The BaBar Detector's Influence on Accelerator Operations and the f_{D_s} Measurement at BaBar

1/28/2009

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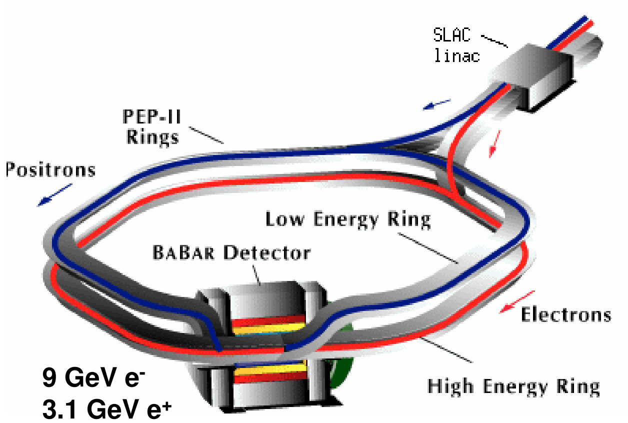
Road Map

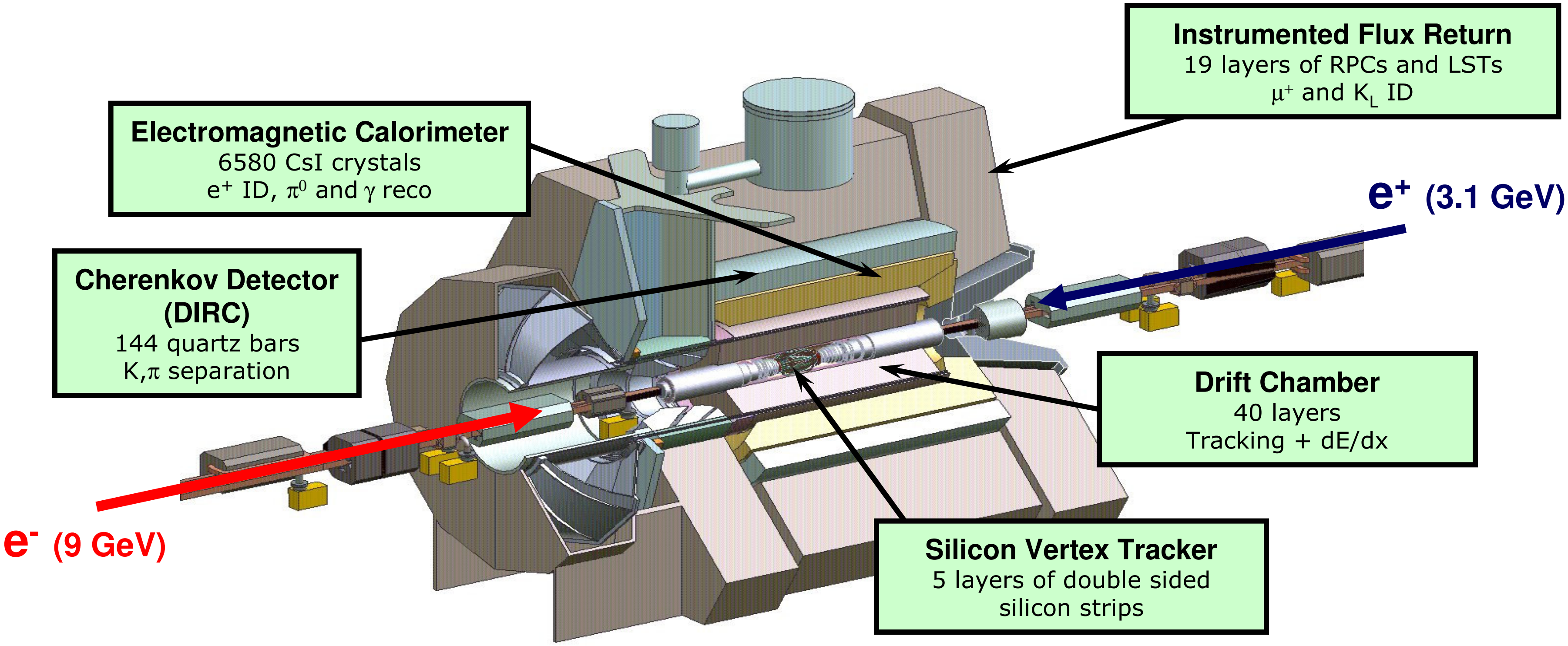
- SLAC and BaBar Overview
- Machine Detector Interface Group
- Detector Protection
  - Dose Rate Monitoring
  - Beam Aborts
  - Trickle Injection
- Accelerator Performance
- Feedback to Operators
- BaBar Analysis
  - Measurement of f_{D_s}

SLAC (PEP-II) / BaBar



Electron Positron Collider
Asymmetric B Factory

Peak Lumi – 12.069 x 10^{33} cm^{-2} sec^{-1}
2069mA HER 3213mA LER



Machine Detector Interface Group

Evaluate Effects of Machine Backgrounds

- Radiation Monitoring
  - Beam Abort Policies
    - Procedure/Threshold Evaluation
  - Detector Subsystem Operational Issues
- Long Term projections
  - Detector Lifetime
- Simulations
  - GEANT - IR description
- Parameterization
  - Forward Shield Wall

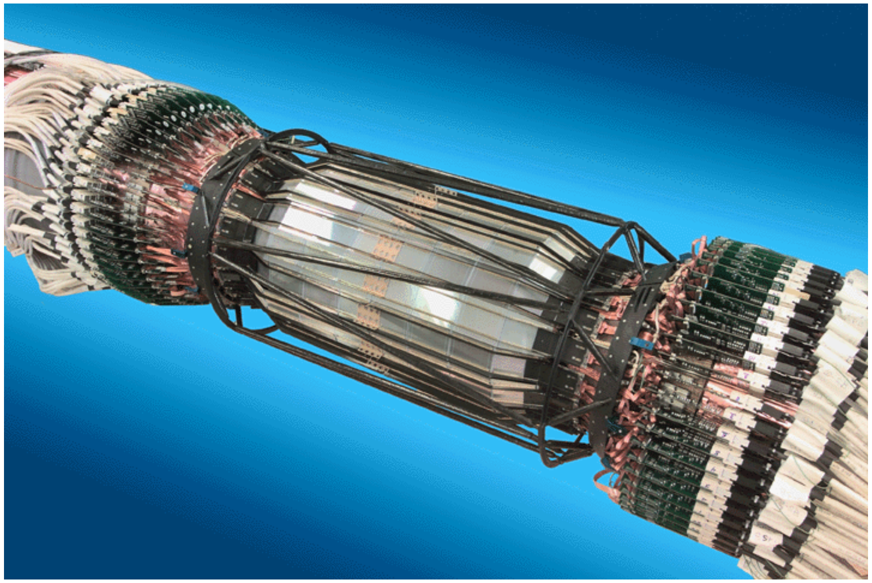
Accelerator Performance

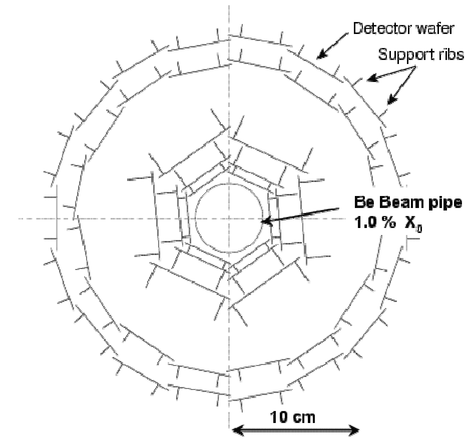
- Machine Tuning
  - Trickle Injection
  - Detector Occupancies
  - Backgrounds
- Beam Size Measurements
  - BaBar Data (e^+e^-; $\mu^+\mu^-$)
- Beam-Beam Simulations

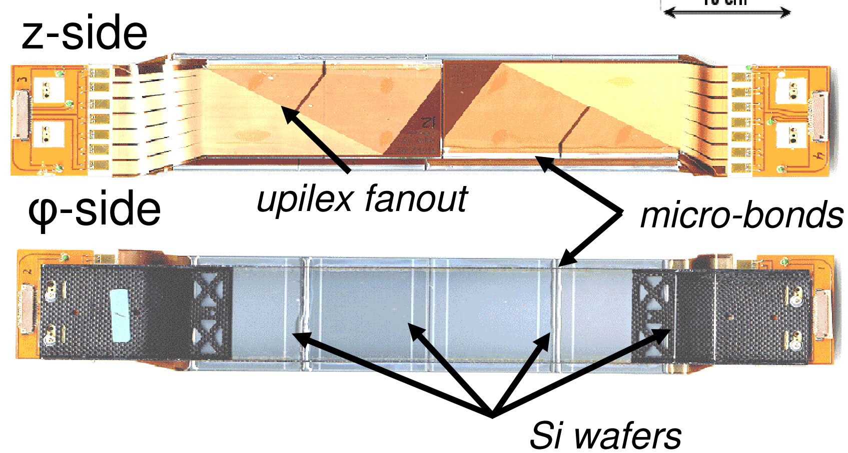
Goal:

Provide operational feedback to operators to improve machine performance and reduce possible downtime.

Silicon Vertex Tracker





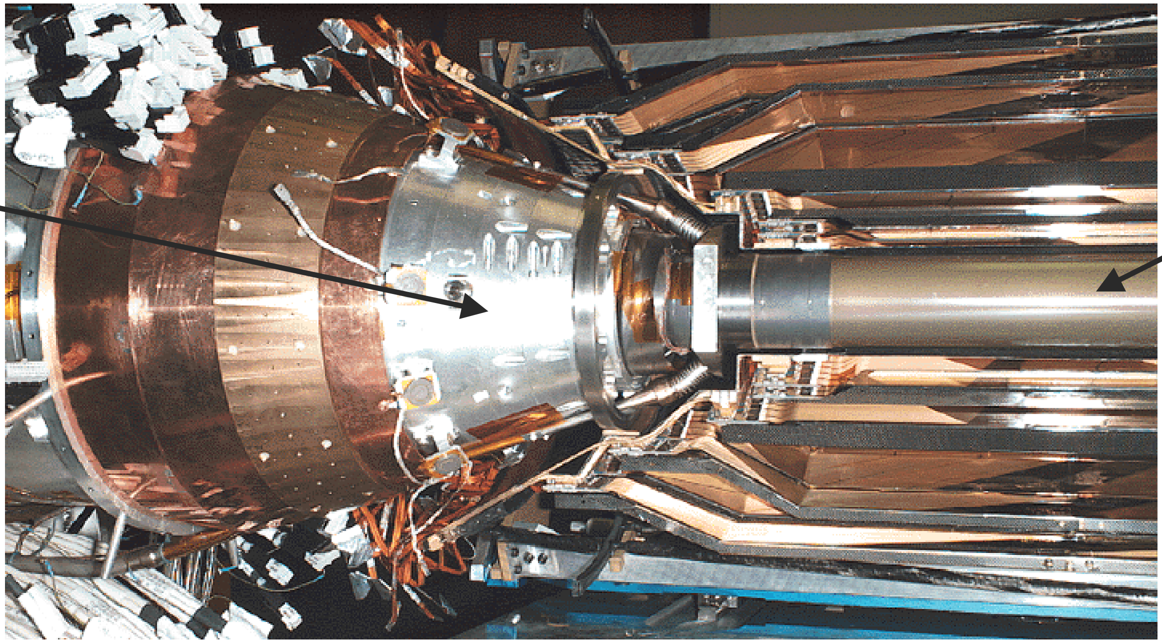


- 5 Layers of Double-Sided, AC-Coupled Silicon, 0.94 m^2 of Si
- Φ and z Strips
- Custom Rad-Hard Readout IC (the AToM Chip).
- Low-Mass Design (Kevlar/Carbon Fiber Mechanical Support)
- Inner 3 Layers: Precision Vertexing
- Outer 2 Layers: Pattern Recognition, Low P_t Tracking.

SVT Protection

- The Silicon Vertex Tracker (SVT), (centimeters from the beam pipe), is highly susceptible to radiation damage
- Receives ≈ 1 MRad/yr (electromagnetic)
- Monitored/Protected by the SVT Radiation Monitoring System (SVTRAD)

Magnet



Be Beam Pipe

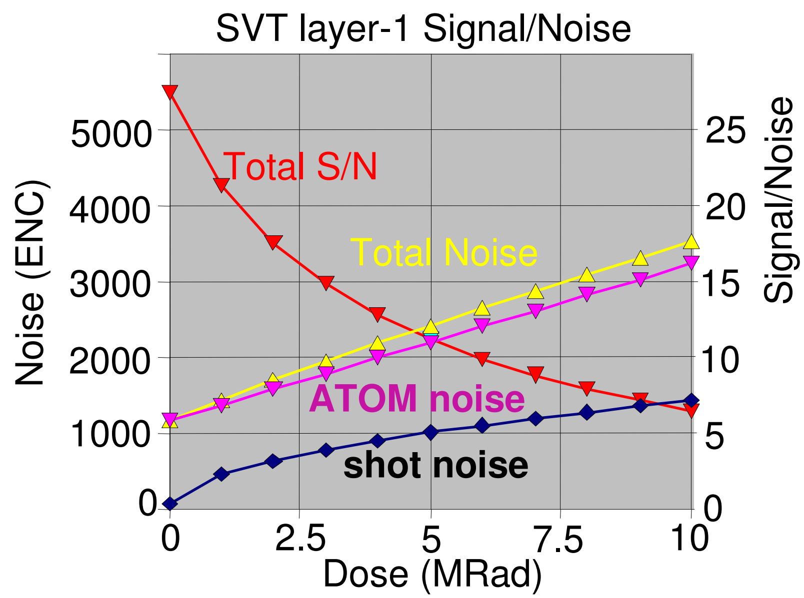
SVT Sensors
- Leakage Current Increase
- Shift of Depletion Voltage
- Loss of Charge Collection Efficiency
- P-Stop Shorts

