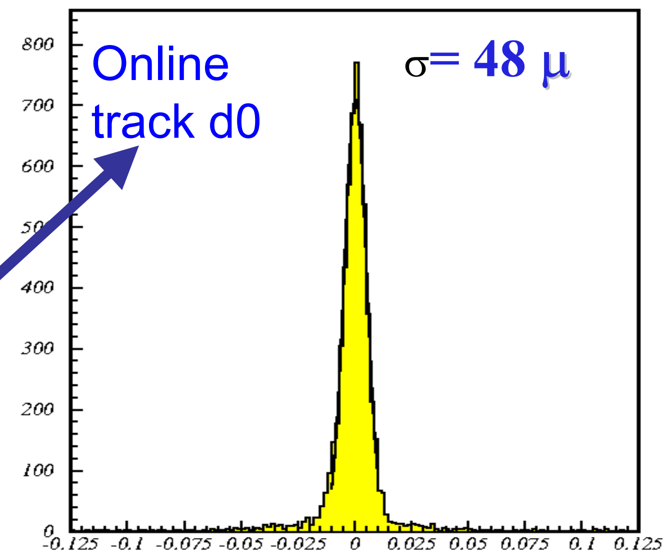
Performance Optimization: CDF SVX Trigger



Cerri

J/ψ -> μμ trigger on impact parameter compared to μ high–pt trigger

SVT impact parameter



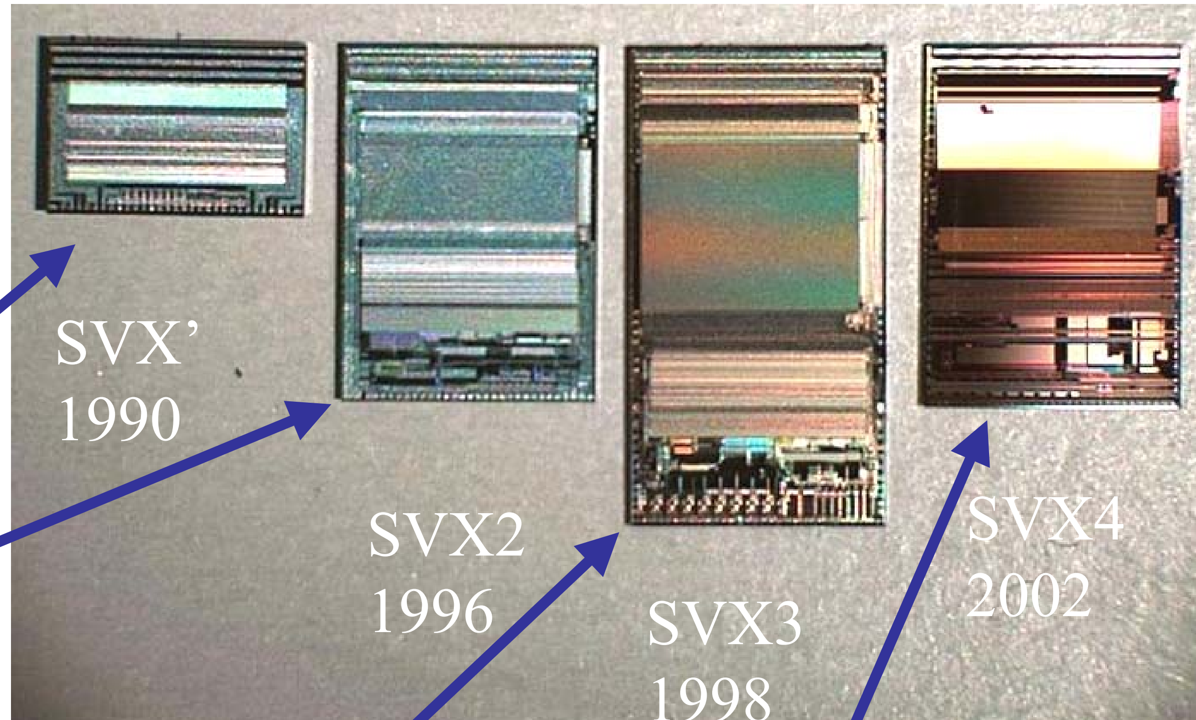
on-line

Level 1:pt>1.5 GeV

Level 2: add SVX 120 μ impact parameter required

Upgrades - CDF

SVX family of radiation tolerant silicon strip readout chips



First rad-hard chip

Analog pipeline + on-chip ADC

Dead-timeless operation, on-chip common mode subtraction

x10 more rad hard + better noise performance

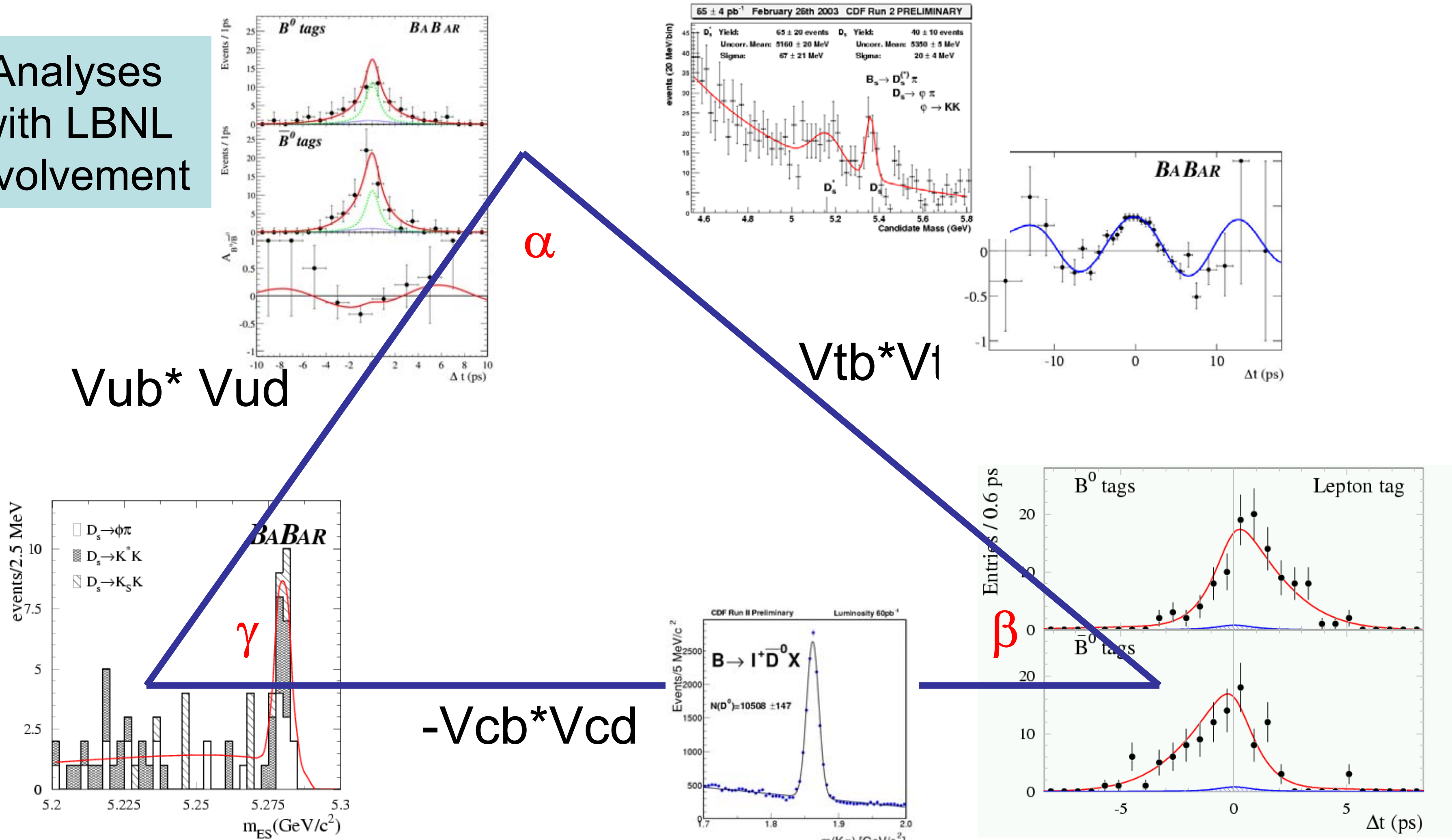
Analysis: B Physics Goals

- Precision tests
  - Angles and sides of unitarity triangle
- Study of decay dynamics
  - Direct CP violation
  - QCD/HQET

We claim to have a complete model of the physical phenomena below the TeV domain. Such a sweeping assertions requires real verification. B physics provides the ideal theatre in which to test this claim.