SVT Readout Electronics
- Noise Increase
- Gain Decrease
- Pedestal Increase

SVT Protection

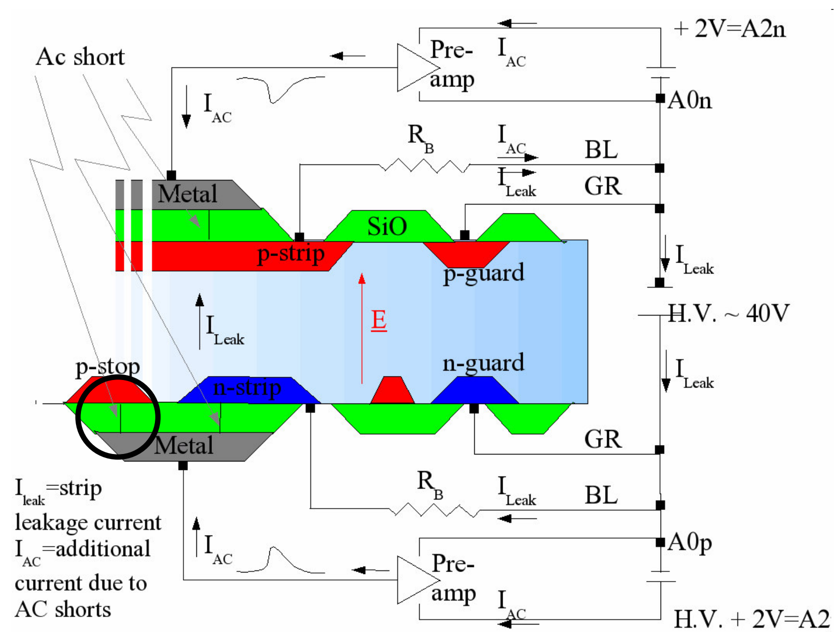
Monitor/Limit Dose Rates:

- Limit S/N for Optimum Performance
  - S/N < 10
- 5 MRad Radiation Budget
  - Chronic Threshold ~ 100 mRad/s
    - 10 Minute Timer
    - Dump Beams
- Damage to SVT – (p-stop shorts)
  - Acute Threshold ~ 1000 mRad/s
  - Dump Beams

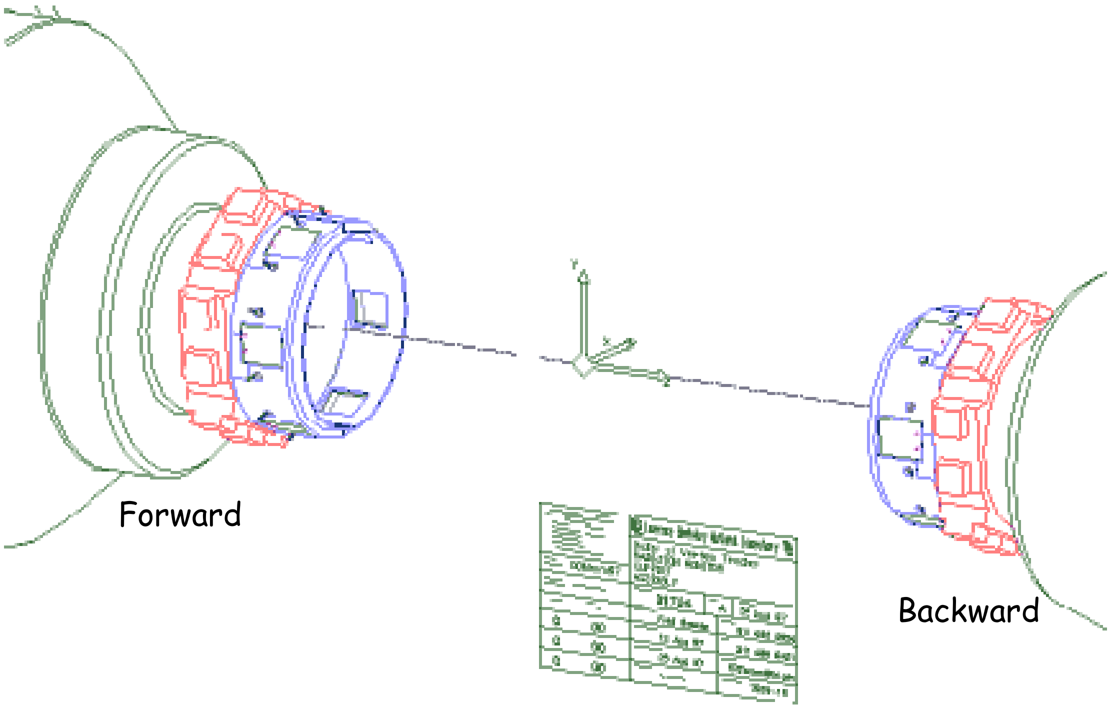


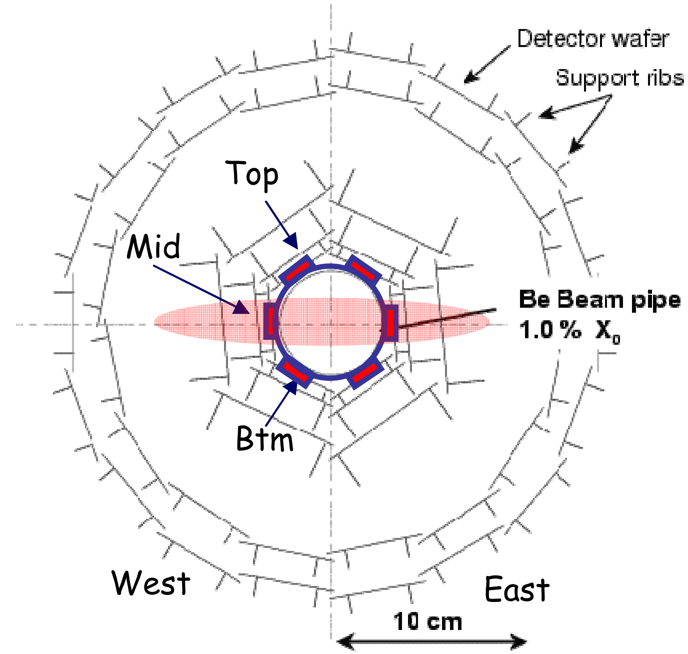
Protection System Limits How Hard the Machine is Pushed

- Startup
- Scrubbing
- Steering

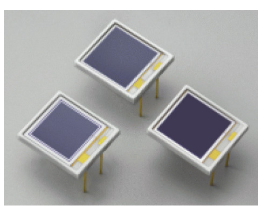


SVTRAD System



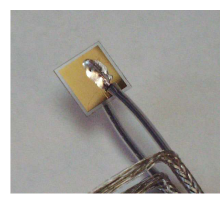


SVT Cross-Section



12 Silicon PIN Diodes

- 1cm x 1cm x 300μm
- 50V Reverse-Biased
- 6 Diodes Forward Side
- 6 Diodes Backward Side



2 pCVD Diamonds

- 1cm x 1cm x 500μm
- 500V Bias
- 1 DM Backward East
- 1 DM Backward West

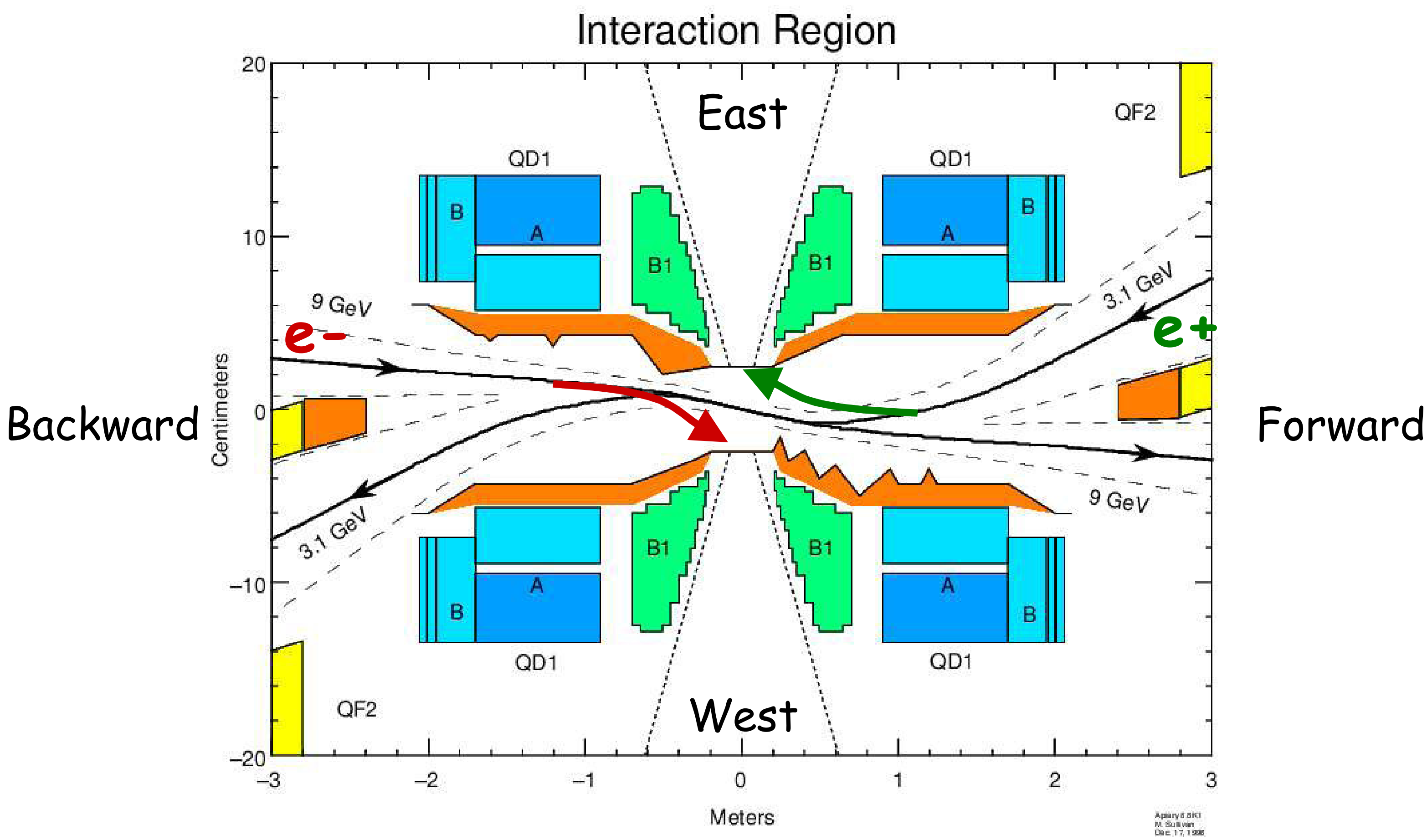
Background Categories

1. **Beam Gas Interactions – Chronic Thresholds**
   - Bremsstrahlung (e + H -> e + γ + H)
   - Coulomb scattering (e + H -> e + H)

2. **Beam "Instabilities" – Acute Thresholds**
   - Something causes "wild" background and SVTRAD system dumps both beams in ~1-100ms
   - Some Known Causes: Beam Instabilities, Pressure Bursts, "dust" events

3. **Trickle Injection**

Beam Gas Backgrounds



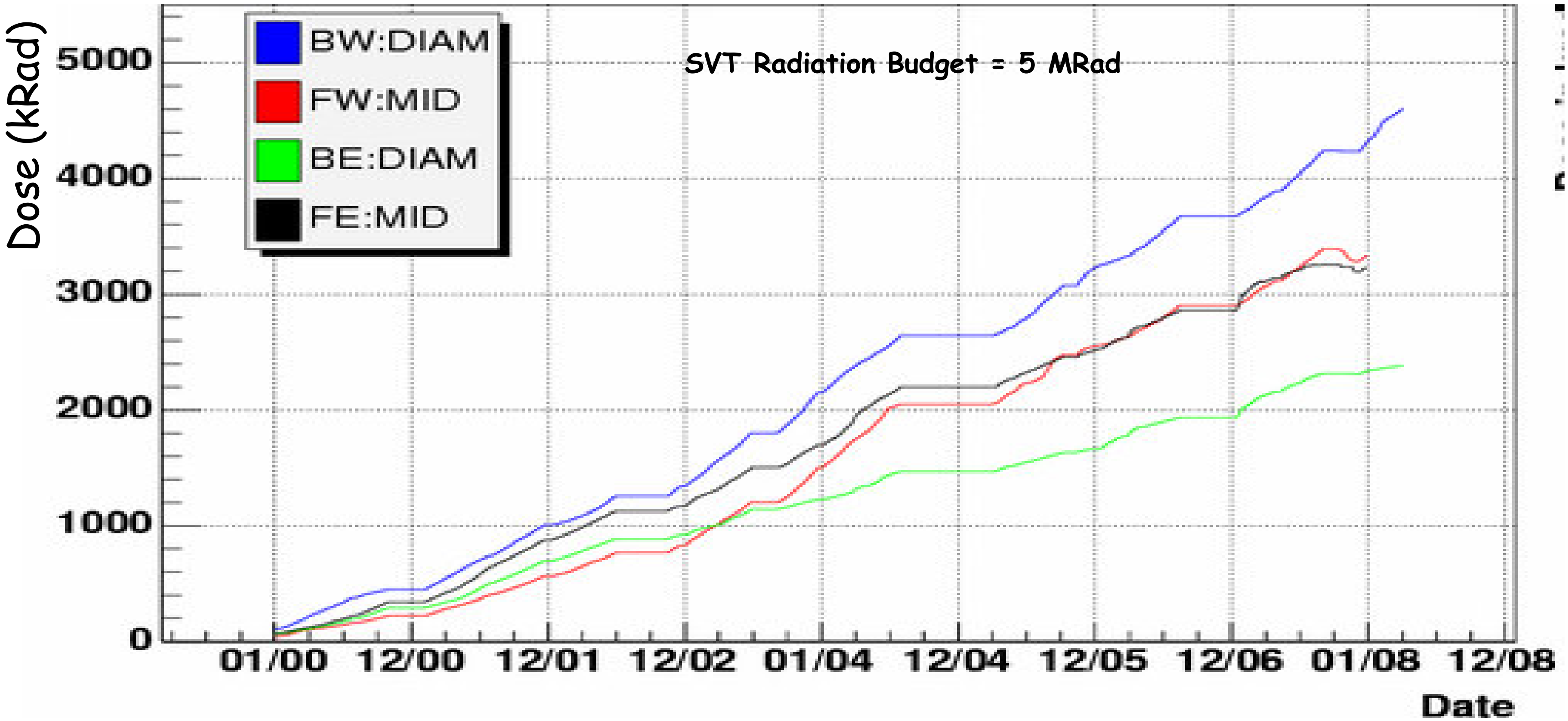
Off Energy/Angle Electrons Hit West Midplane Diodes