Measuring the Unitarity Triangle

Analyses with LBNL involvement



Measuring Mixing

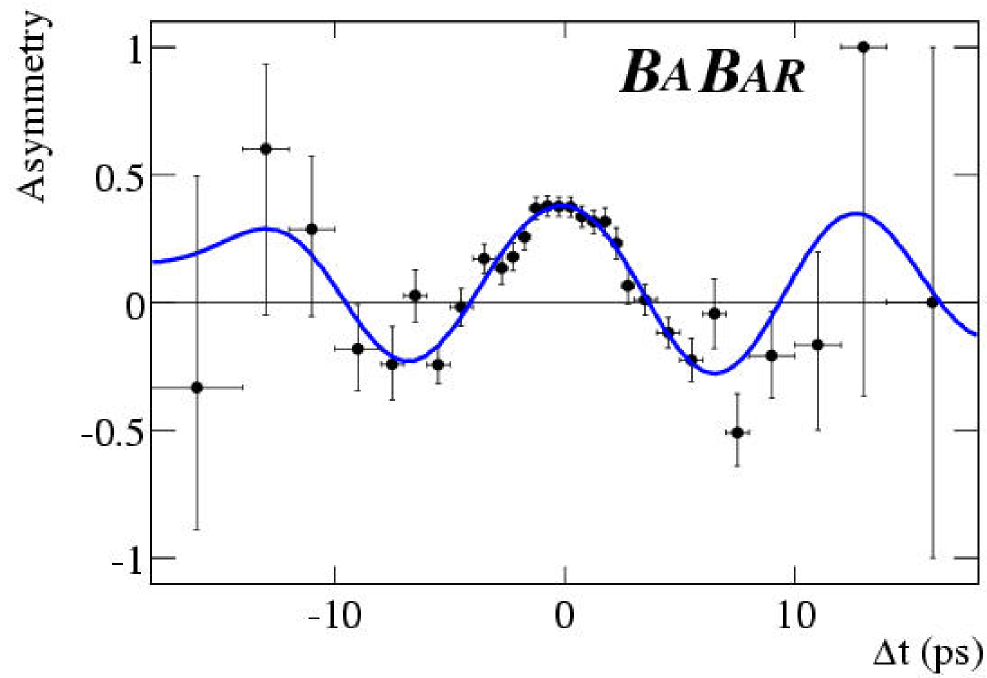
LBL-Stanford measurement

In D* l ν

$$\tau_B = 1.523 \begin{matrix} +0.023 \\ -0.028 \end{matrix} \pm 0.022 \text{ ps}$$

$\Delta m = 0.492 \pm 0.018 \pm 0.013 \text{ ps}^{-1}$

LeClerc, Roe



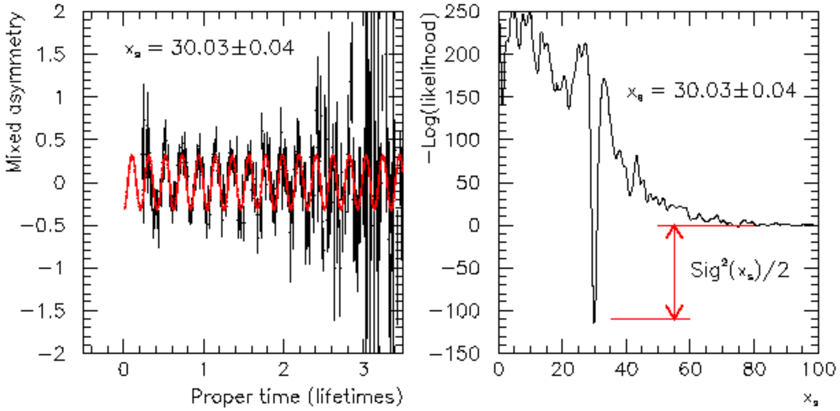
Measures Δm_d. Amplitude is not 1.0 because we mistag a fraction w of events.

Mixing provides calibration of tagging. Best done with nonleptonic decays.

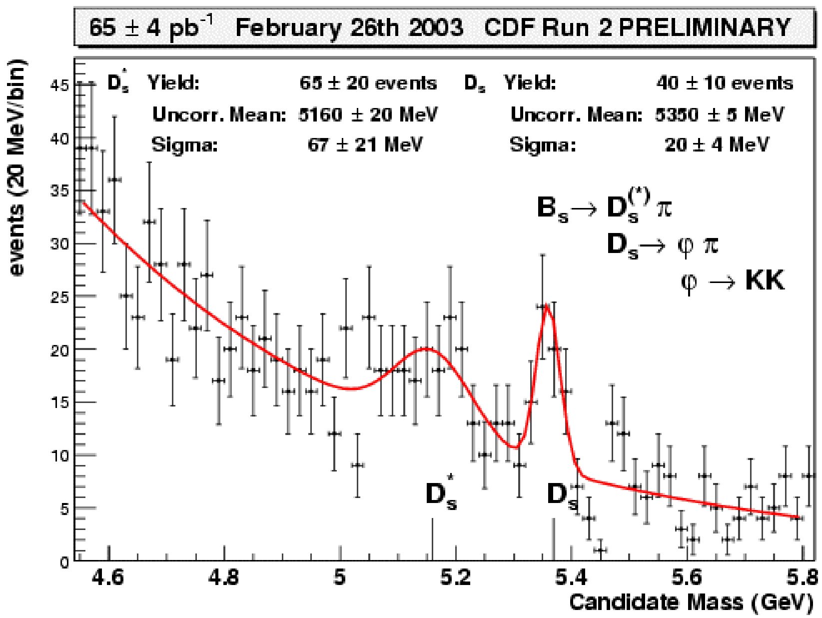
Mixing at CDF

Goal is measuring Bs mixing.

Toy MC shown →



Nonleptonic Bs decays provide ideal basis for mixing. First observation of nonleptonic Bs decays at CDF.

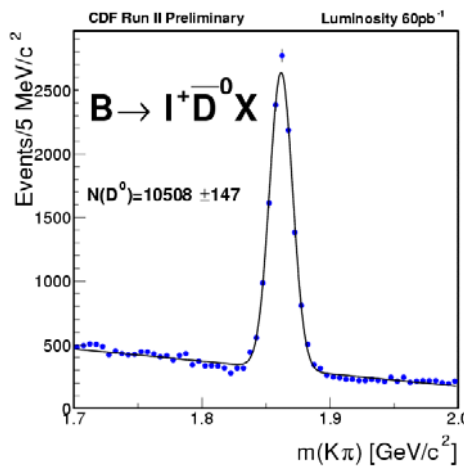


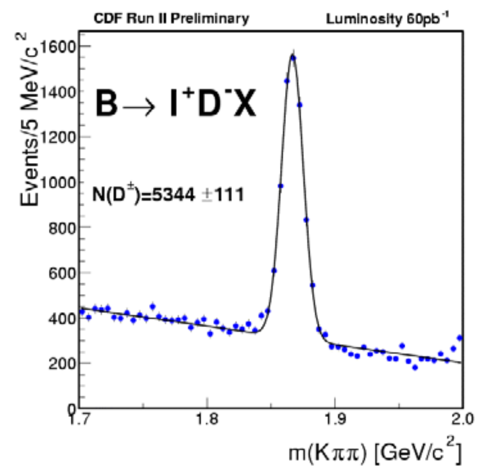
Δm_s measurement is next big step in pinning down unitarity triangle

Cerri,

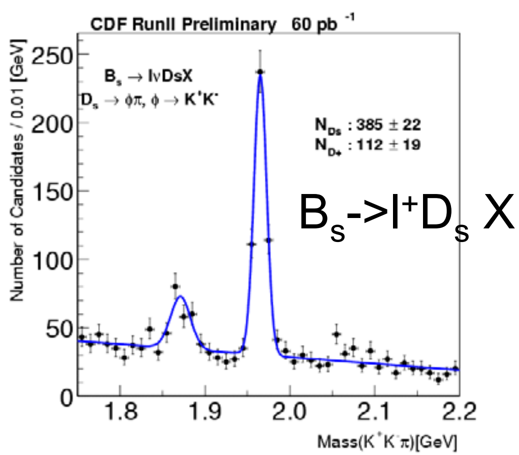
Mixing with Semileptonic Decays at CDF

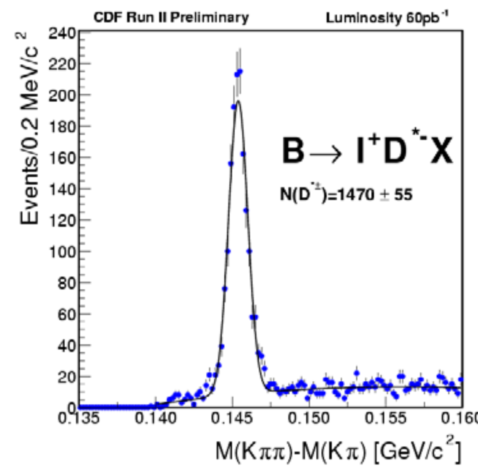
Semileptonic Bd is warm up exercise. First do inclusive, then full reco.





Semileptonic Bs is check on nonleptonic and means of finding Bs lifetime



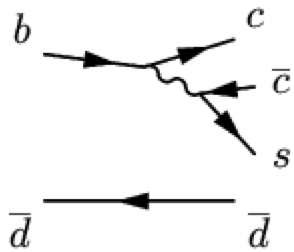


CDF semileptonic group

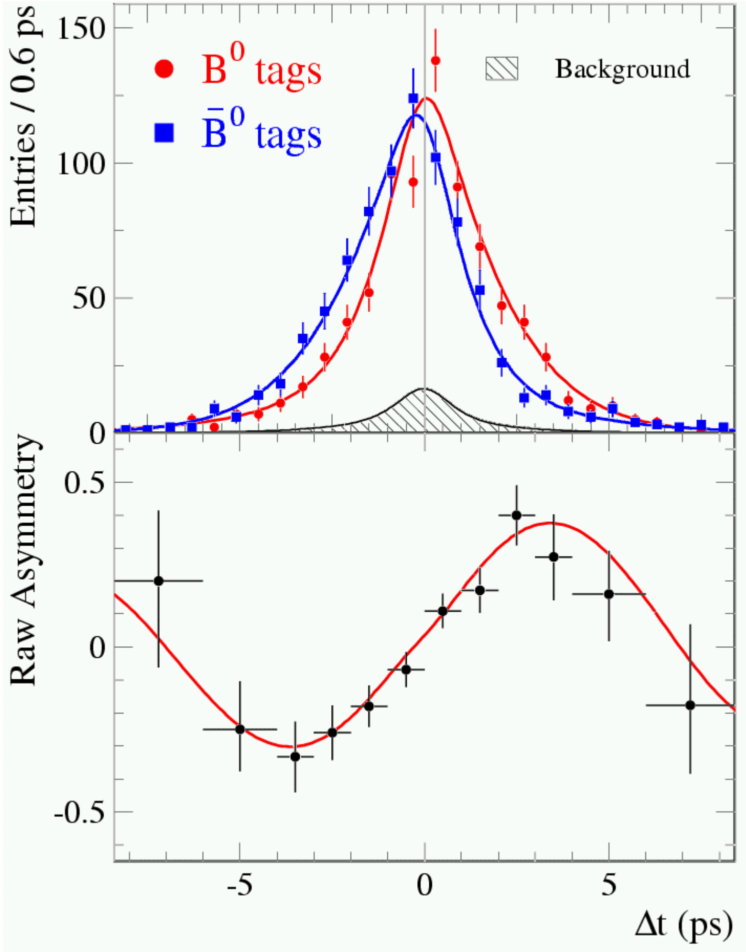
sin 2 β

Tree has "no phase."