- Largest Source of Radiation of Chronic Radiation

Off Energy/Angle Positrons Hit East Midplane Diodes

Monitoring – Total Integrated Dose

Mid-Plane Diodes/Diamonds

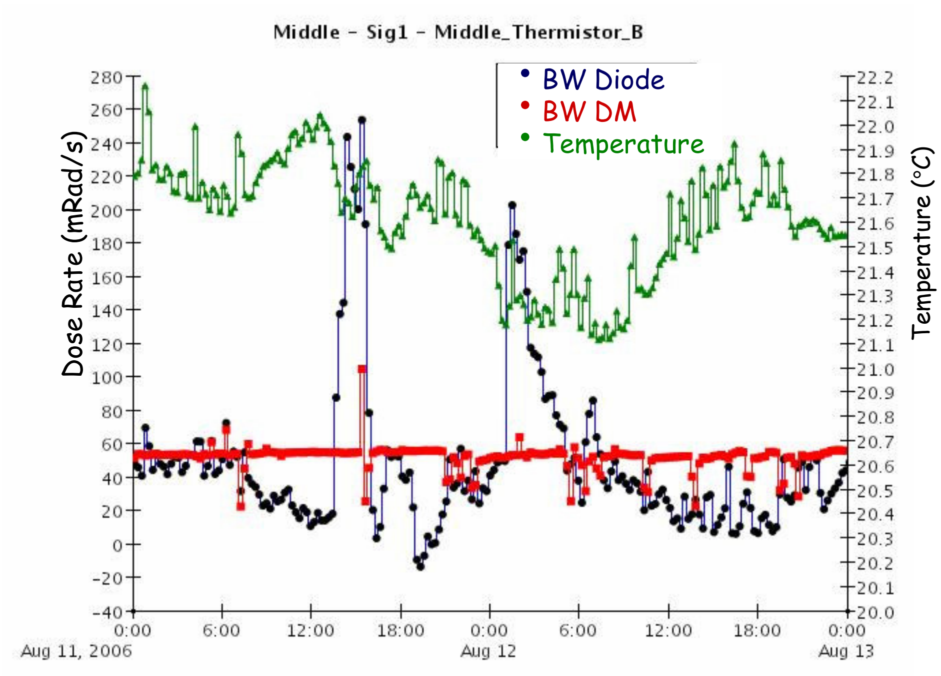


Limiting Dose Rates to Under 100 mRad/s
Allowed the Total Integrated Dose to Remain
Below Budget of 5 MRad Over the Lifetime of BaBar
and Ensured Optimum Detector Performance

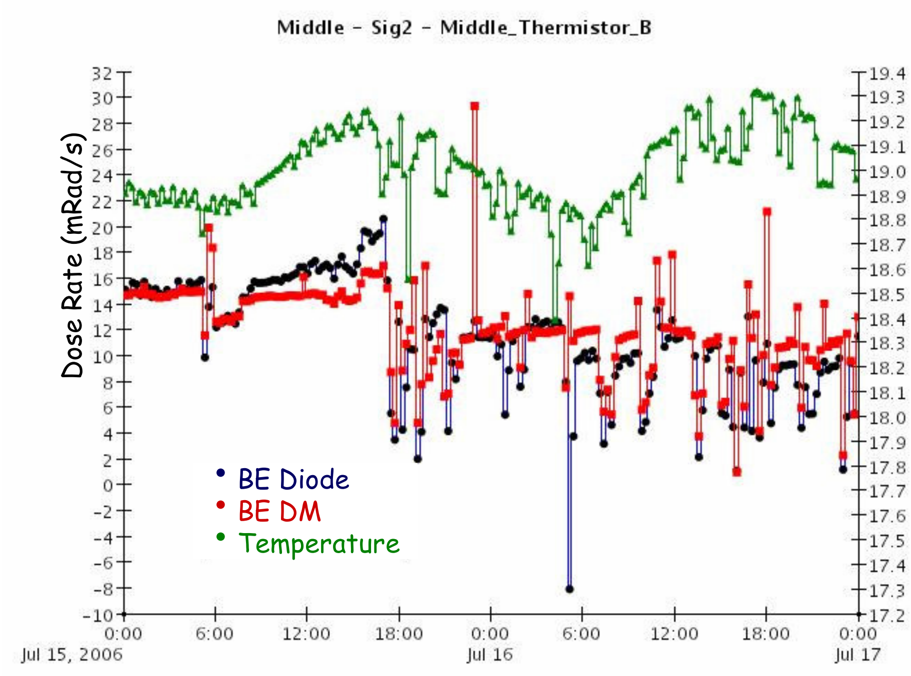
Monitoring - Diodes vs Diamonds

- Machine Operator's Frustrations
  - Inconsistent Diode Performance
  - Increasingly Difficult to Operate Diodes Due to Radiation Damage
  - MID Plane Diodes Replaced by Diamonds for Monitoring

BW-MID Diode vs BW-MID DM

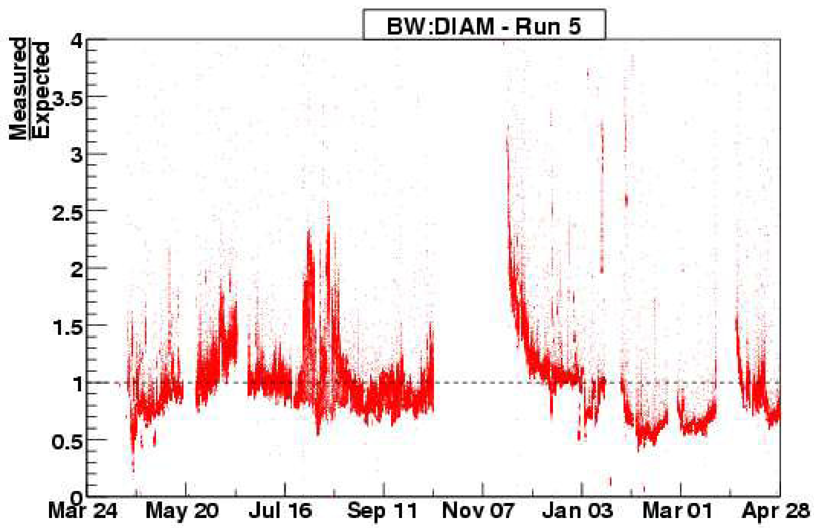


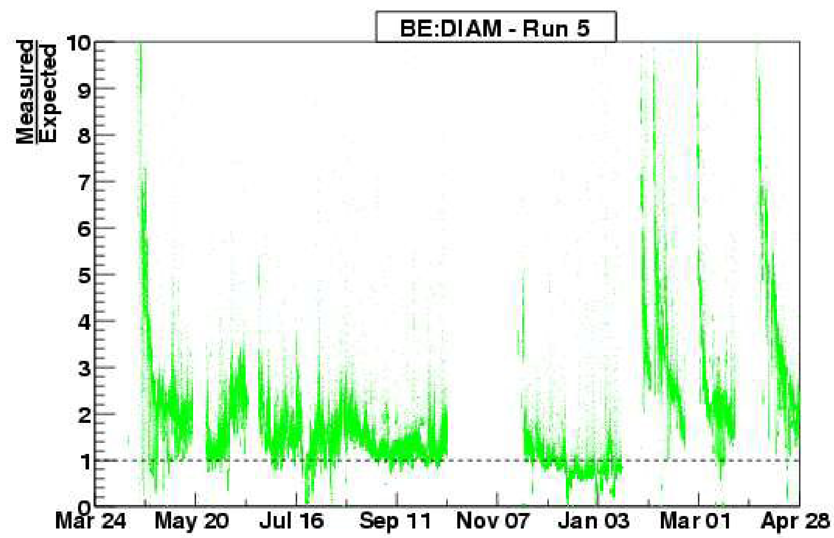
BE-MID Diode vs BE-MID DM



Measured vs Expected Dose Rates

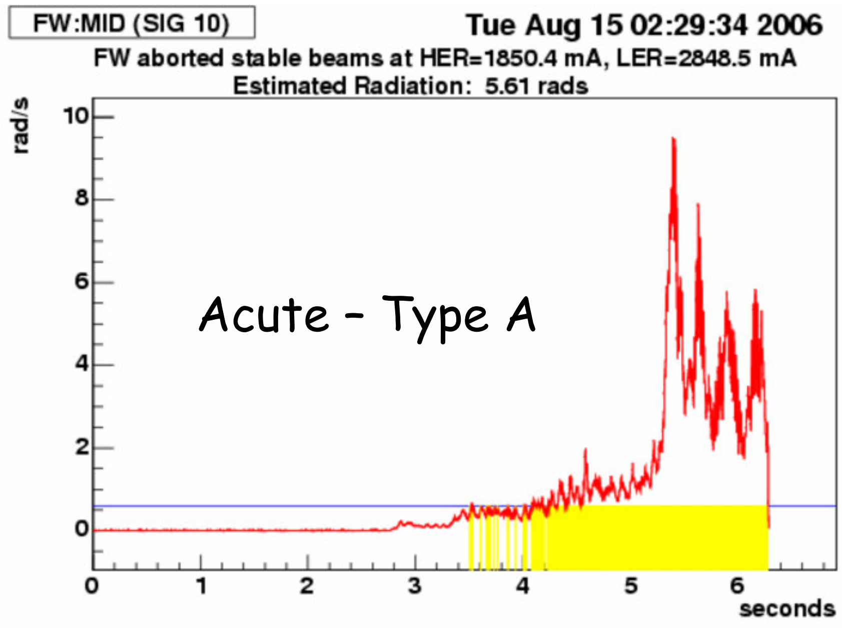
Expected Dose Rate
- Is the Current Level That Bad?
- Function of:
  - HER Current
  - LER Current
  - Luminosity
- Measured During Stable Running
  - Single Beams
  - Colliding Beams

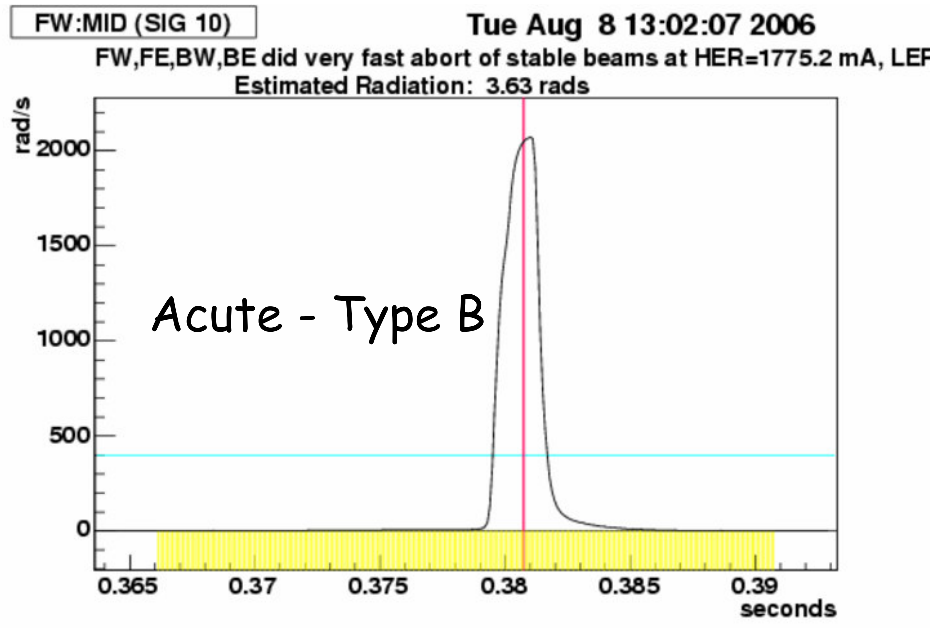




Can see periods where the vacuum was broken

Protection – Beam Aborts





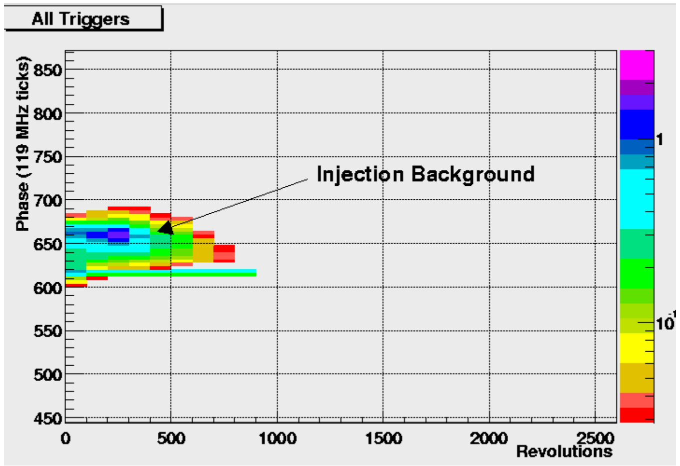
Radiation Damage Protection – Beam Aborts

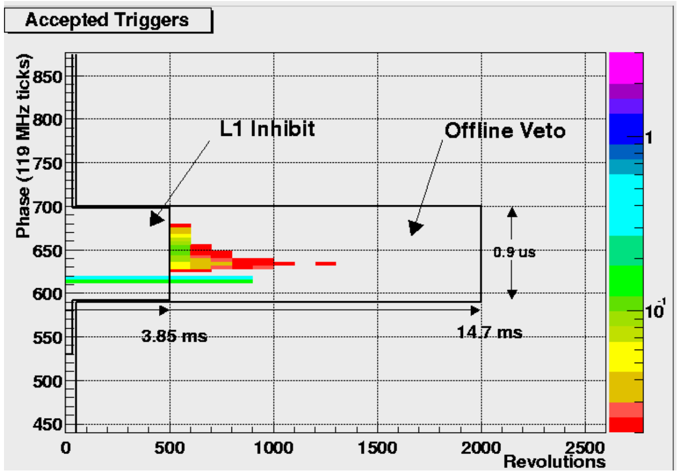
- "Acute" - Fast Radiation Damage
  - A - Dose Rate > 1000 mRad/s and Integrates to 5 Rad
  - B - Dose Rate > 400 Rad/s
- "Chronic" - Integrated Radiation
  - Dose Rate > 100 mRad/s for 10 minutes – "10 Minute Timer"
  - Control "Unnecessary" Doses

Trickle Injection

Injection is necessary to refill beam "buckets" which have lost charge. A particular bucket is targeted for each injection shot.