Penguin same.



sin 2β =0.741 +/- 0.067 +/- 0.033



BaBar flagship measurement.

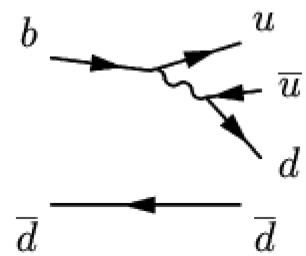
CDF should become competitive.

Results in ϕKs may yet upset the picture.

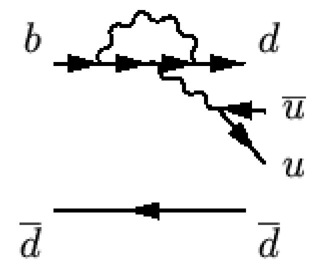
BaBar sin 2β group, Cahn

sin 2α

B → ρ π: alternative to B →ππ



Tree



Penguin

Eventually, do time-dependent Dalitz plot.

For now, treat ρ as stable particle.

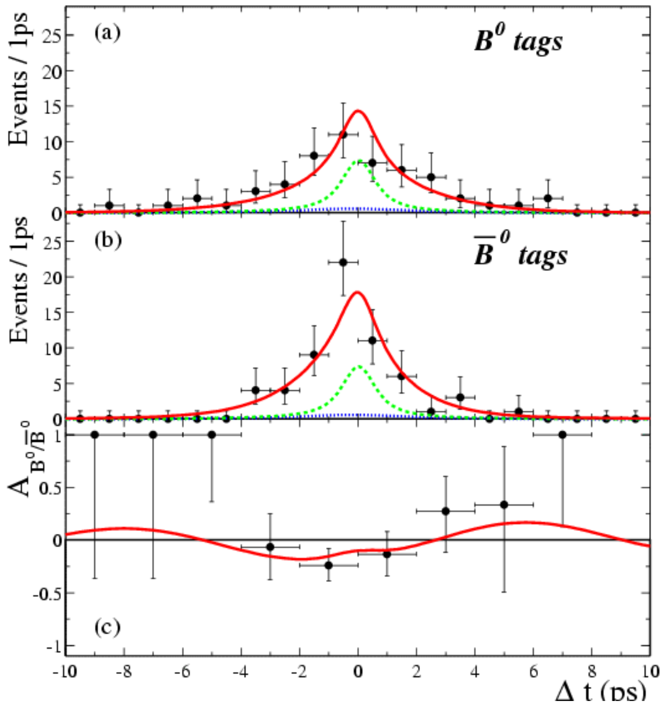
Measure coefficients of sin Δmt , cos Δm t.

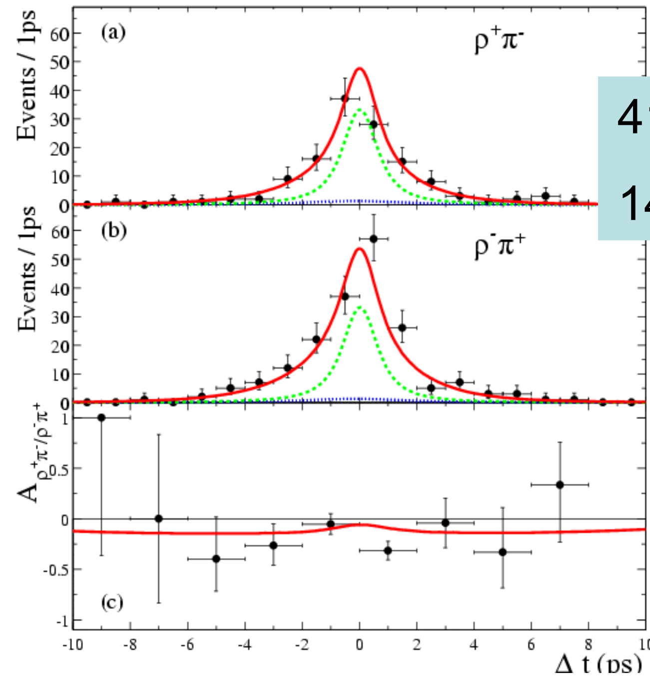
Penguin prohibits clean interpretation.

$$f^{\rho^\pm h^\mp}_{B^0\mathrm{tag}}(\Delta t) = (1 \pm A^{\rho h}_{CP})\frac{e^{-|\Delta t|/\tau}}{4\tau}\left[1 + \Big((S_{\rho h} \pm \Delta S_{\rho h})\sin(\Delta m_d \Delta t) - (C_{\rho h} \pm \Delta C_{\rho h})\cos(\Delta m_d \Delta t)\Big)\right],$$

$$f^{\rho^\pm h^\mp}_{\overline{B}^0\mathrm{tag}}(\Delta t) = (1 \pm A^{\rho h}_{CP})\frac{e^{-|\Delta t|/\tau}}{4\tau}\left[1 - \Big((S_{\rho h} \pm \Delta S_{\rho h})\sin(\Delta m_d \Delta t) - (C_{\rho h} \pm \Delta C_{\rho h})\cos(\Delta m_d \Delta t)\Big)\right]$$

$B \to \rho\pi$: sin 2α





413 ρπ events

147 ρK events

Shelkov

$$A_{CP}^{\rho K} = 0.19 \pm 0.14 \text{ (stat)} \pm 0.11 \text{ (syst)}, \qquad A_{CP}^{\rho\pi} = -0.22 \pm 0.08 \text{ (stat)} \pm 0.07 \text{ (syst)},$$

$$C_{\rho\pi} = 0.45 \, ^{+0.18}_{-0.19} \text{ (stat)} \pm 0.09 \text{ (syst)}, \qquad S_{\rho\pi} = 0.16 \pm 0.25 \text{ (stat)} \pm 0.07 \text{ (syst)}.$$

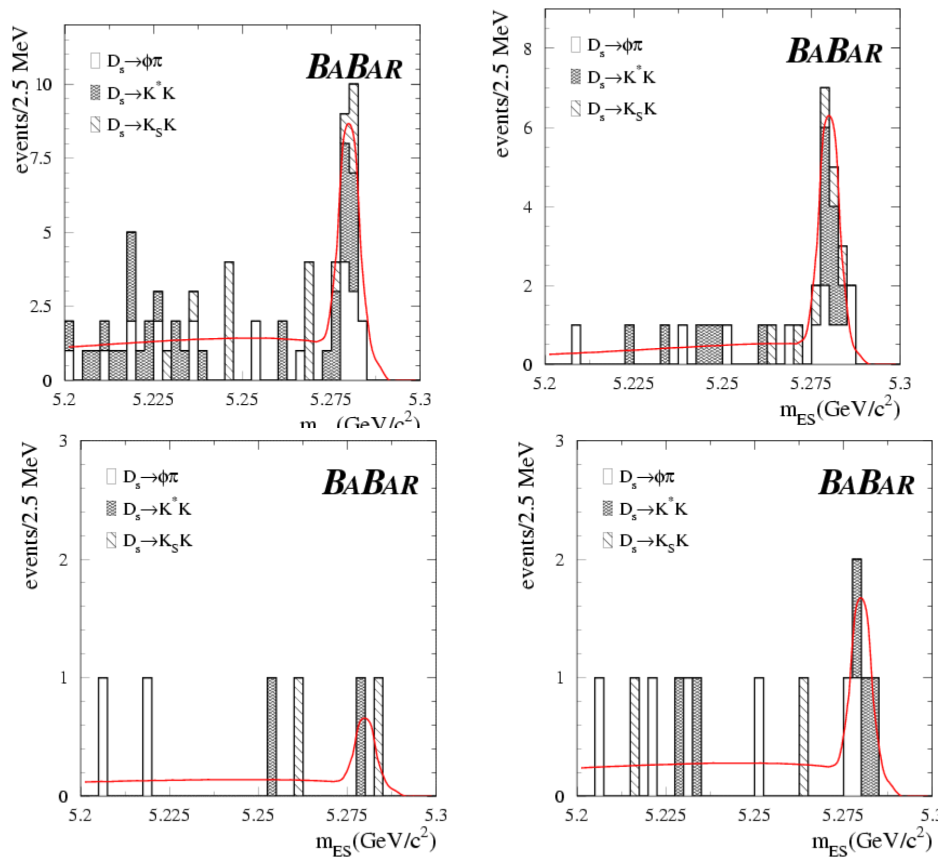
New results this month

sin(2β + γ)

$D_s^+\pi^-$ is SU(3) variant of

Cabibbo suppressed $D^+\pi^-$.

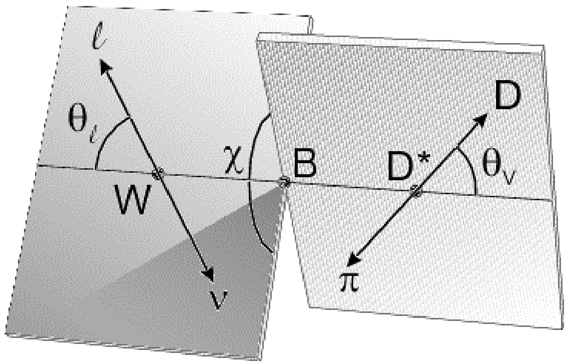
whose BR is needed in the measurement of γ in $D^+\pi^-$.

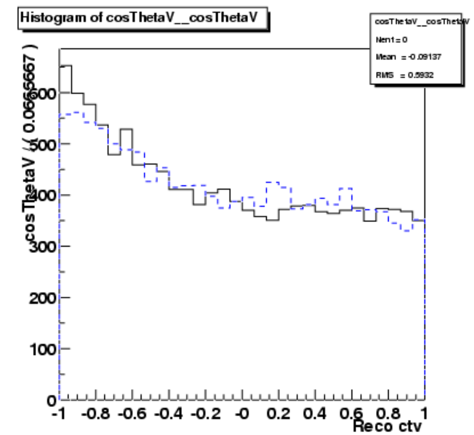


Kolomensky, Orimoto

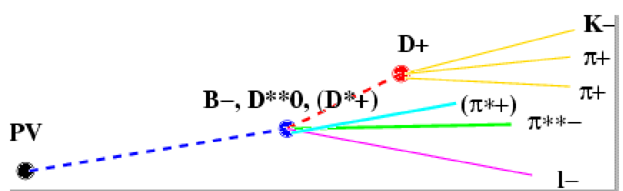
$$\mathrm{BR}(B^0 \to D_s^+\pi^-) = (3.2 \pm 0.9\,(\mathrm{stat.}) \pm 1.0\,(\mathrm{syst.})) \times 10^{-5} \quad \mathrm{BR}(B^0 \to D_s^{*+}\pi^-) < 4.1 \times 10^{-5},$$
$$\mathrm{BR}(B^0 \to D_s^- K^+) = (3.2 \pm 1.0\,(\mathrm{stat.}) \pm 1.0\,(\mathrm{syst.})) \times 10^{-5} \quad \mathrm{BR}(B^0 \to D_s^{*-} K^+) < 2.5 \times 10^{-5}$$

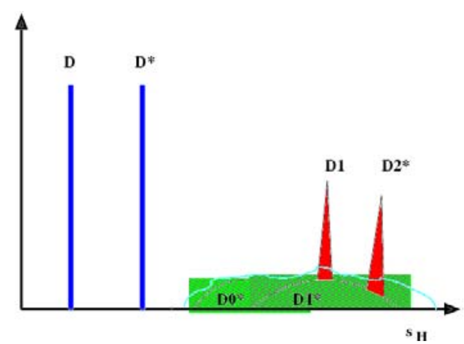
Vcb





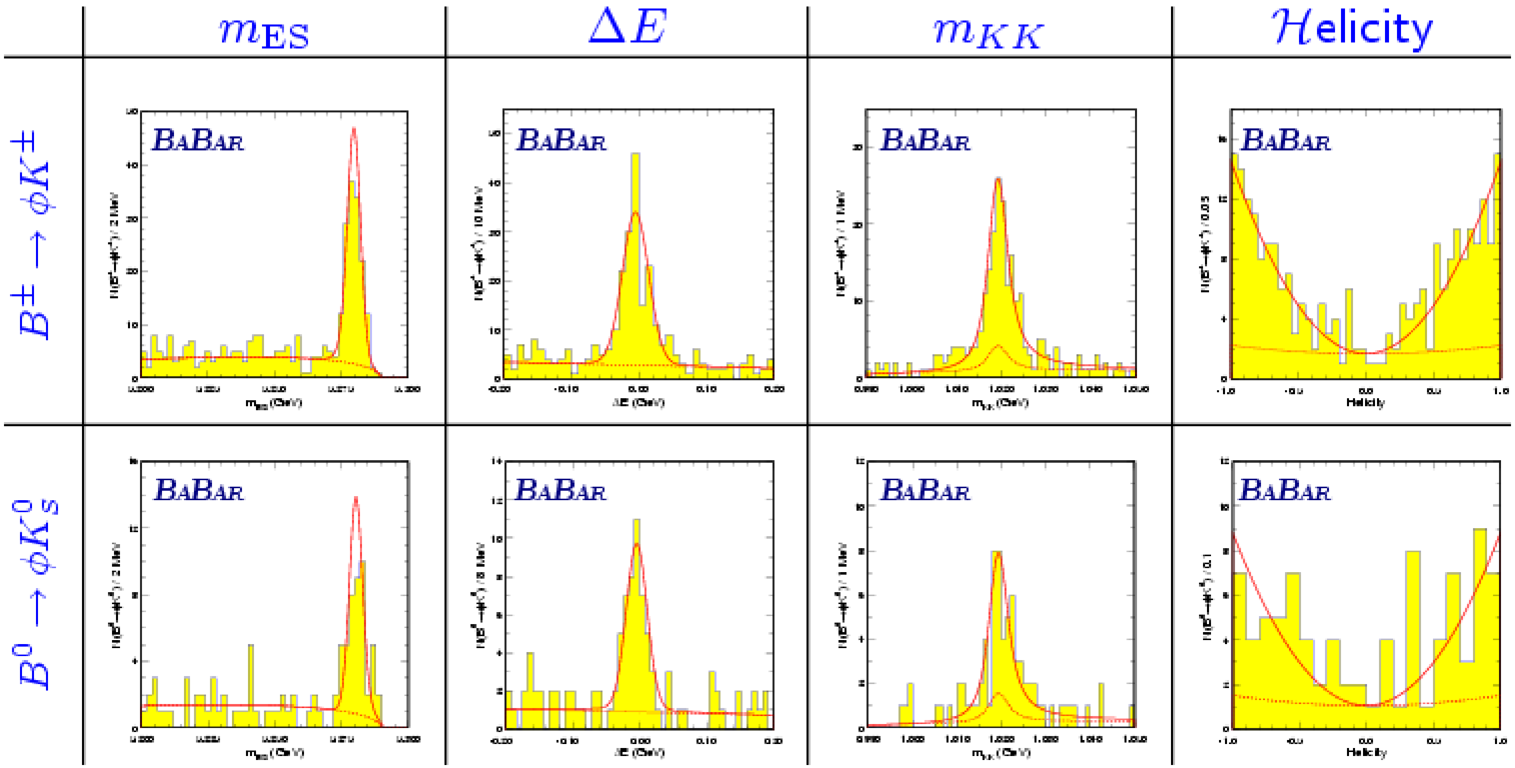
BaBar: Exclusive D* l ν *Gill*





CDF: Inclusive

Direct CP Violation: φK



Telnov

$$\mathcal{B}(\phi K^{+}) = (9.2 \pm 1.0 \pm 0.8) \times 10^{-6}$$

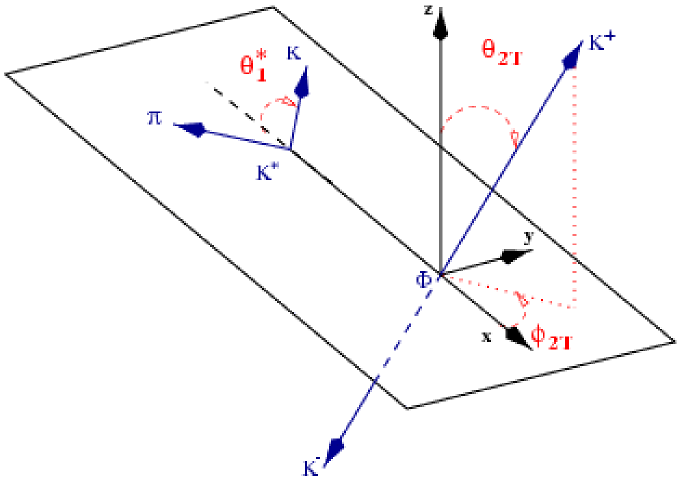
$$\mathcal{B}(\phi K^{0}) = (8.7^{+1.7}_{-1.5} \pm 0.9) \times 10^{-6}$$

$$\mathcal{B}(\phi \pi^{+}) < 0.56 \times 10^{-6} \quad (90\% C.L.)$$

New results this month

$B \to V\,V$

- For direct CP
- For mixing+decay CP: signal&bkgd!
- Three decay amplitudes
- Two relative strong phases
- Angular analysis required