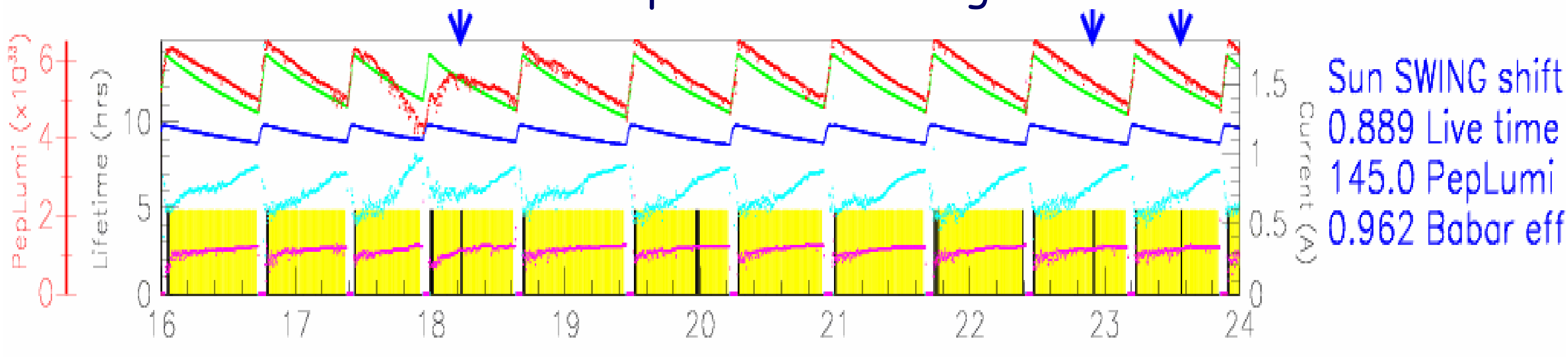
- Important factor in increasing integrated luminosity.
- Keep LER/HER at constant current by continuously injecting positrons/electrons at 1-30Hz.
- The injected bunch causes backgrounds in BaBar.
  - "Upsets" detector electronics
  - Increases detector deadtime
    - An L1 trigger inhibit window around injection is used to control dead-time.





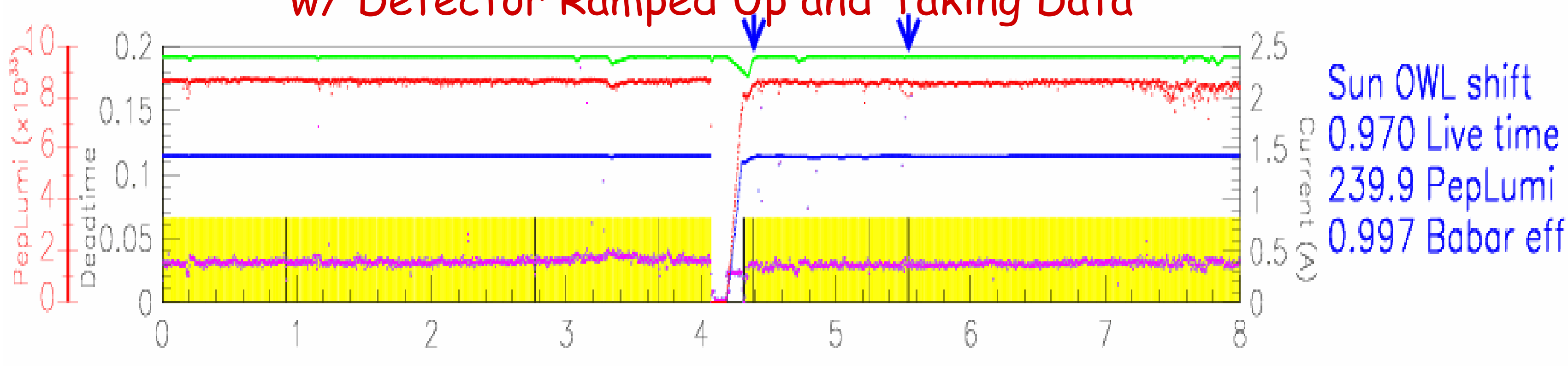
Trickle Injection

Fill and Coast
Detector Ramped Down During Fills



- HER Current
- LER Current
- Luminosity

Continuous Trickle of HER and LER
w/ Detector Ramped Up and Taking Data

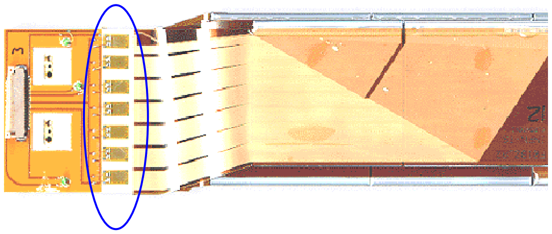


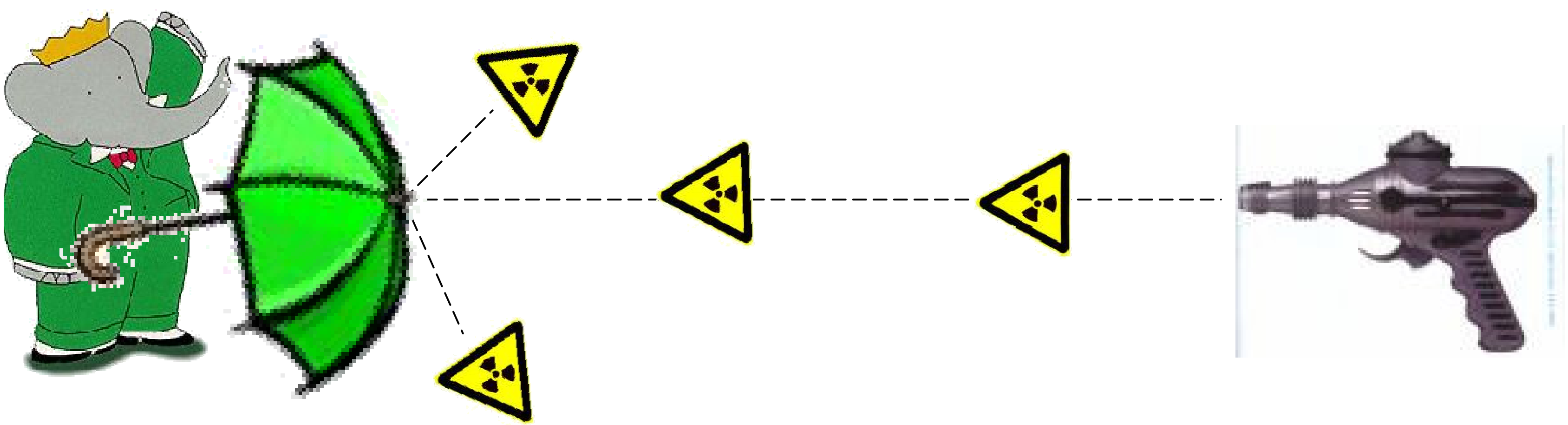
SVTRAD Trickle Injection Monitoring

SVTRAD Flexibility:

- Injection Monitoring
  - Provide Injection Quality Feedback to Machine Operators
  - Identify Probable SVT "Configuration Loss" Periods
    - Reset of Front End Electronics = "Configuration Loss"
    - Data Taking is Stopped While SVT is Reconfigured

Burst of Radiation Causes
SVT AToM Chips to Reset,
Results - Corrupted Data

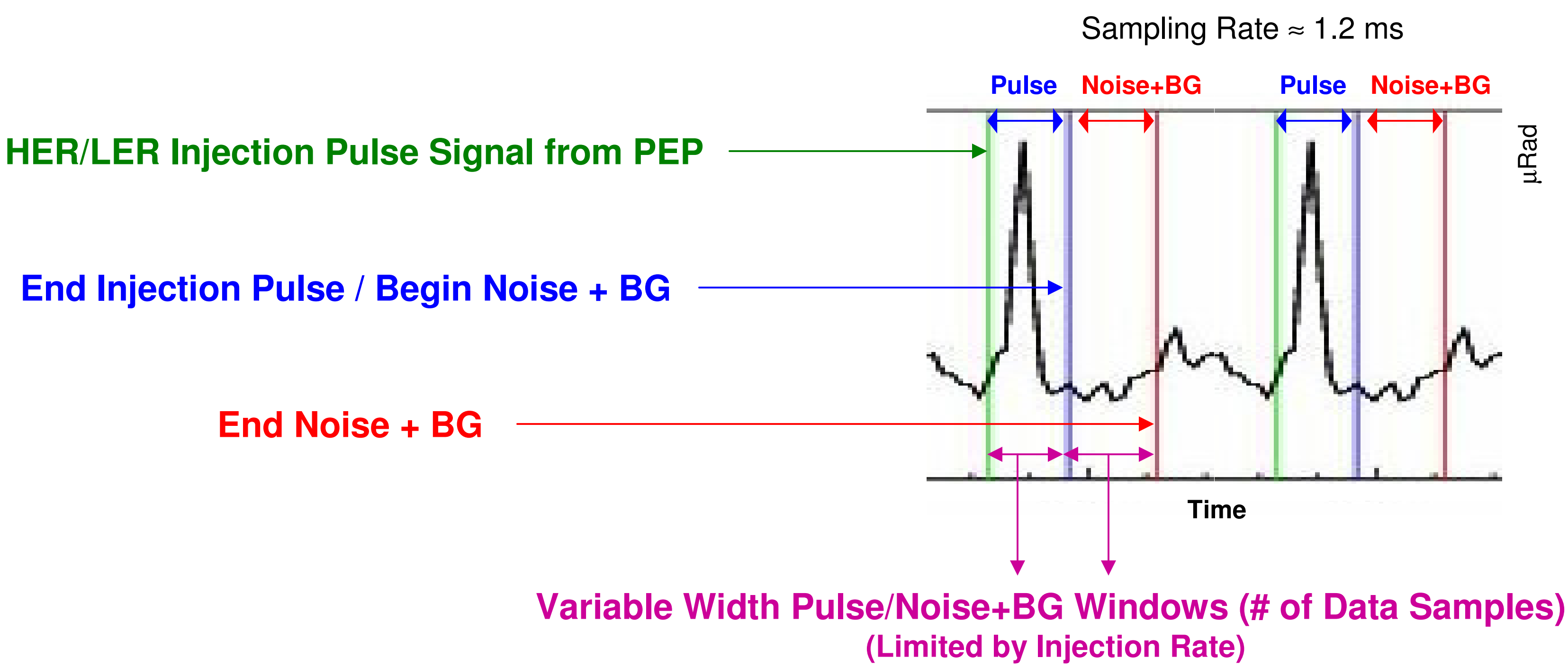




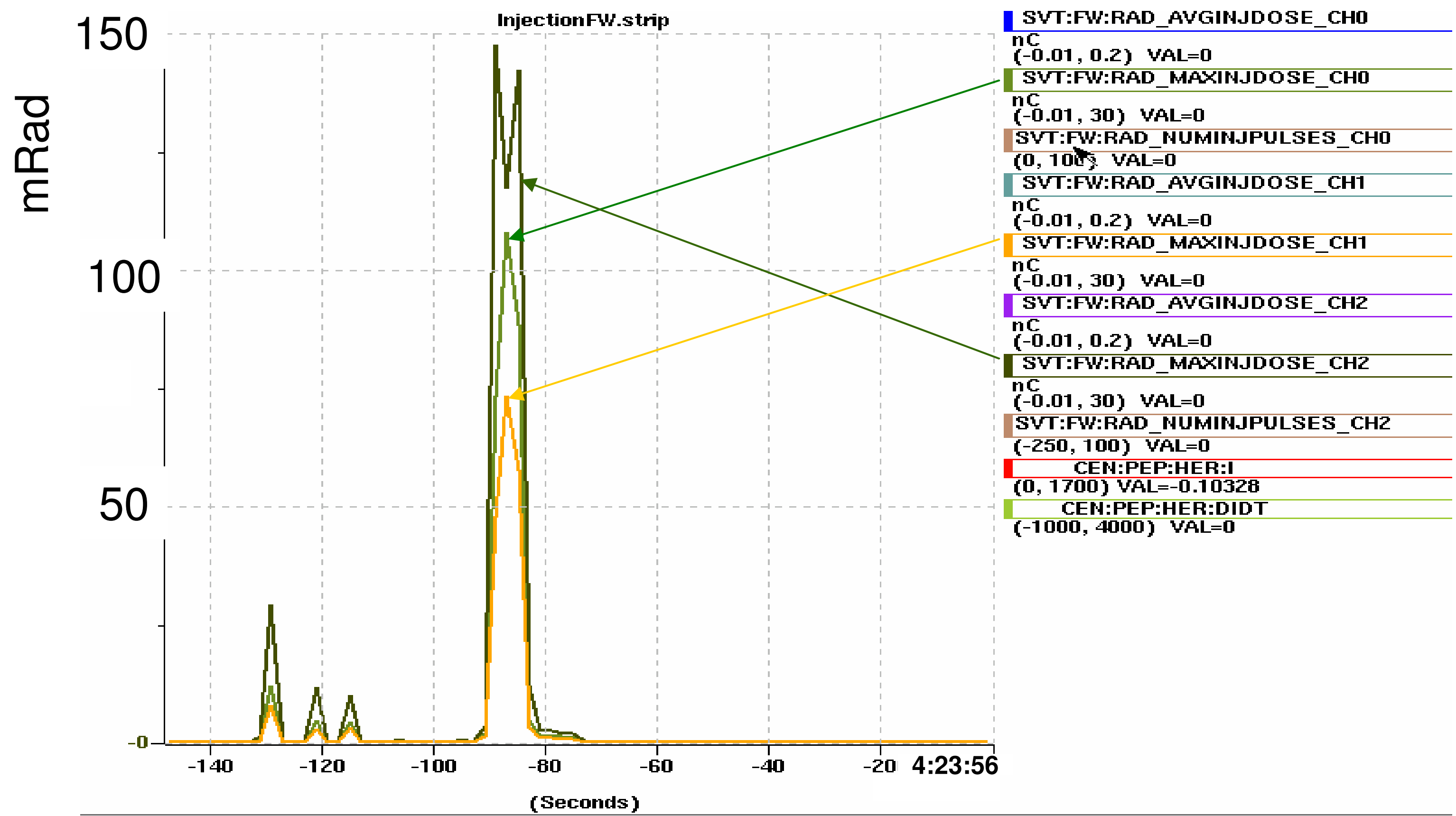
Injection Monitoring Logic (On Board)

1. Receive: Injection Pulse Signal from PEP
2. Integrate: Pulse
3. Integrate: Noise + Stable Beam BackGround
4. Dose = Pulse – (Noise + BG) → No Temperature Dependence
5. Reported as EPICS Variables: Max Dose : Avg Dose : # Injection Pulses

   (Report Max Dose Over 2 Seconds and Average Dose Over 2 Seconds)