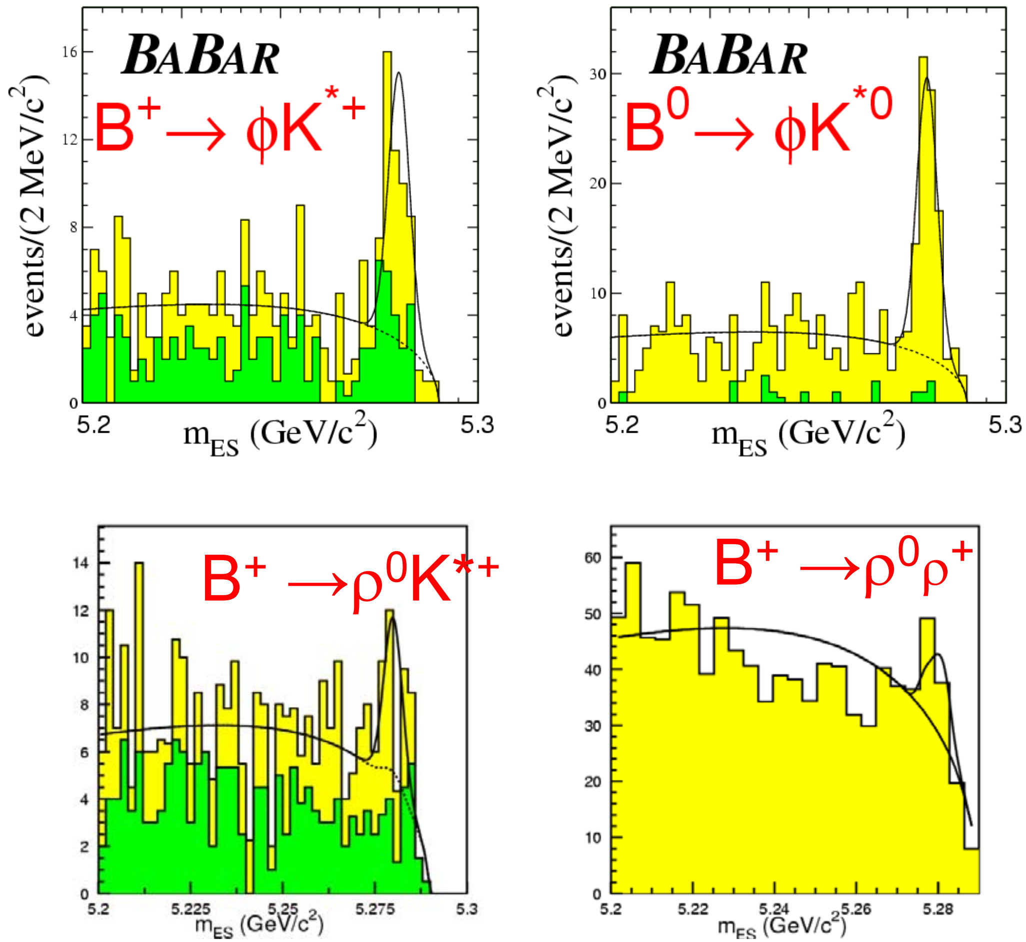


$B \to V\,V$

$$\mathcal{B}(\phi K^{*0}) = (11.1^{+1.3}_{-1.2} \pm 1.1) \times 10^{-6}$$
$$\mathcal{B}(\phi K^{*+}) = (12.1^{+2.1}_{-1.9} \pm 1.5) \times 10^{-6}$$
$$\mathcal{B}(\rho^0 K^{*+}) = (7.7^{+2.1}_{-2.0} \pm 1.4) \times 10^{-6}$$
$$\mathcal{B}(\rho^0 \rho^+) = (9.9^{+2.6}_{-2.5} \pm 2.5) \times 10^{-6}$$

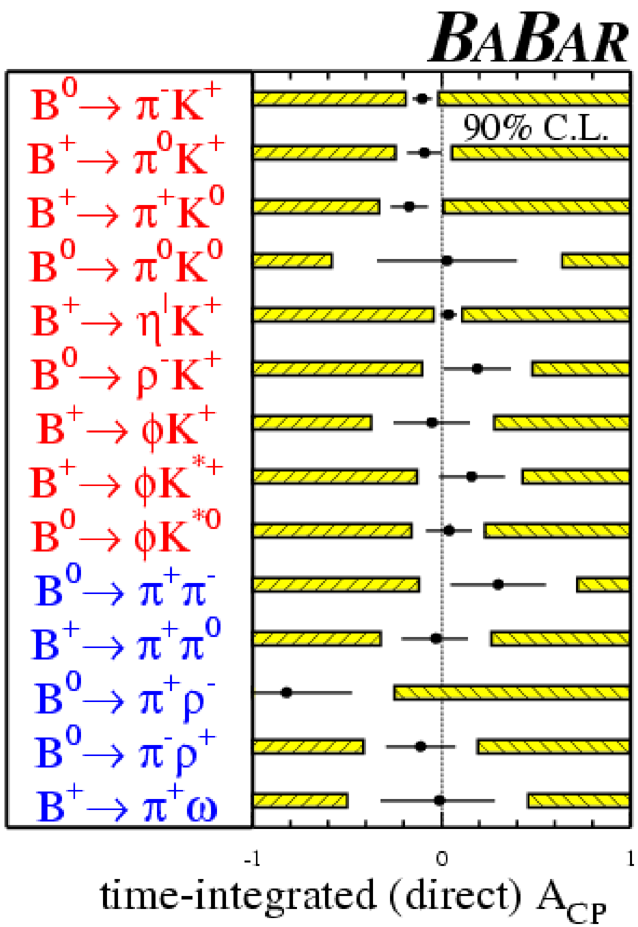
$$\Gamma_L/\Gamma(\phi K^{*0}) = 0.65 \pm 0.07 \pm 0.04$$
$$\Gamma_L/\Gamma(\phi K^{*+}) = 0.46 \pm 0.12 \pm 0.05$$

$$\mathcal{A}_{CP}(\phi K^{*0}) = +0.04 \pm 0.12 \pm 0.02$$
$$\mathcal{A}_{CP}(\phi K^{*+}) = +0.16 \pm 0.17 \pm 0.04$$



Gritsan, Mir

Direct CP Summary



No convincing evidence.

Getting close.

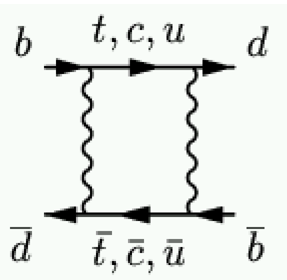
Gritsan

LBNL: Doing the Physics From Start to Finish

- LBNL pioneered B physics at CDF and BaBar.
- Efforts continue to improve detector performance and analysis capability to meet the challenge of precision B physics.
- Analysis is attacking the unitarity triangle from all sides (and angles).
- Increased luminosity at both experiments promises important new results.

Extra Slides

How B's Mix



$$H = M - \frac{i}{2}\Gamma$$

$$M = \begin{pmatrix} M_{11} & M_{12} \\ M_{12}^* & M_{22} \end{pmatrix} \qquad \Gamma = \begin{pmatrix} \Gamma_{11} & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_{22} \end{pmatrix}$$

$$M_{12} : \overline{B}^0 \rightarrow \text{virtual} \rightarrow B^0; \qquad \Gamma_{12} : \overline{B}^0 \rightarrow \text{real} \rightarrow B^0$$

$$CP \text{ or } CPT \text{ good} \rightarrow M_{11} = M_{22}$$

$$CP \text{ or } T \text{ good} \rightarrow (\Gamma_{12}/M_{12}) \text{ real}$$

$$\Delta M = 2|M_{12}|; \qquad \Delta\Gamma = 2|M_{12}| \text{ Re } (\Gamma_{12}/M_{12})$$

$$\Delta M/\Gamma \approx 0.75, \qquad \text{expect } \Delta\Gamma/\Delta M \approx \mathcal{O}(m_b^2/m_t^2), \qquad \Delta\Gamma/\Gamma \approx 3 \times 10^{-3}$$

Oscillations

$$|B^0_{phys}(t)\rangle \propto \cos(\Delta M t/2)|B^0\rangle + i\frac{q}{p}\sin(\Delta M t/2)|\overline{B}^0\rangle$$

$$|\overline{B}^0{}_{phys}(t)\rangle \propto \cos(\Delta M t/2)|\overline{B}^0\rangle + i\frac{p}{q}\sin(\Delta M t/2)|B^0\rangle$$

$$\frac{q}{p} = -\sqrt{\frac{M^*_{12} - i\Gamma^*_{12}/2}{M_{12} - i\Gamma_{12}/2}}$$

$$\left|\frac{q}{p}\right|^2 = 1 - \mathrm{Im}\frac{\Gamma_{12}}{M_{12}}$$

$\Delta\Gamma$ & CP/CPT Violation in Mixing

- Use fully reconstructed “flavor” and CP eigenstates
- Fit time dependence
- Measure or limit $\Delta\Gamma$ and $|q/p|^2$ (i.e. Γ_{12} / M_{12})

New Results This Month

- Measure or limit CPT violation

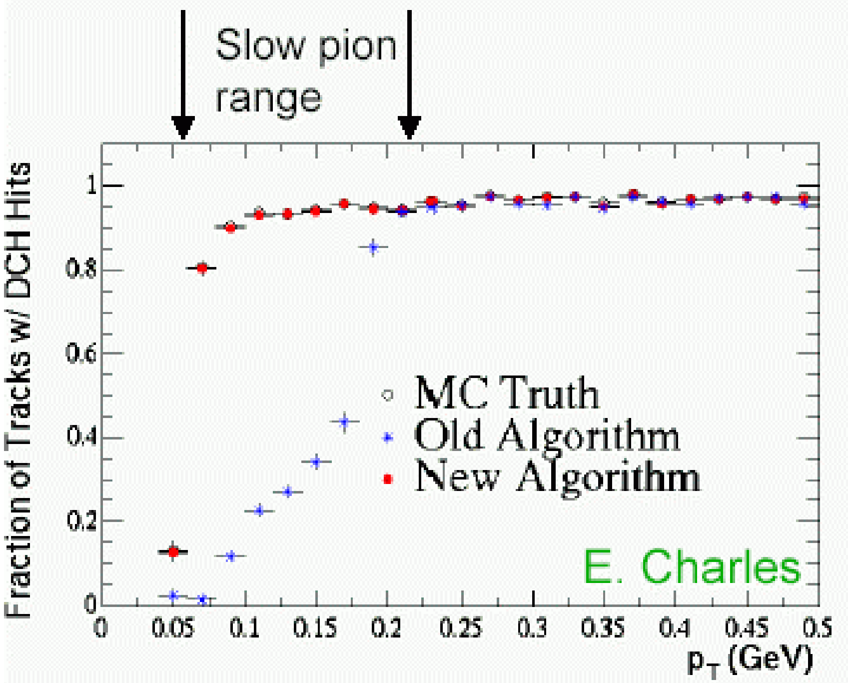
$$z \approx \frac{\delta M - i\delta\Gamma/2}{|M_{12}|}$$

Cahn

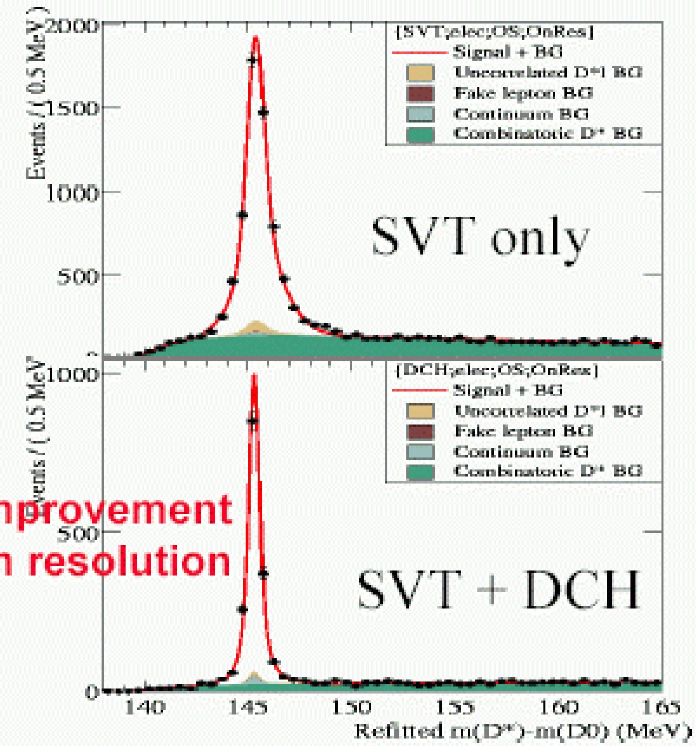
$$\delta M = M_{11} - M_{22}; \qquad \delta\Gamma = \Gamma_{11} - \Gamma_{22}$$

Reconstructing Tracks in BaBar with Few Drift Chamber Hits

- The existing tracking algorithm is inefficient adding DCH hits to low-momentum tracks (found in the SVT)
  - Affects resolution of 'slow' pions (from $D^* \to D\pi$)
- A new algorithm developed at LBL recovers essentially all available hits



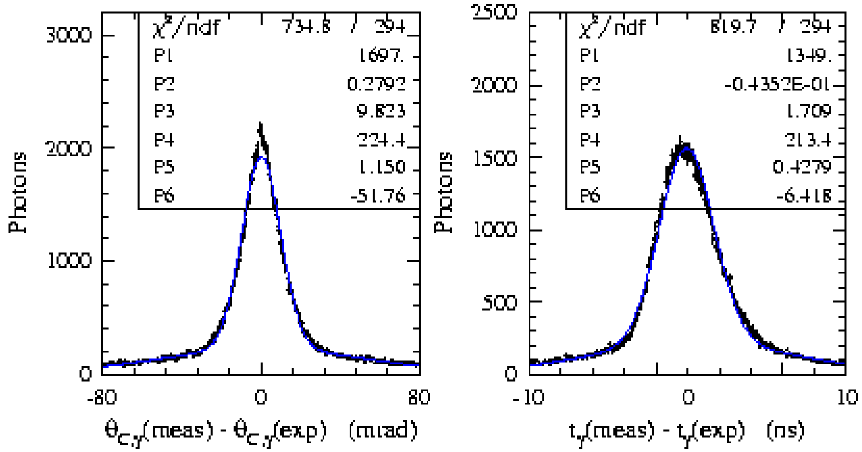
X2 improvement
In Δm resolution



Governance/Direction: BaBar

- Brown:Computing Model Task Force
- Cahn: Publications Board, Long-Term Task Force
- Kolomensky: Computing Model Task Force
- Oddone: Executive Board
- Roe: Long-Term Task Force, IFR Task Force, SVT Task Force

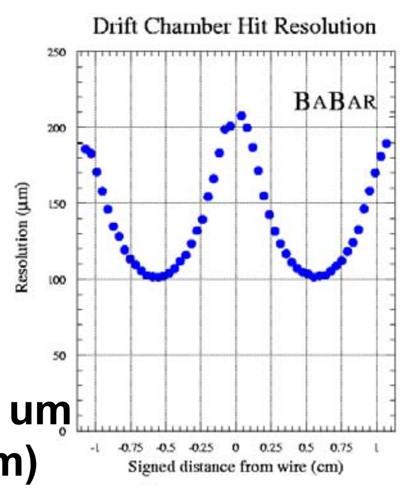
BaBar Commissioning



DIRC angular and time resolutions

Shelkov

DIRC K/π separation



Drift Chamber
Average resolution = 125 um
(Design goal was 140 um)

Oscillations

$$|B^0_{phys}(t)\rangle \propto \cos(\Delta M t/2)|B^0\rangle + i\frac{q}{p}\sin(\Delta M t/2)|\overline{B}^0\rangle$$
$$|\overline{B}^0{}_{phys}(t)\rangle \propto \cos(\Delta M t/2)|\overline{B}^0\rangle + i\frac{p}{q}\sin(\Delta M t/2)|B^0\rangle$$

Mixing: observe final state that is clearly B^0 or $\overline{B}^0$

$$\text{Unmixed: } |\cos\Delta m t/2|^2 = \tfrac{1}{2}(1+\cos\Delta m t)$$
$$\text{Mixed: } |\sin\Delta m t/2|^2 = \tfrac{1}{2}(1-\cos\Delta m t)$$

CP eigenstate gets contributions from both

$$A = \langle f|\mathcal{H}|B^0\rangle; \qquad A = \langle f|\mathcal{H}|\overline{B}^0\rangle$$
$$\lambda = \frac{q}{p}\frac{\overline{A}}{A}$$
$$|\cos\Delta m t/2 + i\lambda\sin\Delta m t/2|^2 = 1 - \mathrm{Im}\lambda\sin\Delta m t \qquad \text{if } |\lambda| = 1$$

Tagging

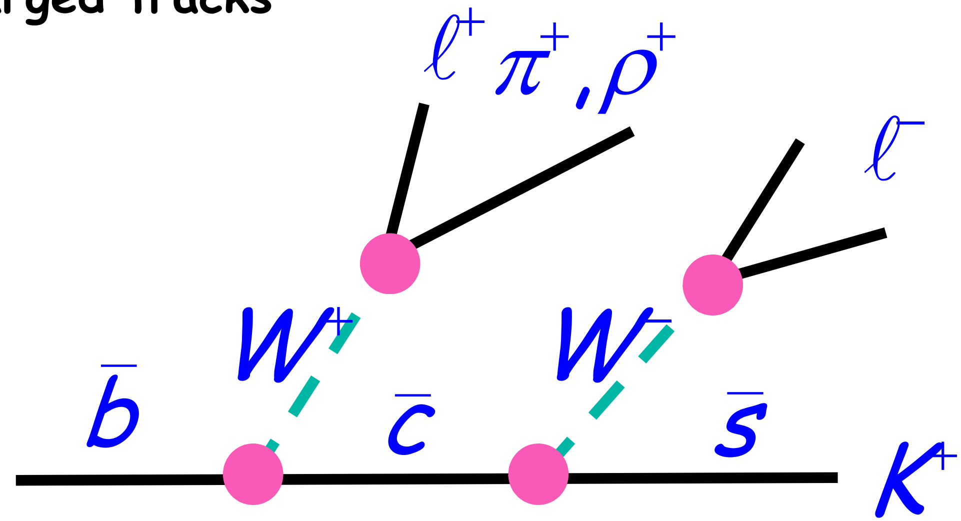
Primary lepton $B^0 \to D^{*-}\ell^+\nu$

Secondary lepton $B^0 \to D^-\pi^+, D^- \to K^{*+}\ell^-\bar{\nu}$

Kaon(s) $B^0 \to \bar{D}X, \bar{D} \to K^+X$

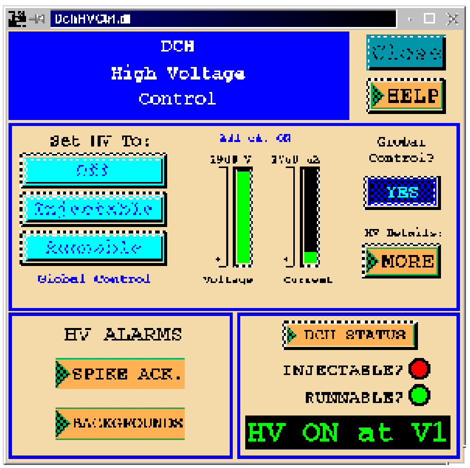
Soft pions from D* decays $B^0 \to D^{*-}X^+, D^{*-} \to \bar{D}^0\pi_s^-$