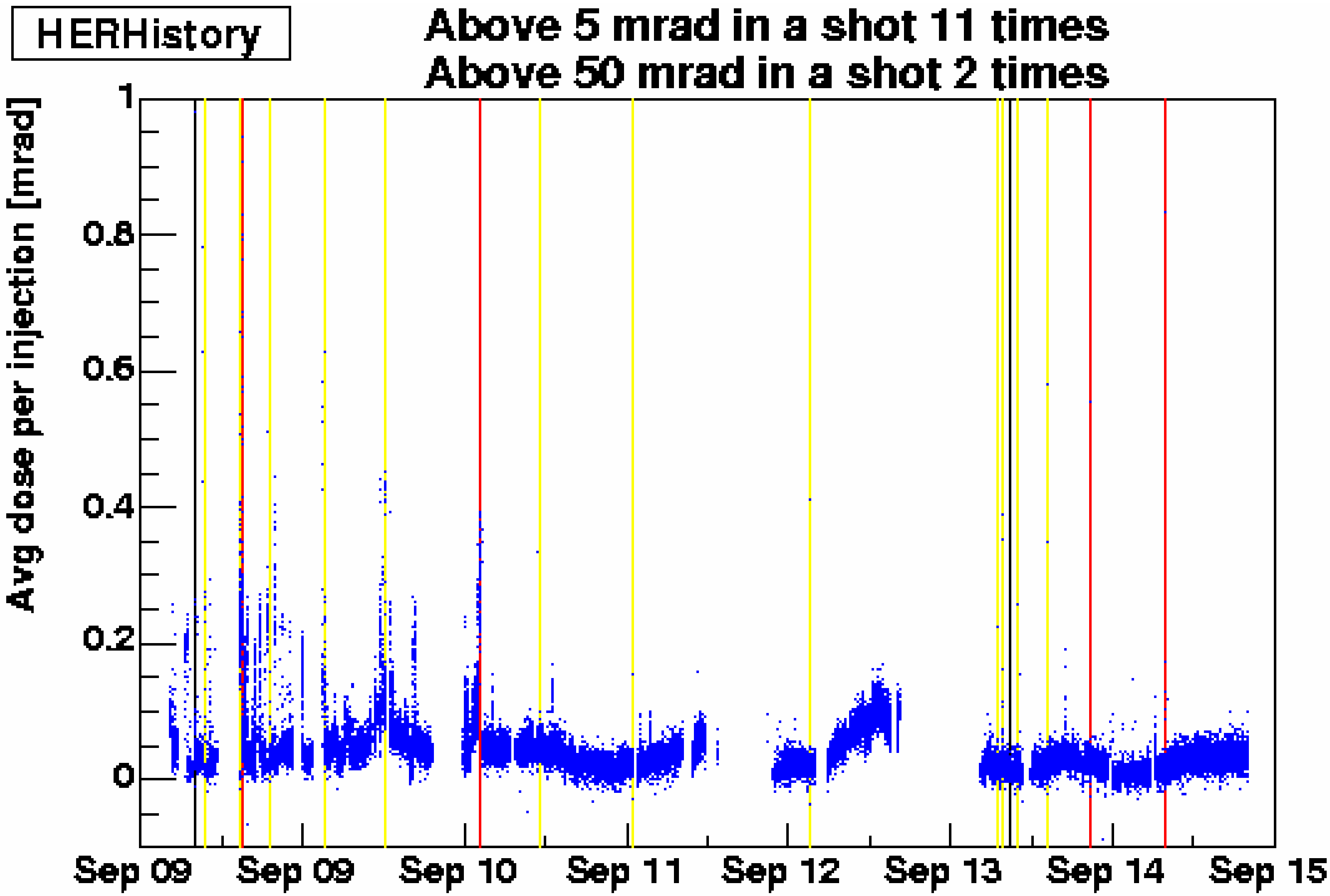


Run Stopped due to SVT Damages



- Able to Correlate SVT Configuration Losses with Large Spikes in Injection Dose
- Injection Quality Alarms Warn of Possible Losses
- Implemented Automated SVT Reconfiguration
  - Limits Downtime

HER Injection Monitoring Summary

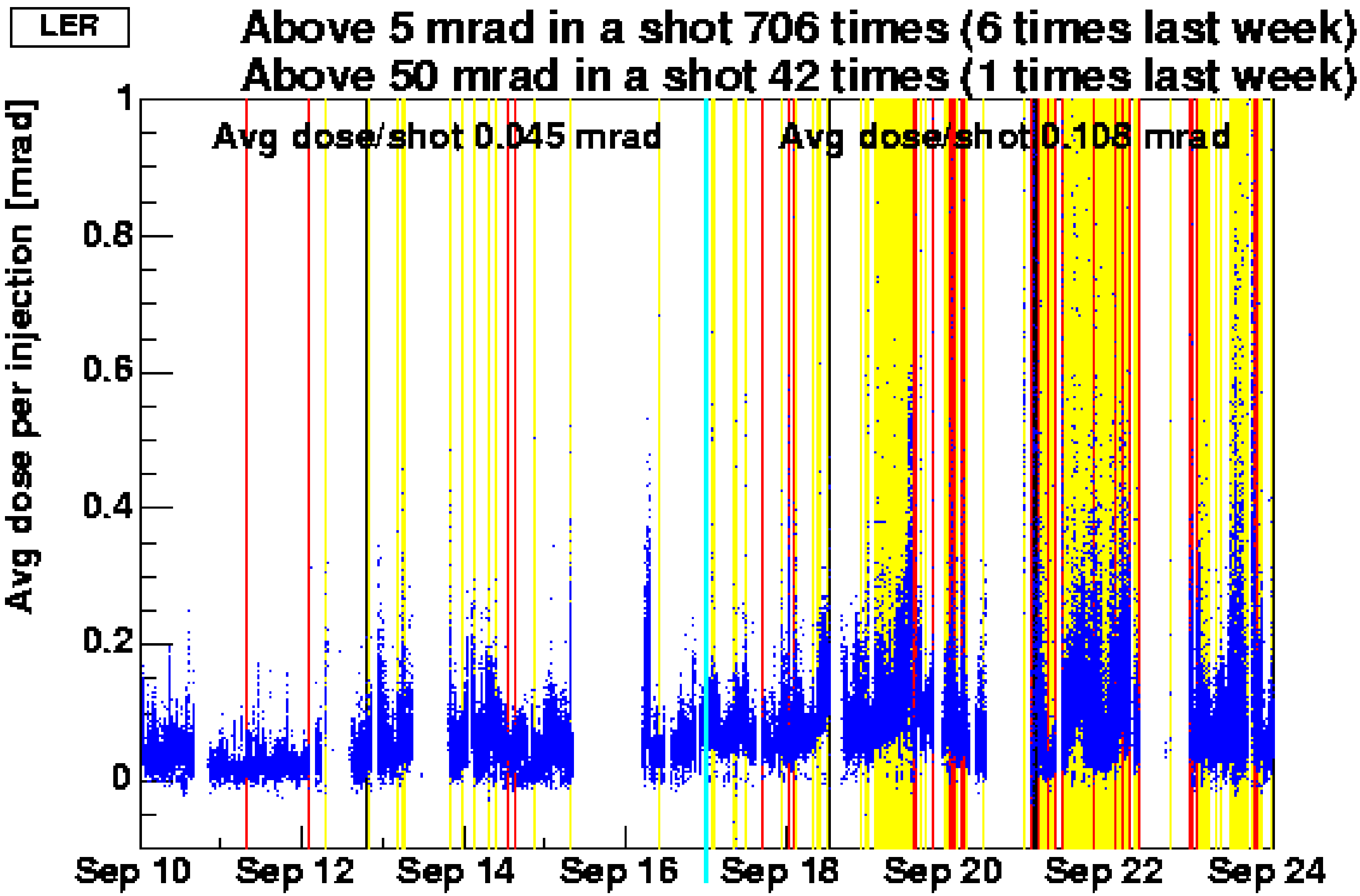


Yellow – Max Inj Dose above 1 mRad

Red – Max Inj Dose above 5 mRad

Black – Max Inj Dose above 50 mRad **(SVT Configuration Losses)**

LER Injection Monitoring Summary



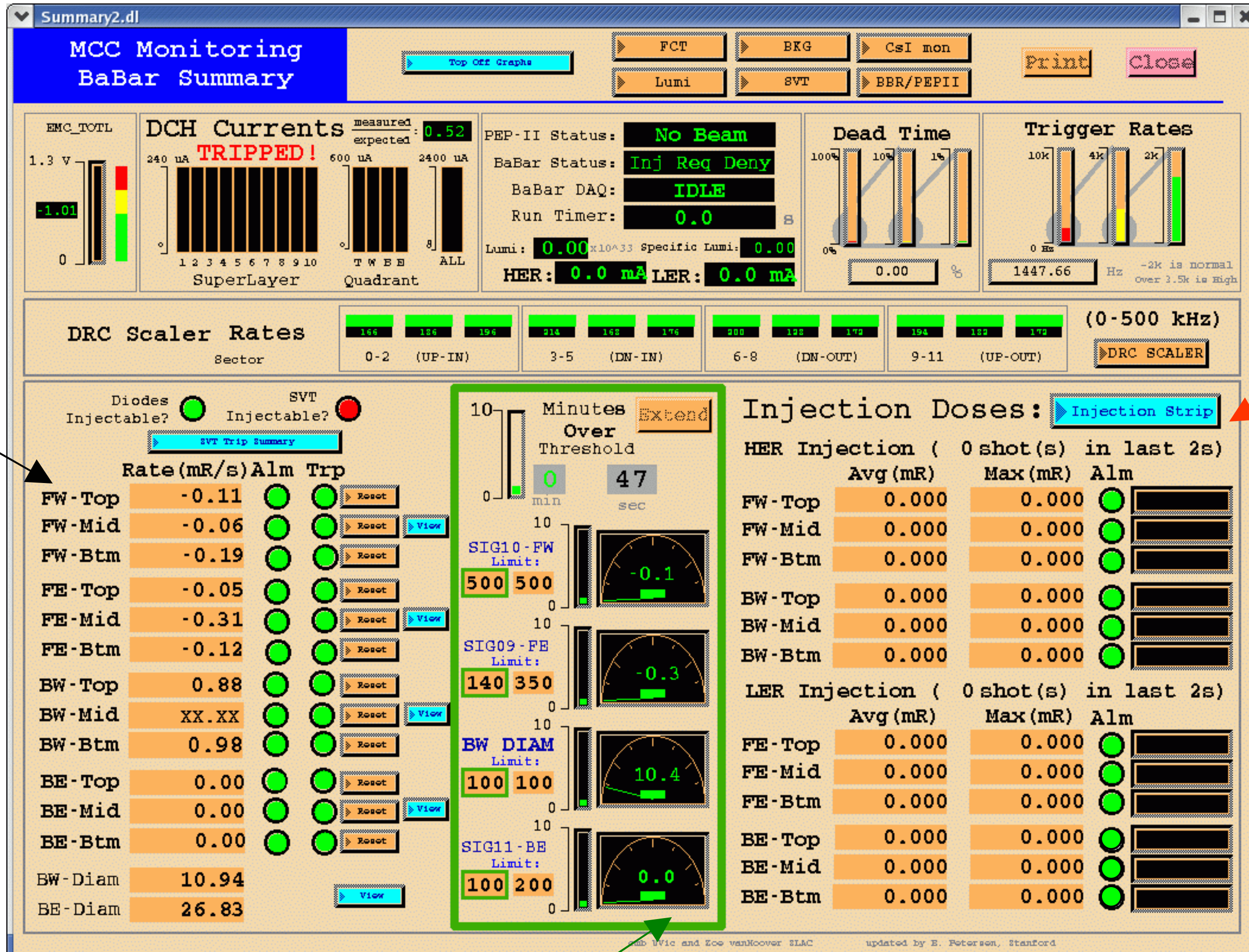
Yellow – Max Inj Dose above 1 mRad

Red – Max Inj Dose above 5 mRad

Black – Max Inj Dose above 50 mRad **(SVT Configuration Losses)**

Machine Operators Background Panel

Dose Rates

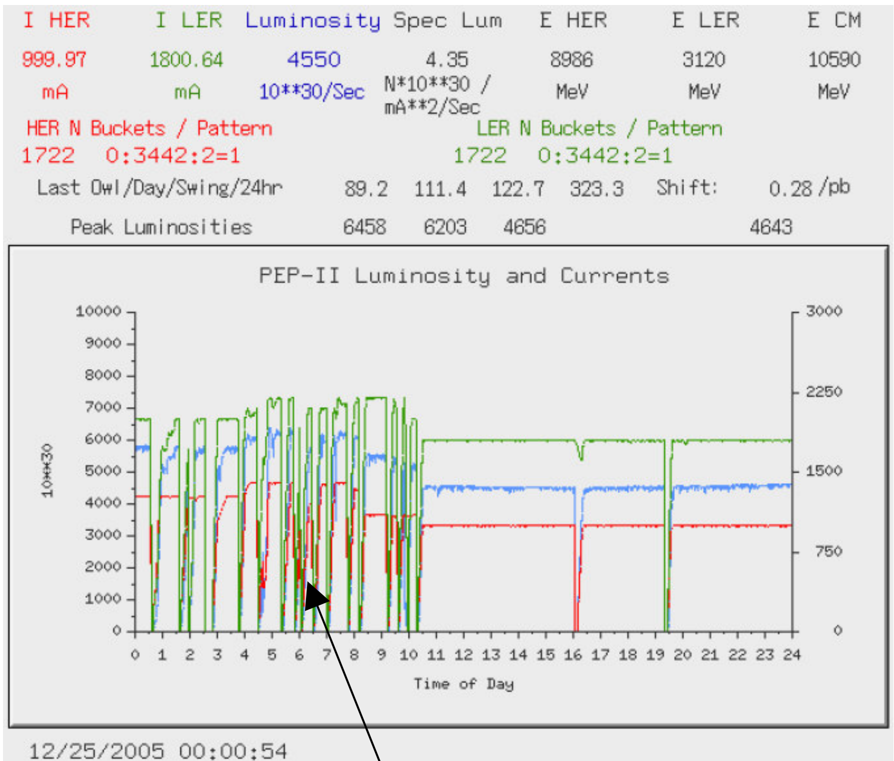


Injection Monitoring

10 minute timer

Provide Background Quality Feedback to Machine Operators for Tuning the Machine to Allow Better Detector Environment and Data Taking Conditions