Fast charged tracks



Slide:D. MacFarlane

Operations & Calibrations at BaBar

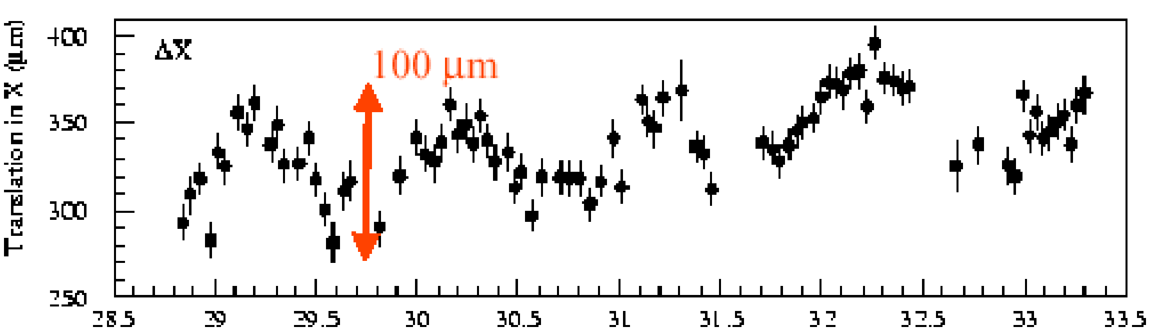


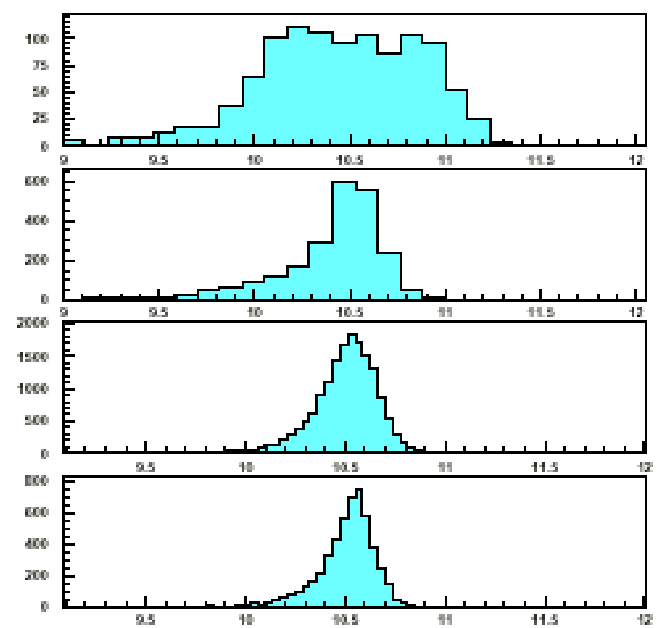
LBNL engineering key to designing on-line system

Rolling calibrations essential to quick reconstruction.

Each run feeds parameters to the next.

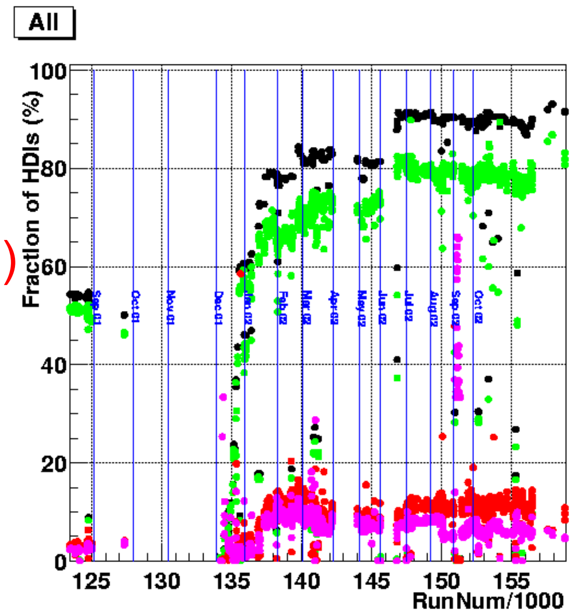
SVT/DCH Global Alignment (Example of diurnal effect)



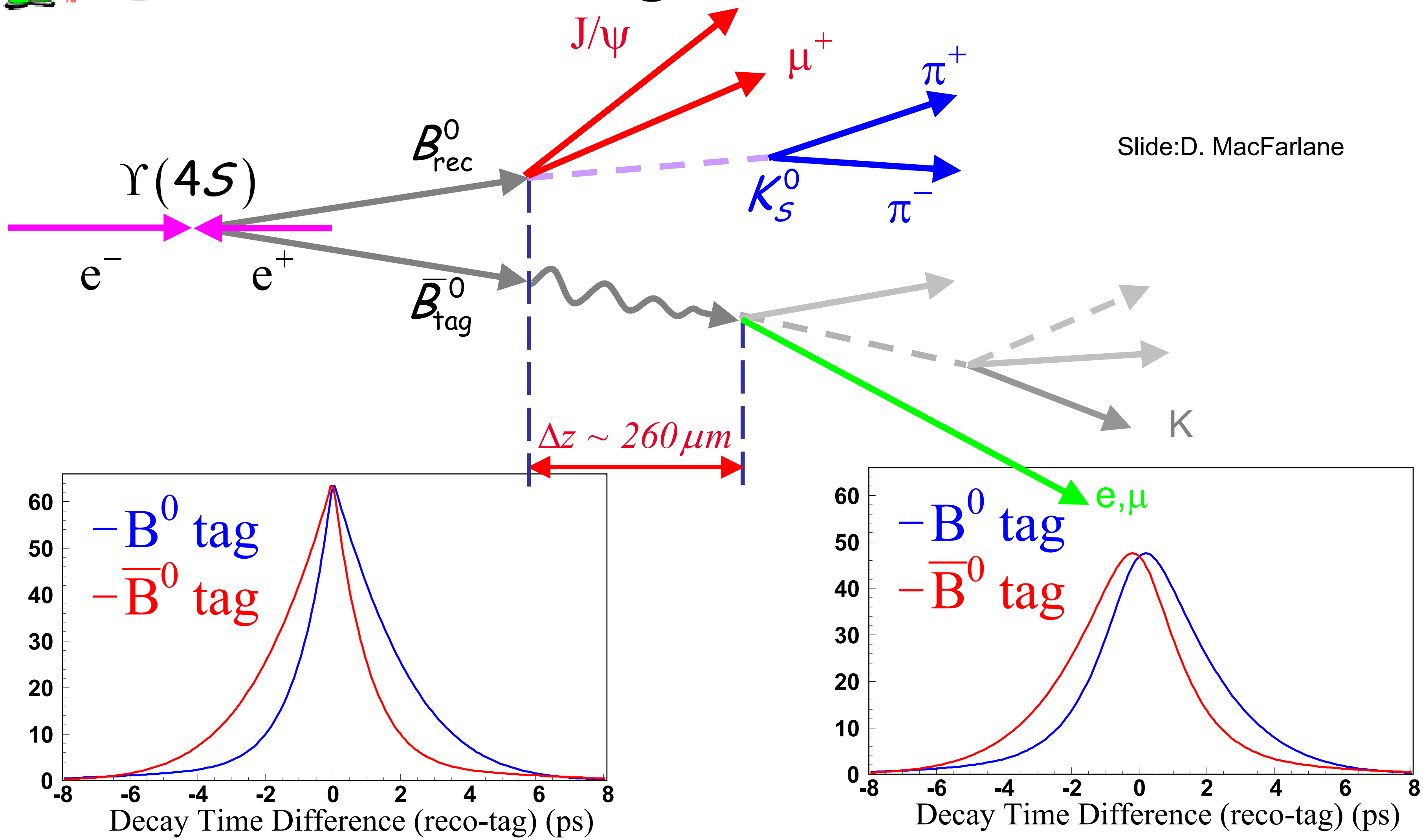


Commissioning

92.5% of ladders are operating
~85 % collect good data
7.5% bad ladders (ISL cooling)
~ 7% error rate