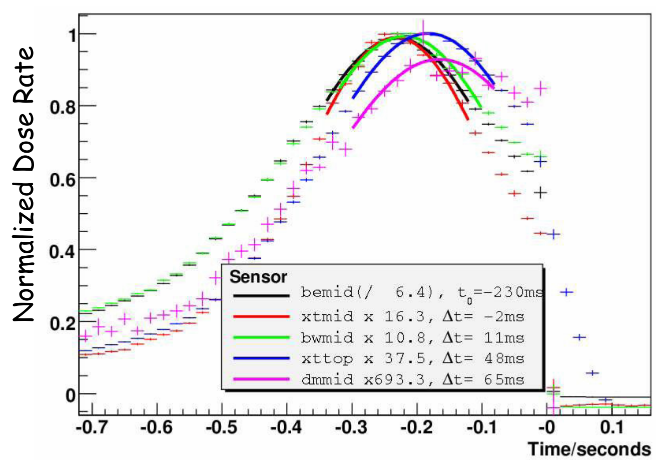
Diagnosing Machine Issues



Excessive Number of Radiation Aborts
At High HER & LER Currents

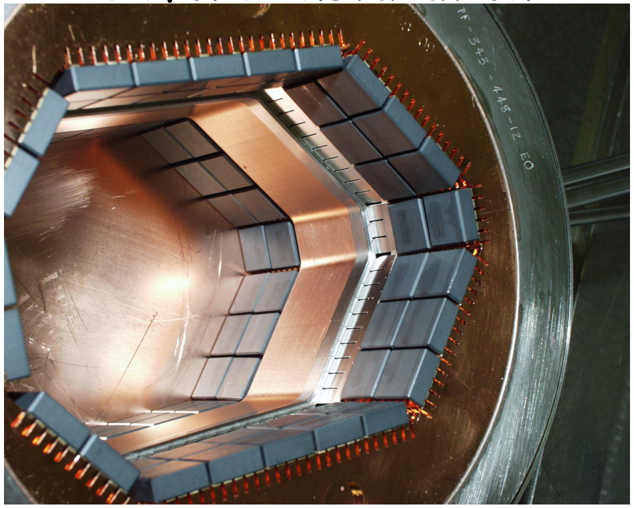
Diagnose:

- Borescoping
- Increased Abort Threshold
- Vacuum Gauges
- Temperature Gauges
- Timing Difference of Diodes
- …



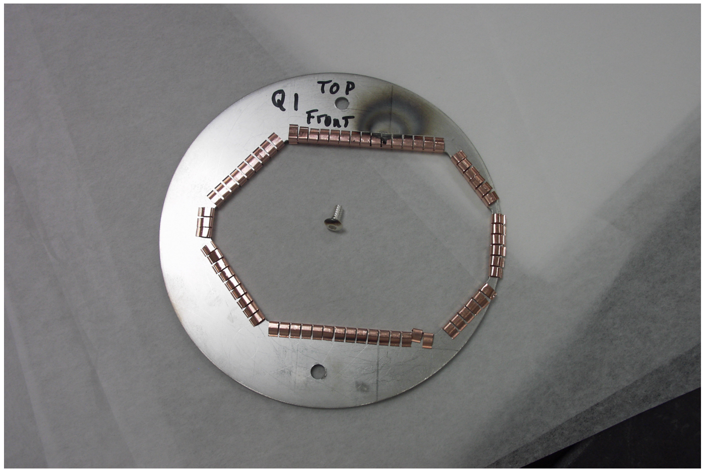
Damage to Bellows and RF Seal

Before Installation

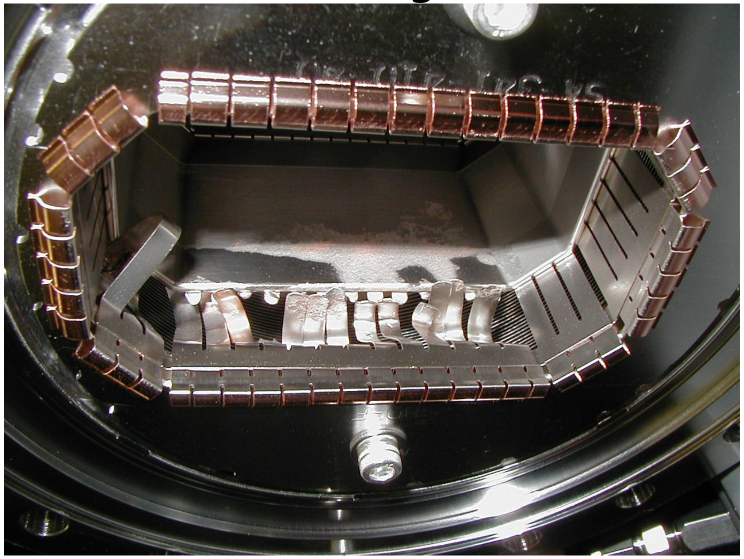


Damage

Damage



Damage



Results

Monitoring
- Balance:
  - Detector Performance
  - Integrated Luminosity

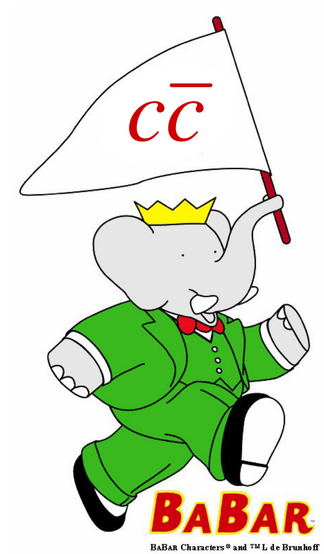
Aborts
- Detector Protection
- Downtime: Refill Machine

Trickle
- Downtime Due to Configuration Losses

A lot of time and effort goes into reducing the amount of downtime for the machine and data taking. Detector subsystems can contribute to machine performance. Cooperation between machine operations and detector personnel helped to achieve a large and quality data sample for precision particle physics analysis.

BaBar Analysis

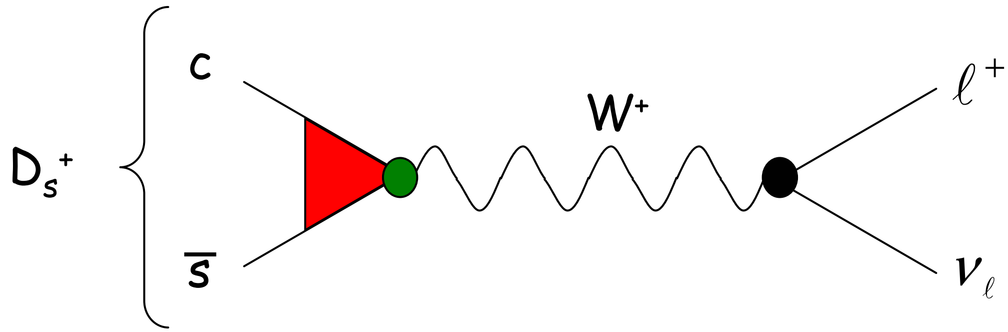
Measurement of the $D_s \to \tau\nu_\tau$ Branching Fraction and Extraction of the Pseudoscalar Decay Constant f_{D_s}



(Not Just a B-Factory)

D_s Pseudoscalar Decay Constant

$$D_s^+ \to \ell^+ \nu_\ell$$



Decay Rate for Purely Leptonic D_s^+ Decay*:

$$\Gamma\left(D_s^+ \to \ell^+ \nu_\ell\right) = \frac{G_F^2}{8\pi} m_{D_s}^3 \left(\frac{m_\ell^2}{m_{D_s}^2}\right)\left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2 \left|V_{cs}\right|^2 f_{D_s}^2$$

Helicity Suppression → (first bracket); Phase Space → (second bracket)

- **m_τ close to m_{D_s}**
  - **Combined Helicity and Phase Space >> e/μ**
- **Ratio of Decay Rates:** $e : \mu : \tau = 2\times10^{-5} : 1 : 10$

* The use of charge conjugation is implied throughout

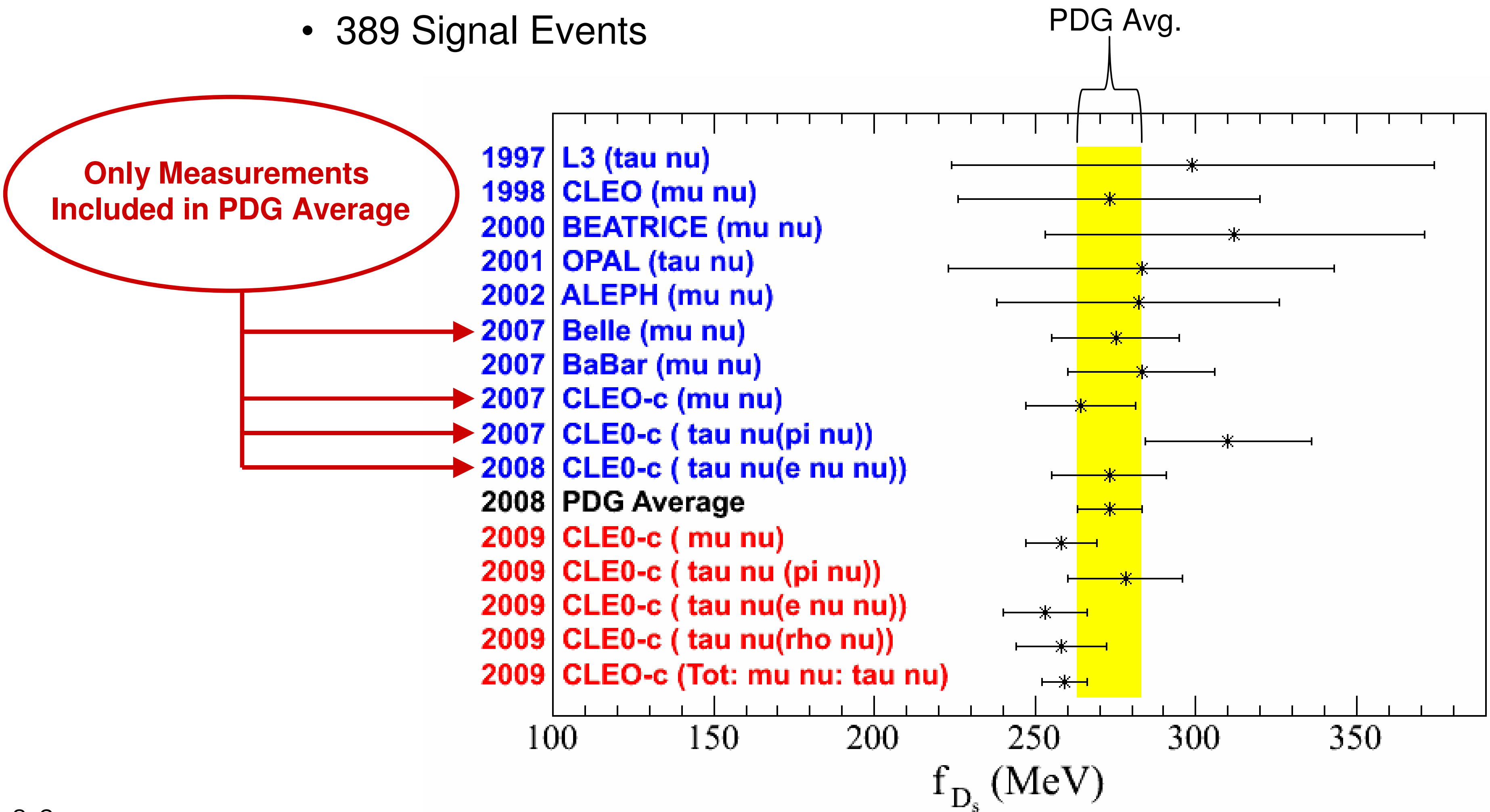
Motivation

- Experimental measurements of f_{D_s} can help to calibrate and validate lattice QCD
  - Study leptonic decays of heavy mesons
  - Applicable to the CKM suppressed B-meson sector
    - Can use f_{D_s} to calibrate QCD that predicts f_B,f_{B_s}
- Relative decay rates to different lepton flavors well predicted
  - Deviations imply ‘New Physics’
    - 2-Higgs Doublet [1]
    - Leptoquarks [2]

(1) A.G. Akeroyd and C.H. Chen, Phys. Rev. D75, 075004 (2007).
(2) B.A. Dobrescu and A.S. Kronfeld, [arXiv:0803.0512v2] (2008).

f_{D_s} - Experimental Results

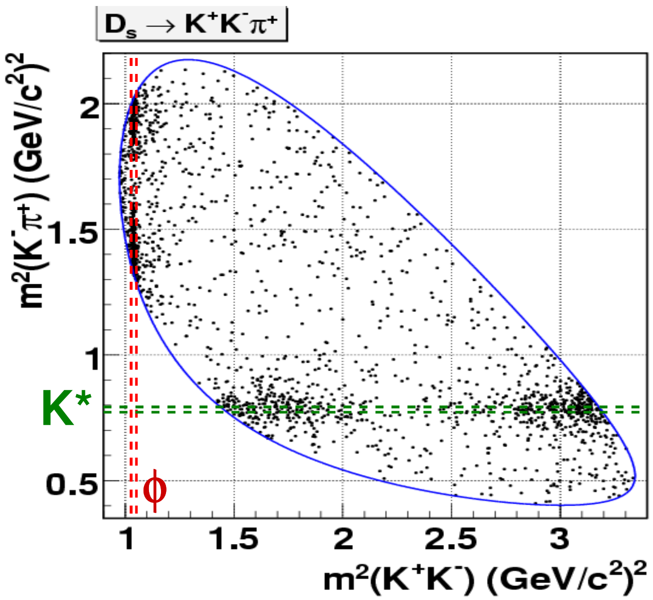
- Only Absolute Measurements are Used for the PDG Average:
  - Relative Measurements Rely on $B(D_s \to \phi\pi)$
    - Measured Ratio: $B(D_s \to l\nu)/B(D_s \to \phi\pi)$
- BABAR Measurement of f_{D_s} : ($D_s \to \mu\nu$)
  - 230.2 fb^{-1}
  - 389 Signal Events



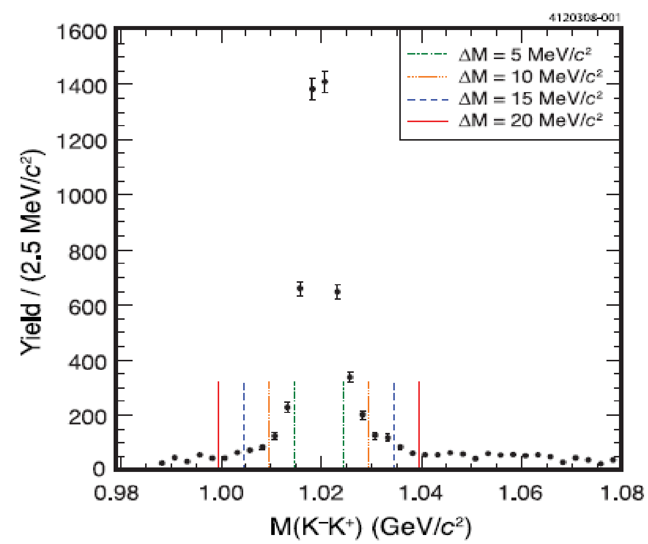
S. Curry

Issues with using $D_s \rightarrow \phi\pi$ for Normalization

- $D_s \rightarrow \phi\pi$ is used as a normalization mode by many experiments:
  - Not well known
  - Error on $B(D_s \rightarrow \phi\pi : \phi \rightarrow K^+K^-) \approx 15\%$
  - $f_0(980) \rightarrow K^+K^-$ also contributes
  - Large source of error
- Resonances in the Dalitz plot:
  - Contributions to yields depends on selection criteria [1]
    - $(K^+K^-)_\phi$ Mass Window
    - Resolution
    - Angular Distribution