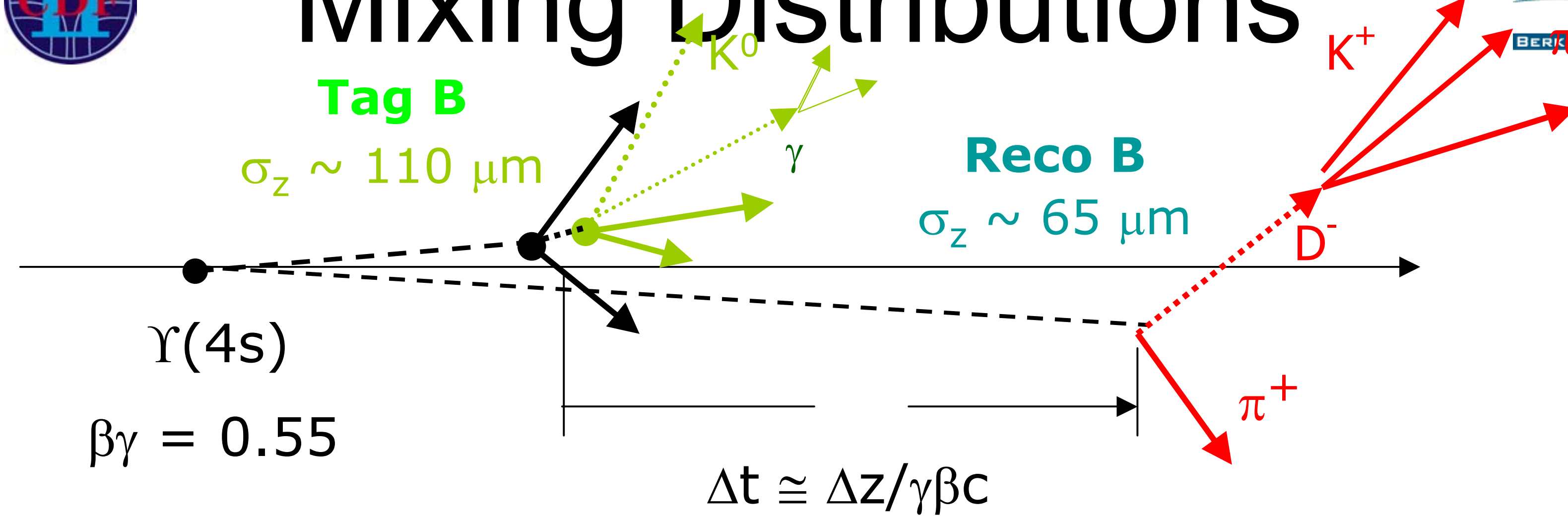


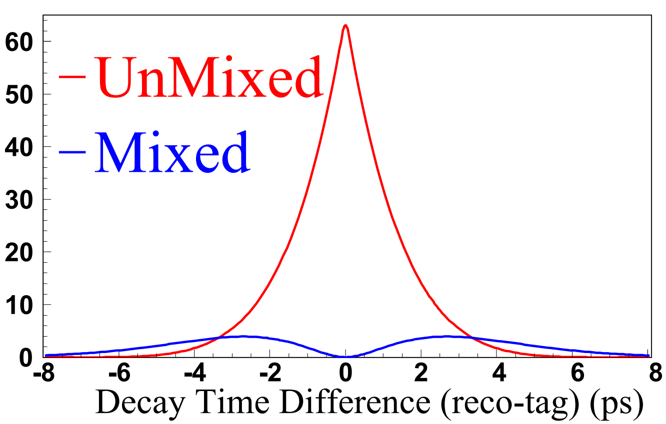
CP eigenstates



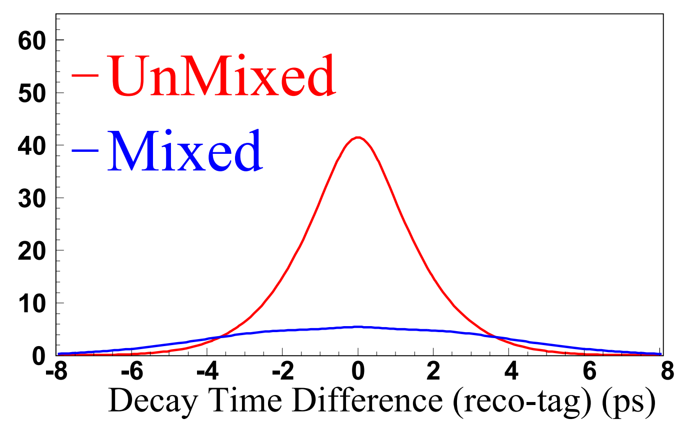
Slide:D. MacFarlane

Mixing Distributions





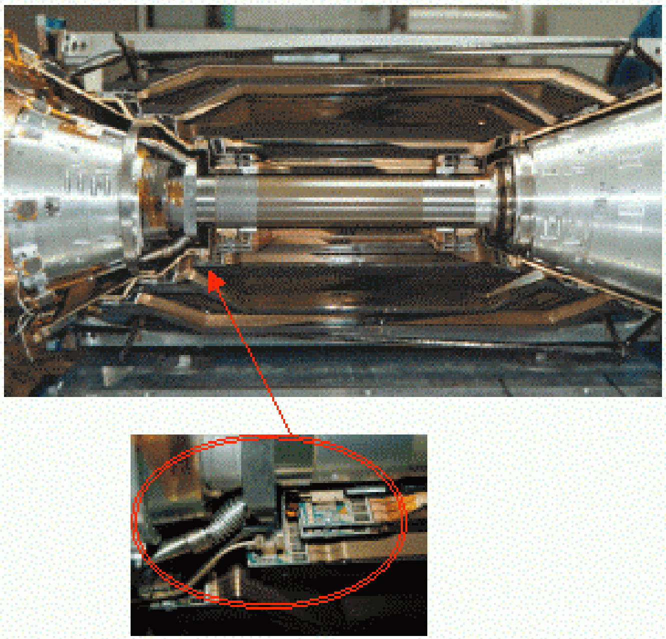
resolution

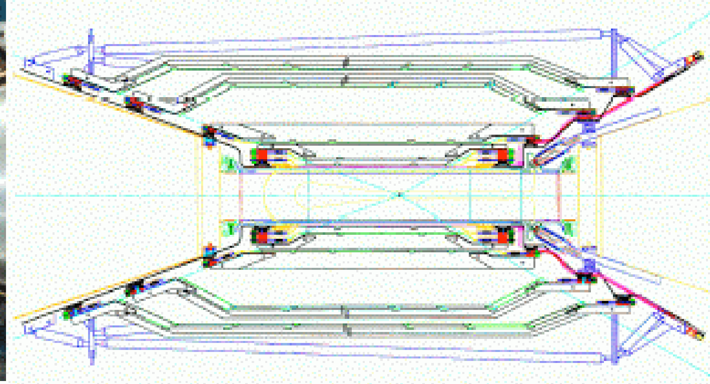


Slide:D. MacFarlane

Upgrades - BaBar

Upgrade Existing SVT or Start Over?





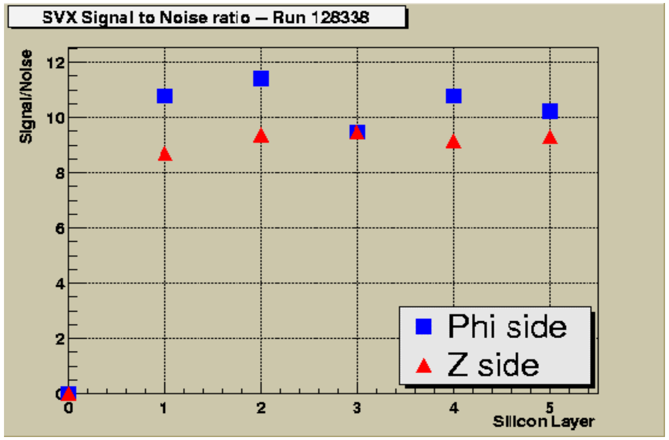
(We have about 800 additional ATоM chips; estimate 3 man-yrs to convert ATоM to 0.25 um CMOS)

It may be possible to replace the present layer 1/2 sextants with new modules that extend in to a smaller radius, while keeping the rest of the SVT intact.

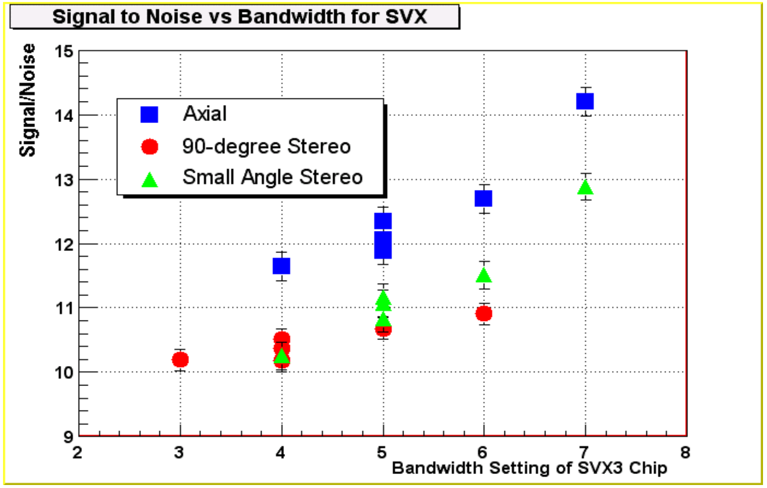
No to new layer-0. Roe co-chairs committee on long-term SVT options.

CDF: Operations

Measured signal-to-noise by layers

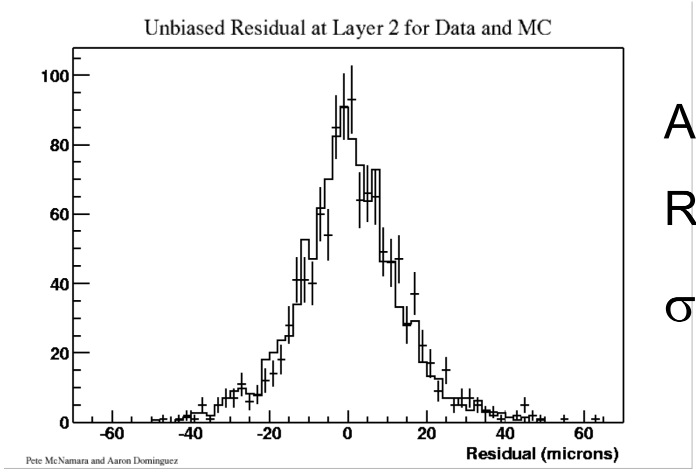


Measured signal-to-noise as function of band-width



Dominguez,Nielsen

CDF Reco/Simulations

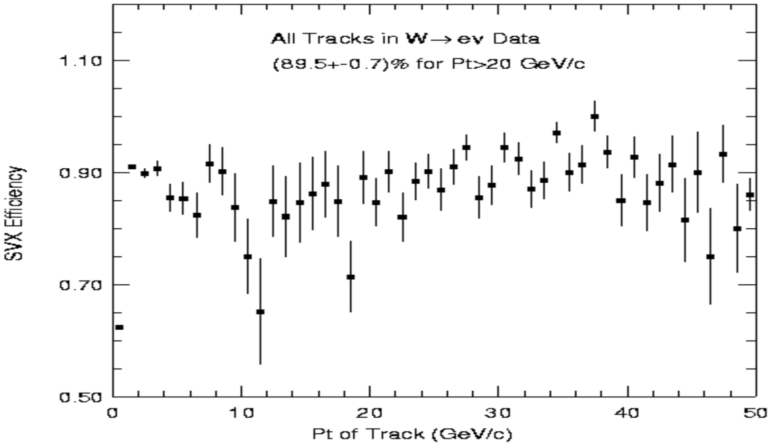


Agreement between MC and measured

Residuals in SVX Layer 2

σ = 8 micron

Dominguez



***SVX efficiency,* $\varepsilon(P_T)$**

ε=89.5%

W-M Yao