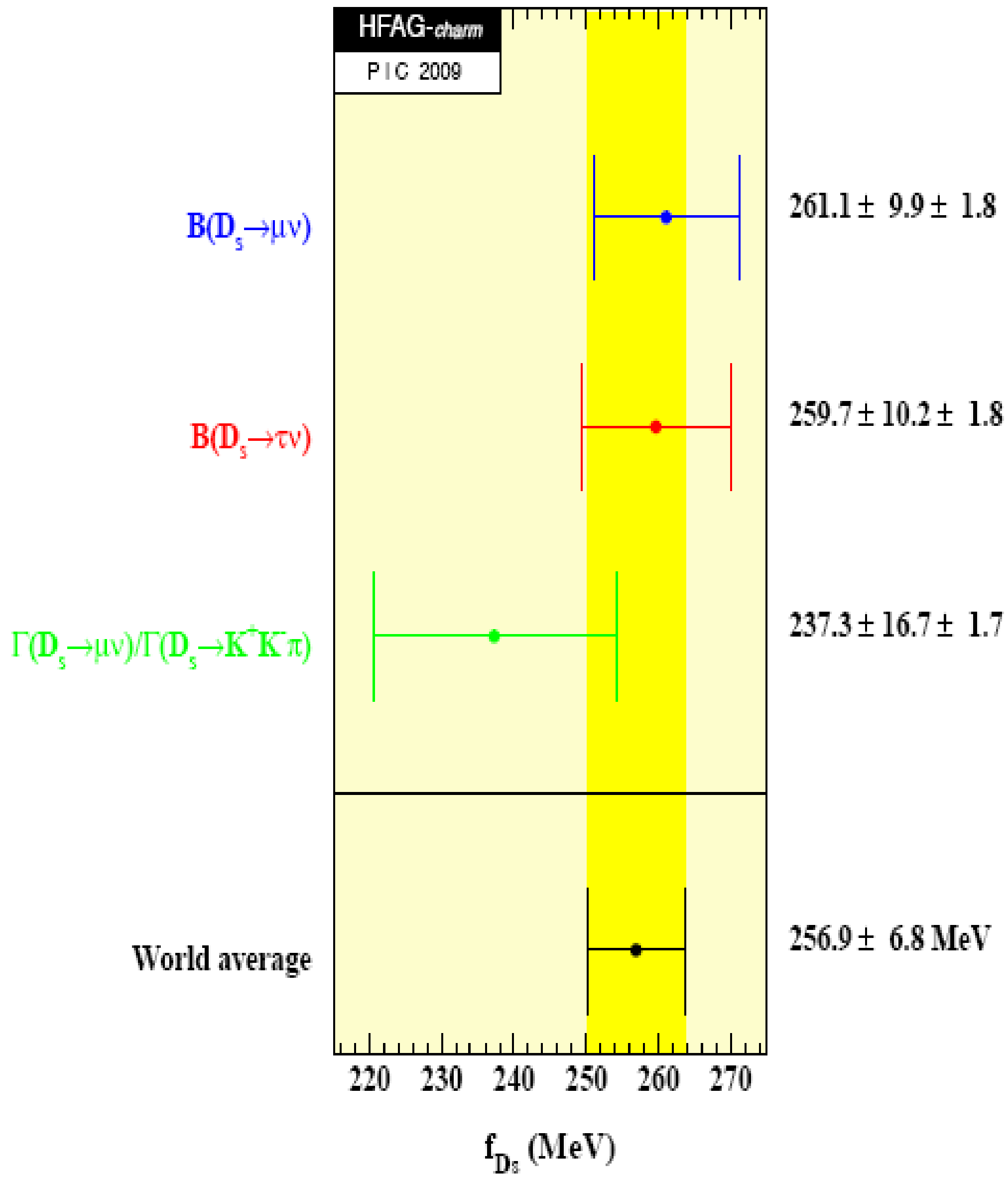
$(K^+K^-)_\phi$ Mass Window	$B(D_s \rightarrow KK\pi)$ (%)
ΔM = 5 MeV	1.69±0.08±0.06
ΔM = 10 MeV	1.99±0.10±0.05
ΔM = 15 MeV	2.14±0.10±0.05
ΔM = 20 MeV	2.24±0.11±0.06



[1] J.P. Alexander et al., (CLEO Collaboration), Phys. Rev. Lett. 100, 161804 (2008)

HFAG Average

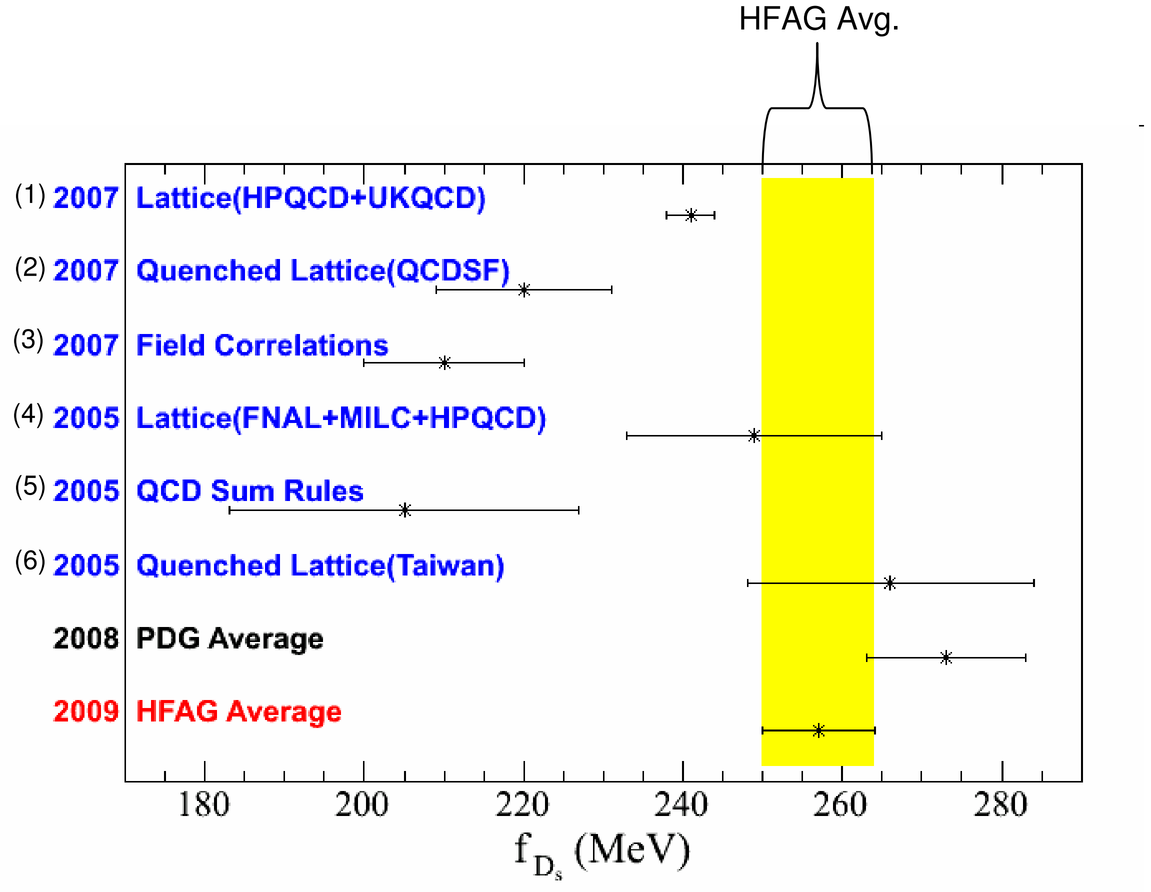
- $D_s \to \mu\nu$:
  - 2-CLEO-c (2007,2009)
  - Belle (2008)
- $D_s \to \tau\nu$:
  - 4-CLEO-c (2007-2009)
  - ALEPH (2002)
  - OPAL (2001)
  - L3 (1997)
- $D_s \to \mu\nu / D_s \to KK\pi$: $|M_{K+K-} - M_\phi| < 5.5$ MeV
  - BaBar (2007)
  - ALEPH (2002)
  - BEATRICE (2000)
  - CLEO (1998)



http://ww.slac.stanford.edu/xorg/hfag/charm/PIC09/f_ds/results.html

f_{D_s} - Theoretical Predictions

- Unquenched Lattice Calc. [1]
  - Includes u,d,s sea
  - f_{D_s} = 241 ± 3 MeV
- Small Error on Theory
  - Motivates Improve Exp.
- PDG Experimental Average
  - 273 ± 10 MeV
- HFAG Average
  - 256.9 ± 6.8 MeV



(1) E. Follana *et al.*, (HPQCD and UKQCD Collabs.), Phys. Rev. Lett. 100, 062002(2008)
(2) A. Ali Khan *et al.*, (QCDSF Collaboation), Phys. Lett. B **652** 150 (2007).
(3) A.M. Badalian *et al.*, Phys. Rev. D **75**, 116001 (2007).
(4) C. Aubin *et al.*, (MILC Collaboration), Phys. Rev. Lett. **95**, 122002 (2005).
(5) J. Bordes, J. Penarrocha, and K. Schilcher, JHEP **0511**, 014 (2005).
(6) T.W. Chiu *et al.*, Phys. Lett. B **624**, 31 (2005).

What Will Be Measured?

Measure $B(D_s^+ \to \tau^+ \nu_\tau)$ via $\tau^+ \to e^+ \nu_e \bar{\nu}_\tau$
Use $K_S K$ instead of $\phi\pi$ for Normalization
$D_s^+ \to K_S K^+$ (1.49±0.09)% (corrected for $K_S \to \pi^0\pi^0$)
Error on $K_S K$ down from 18% to 6% (CLEO-c [1])

⇒Can determine the $B(D_s^+ \to \tau^+ \nu_\tau)$ by using the known $B(D_s^+ \to K_S K^+)$

$$B\left(D_s^+ \to \tau^+ \nu_\tau\right) \Rightarrow \frac{N_{\tau\nu}}{N_{K_s K}} \frac{B(D_s^+ \to K_S K^+)}{B(\tau^+ \to e^+ \nu_e \bar{\nu}_\tau)}$$

Can then extract f_{D_s} using:

$$f_{D_s} = \sqrt{\frac{\Gamma\left(D_s^+ \to \tau^+ \nu_\tau\right)}{\frac{G_F^2}{8\pi}\left(\frac{m_\tau}{m_{D_s}}\right)^2 \left(1 - \frac{m_\tau^2}{m_{D_s}^2}\right)^2 \left|V_{cs}\right|^2}}$$

[1] J.P. Alexander et al., (CLEO Collaboration), Phys. Rev. Lett. 100, 161804 (2008)

Signal Event Selection

- **Blind Analysis**
  - **427 fb^{-1} Runs 1-6 On-Peak Data**
- **$D_s^* \to D_s\gamma$, $D_s \to \tau\nu$ from continuum $c\bar{c}$ events**
- **Charm Tagged**
- **Fully Reconstructed Event**
- **Yield Extraction:**
  - **2-D Fit**
    - **D_s Recoil Mass**
    - **Extra Energy of the Event**

$$e^+e^- \to c\bar{c}$$

$$c\bar{c} \to D_{Tag}\, D_s^*\, K\, X$$

Pions From Fragmentation

$$D_s^* \to D_s\gamma$$

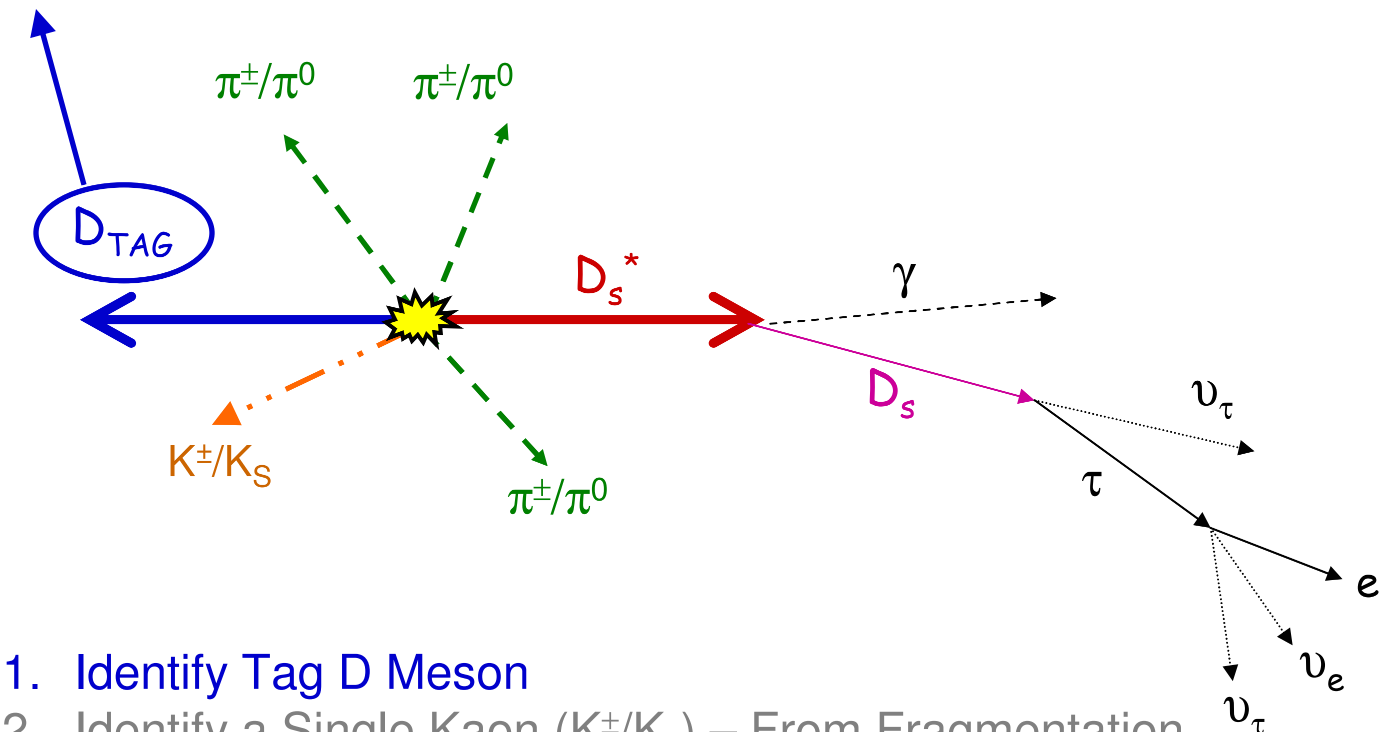
$$D_s \to \tau\nu_\tau$$

$$\tau \to e\,\nu_e\nu_\tau$$

Signal Event Selection

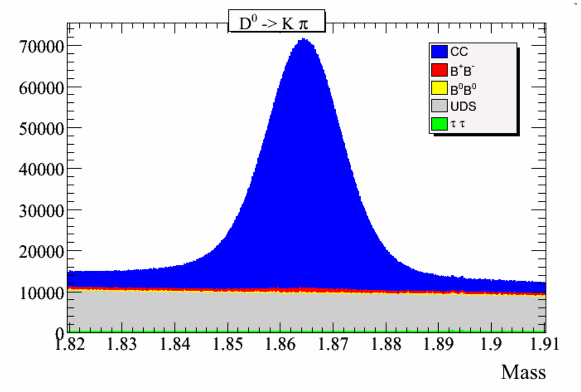
$$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau$$

Tag D Meson (D^0,$D^\pm$) – Reconstructed From Multiple Decay Modes



1. Identify Tag D Meson
2. Identify a Single Kaon ($K^\pm/K_s$) – From Fragmentation
3. Identify any Pions ($\pi^\pm/\pi^0$) – From Fragmentation
4. Identify the “Signal” Photon from $D_s^* \rightarrow D_s\ \gamma$

Charm Tagging Decay Modes



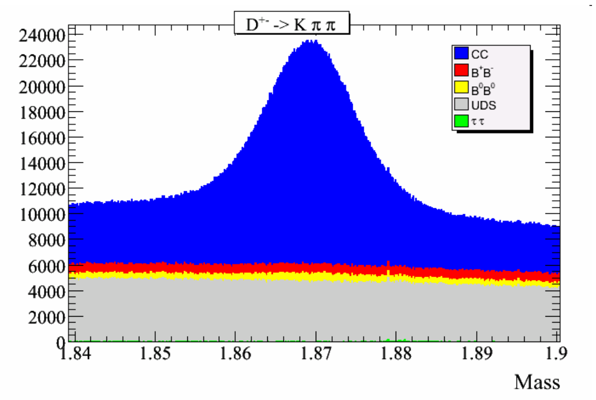


Table 6: Charm Tag Modes

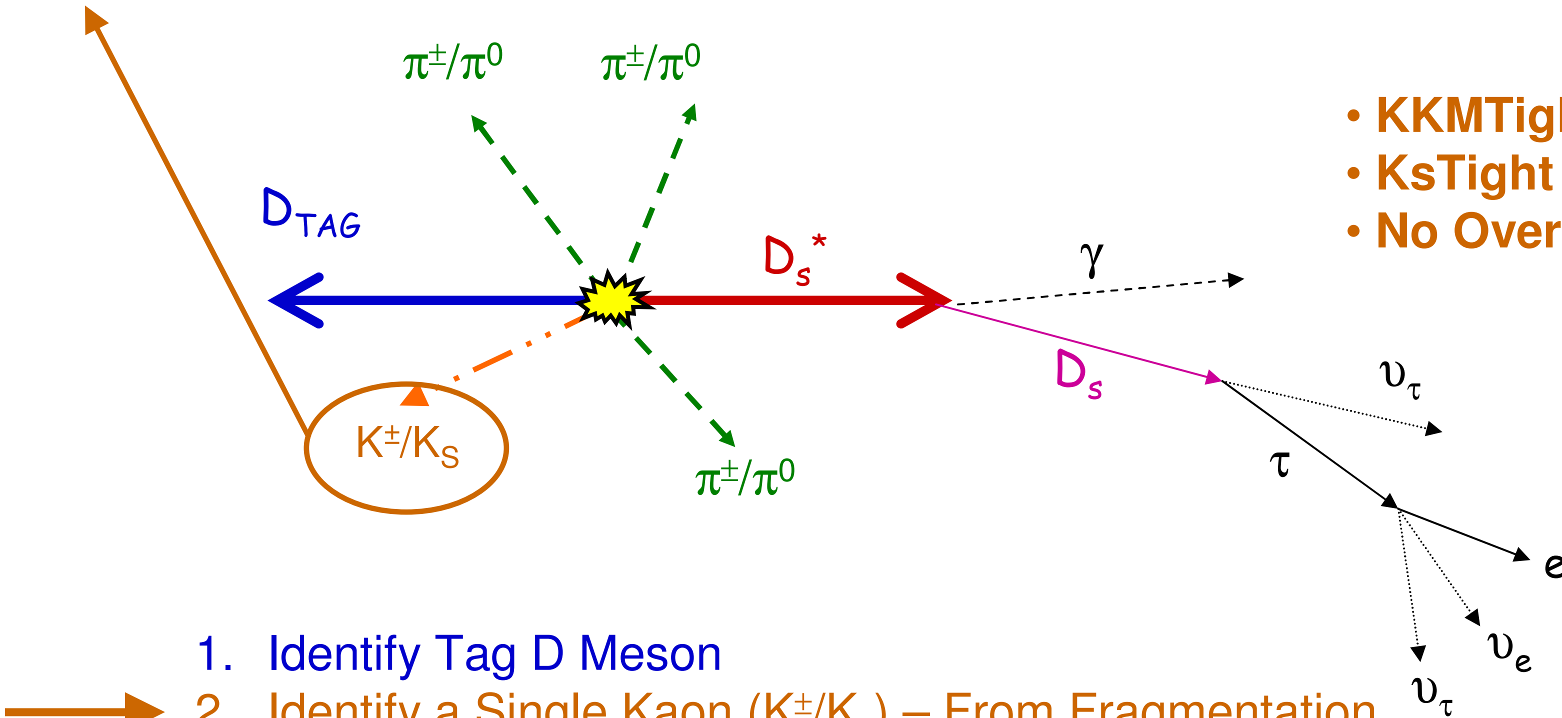
Index	Decay Mode	Branching Fraction(%)
1	$D^0 \to K\pi$	3.80±0.07
2	$D^0 \to K\pi\pi^0$	14.1±0.5
3	$D^0 \to K\pi\pi\pi$	7.72±0.28
4	$D^0 \to K\pi\pi\pi\pi^0$	4.2±0.4
5	$D^0 \to K^0_S\pi\pi$	2.90±0.19
6	$D^0 \to K^0_S\pi\pi\pi^0$	5.4±0.6
7	$D^+ \to K\pi\pi$	9.51±0.34
8	$D^+ \to K\pi\pi\pi^0$	5.5±2.7
9	$D^+ \to K^0_S\pi$	1.47±0.06
10	$D^+ \to K^0_S\pi\pi^0$	7.0±0.5
11	$D^+ \to K^0_S\pi\pi\pi$	3.11±0.21

- Using the cleanest reconstructed decay modes.
- Using D modes that have the largest branching fractions
- Reconstructed Using CharmTagTools
- p* > 2.35 GeV – Reduce BB background

Signal Event Selection

$$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \overline{\nu}_\tau$$

Single Kaon from Fragmentation – Flavor Balancing (s-quark)

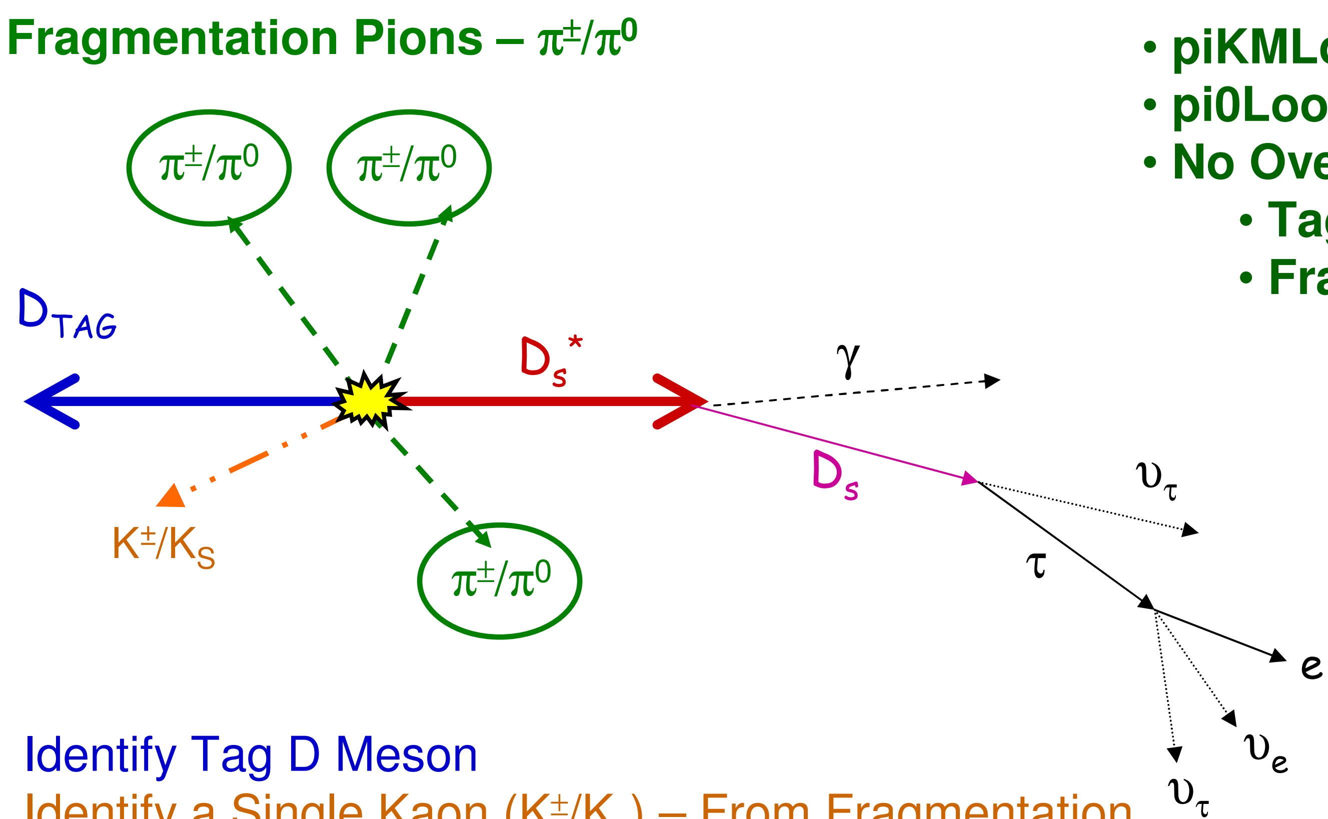


- **KKMTight**
- **KsTight**
- **No Overlap w/ Tag**

1. Identify Tag D Meson
2. Identify a Single Kaon ($K^\pm/K_s$) – From Fragmentation
3. Identify any Pions ($\pi^\pm/\pi^0$) – From Fragmentation
4. Identify the "Signal" Photon from $D_s^* \rightarrow D_s\, \gamma$

Signal Event Selection

$$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \overline{\nu}_\tau$$



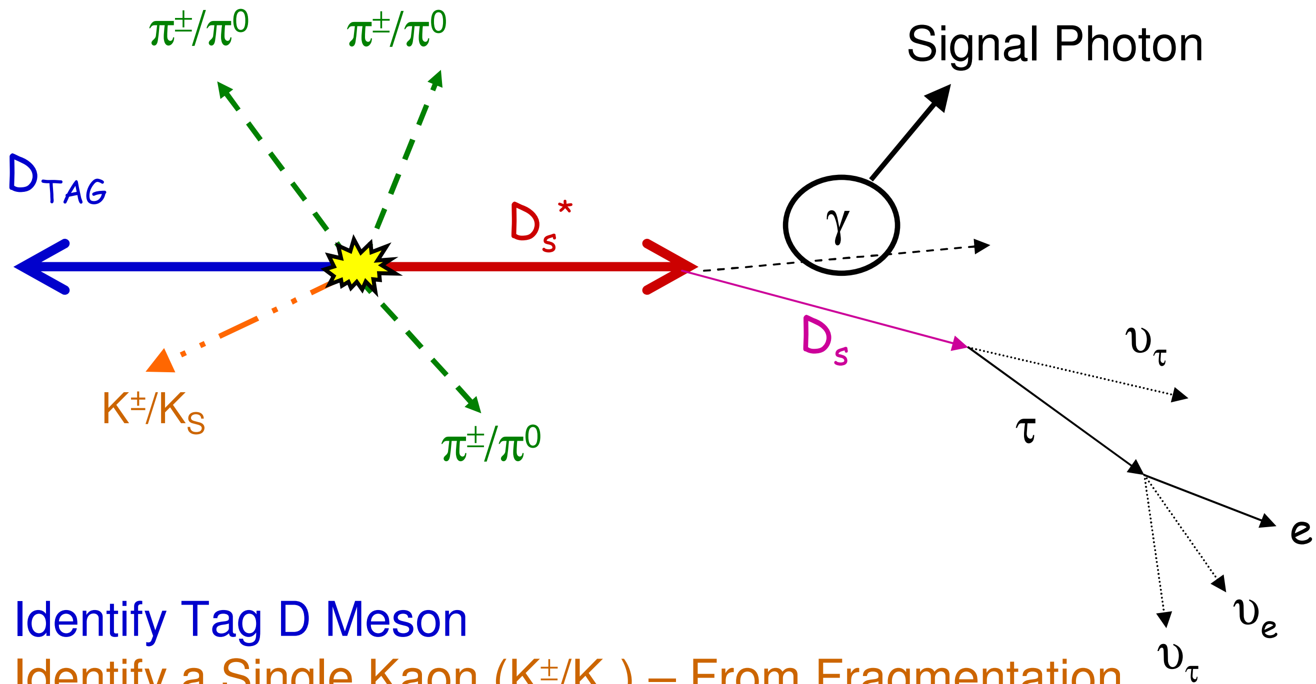
- piKMLoose
- pi0Loose
- No Overlap w/
  - Tag
  - Frag. Kaon

1. Identify Tag D Meson
2. Identify a Single Kaon ($K^\pm/K_s$) – From Fragmentation
3. Identify any Pions ($\pi^\pm/\pi^0$) – From Fragmentation
4. Identify the “Signal” Photon from $D_s^* \rightarrow D_s \gamma$

Signal Event Selection

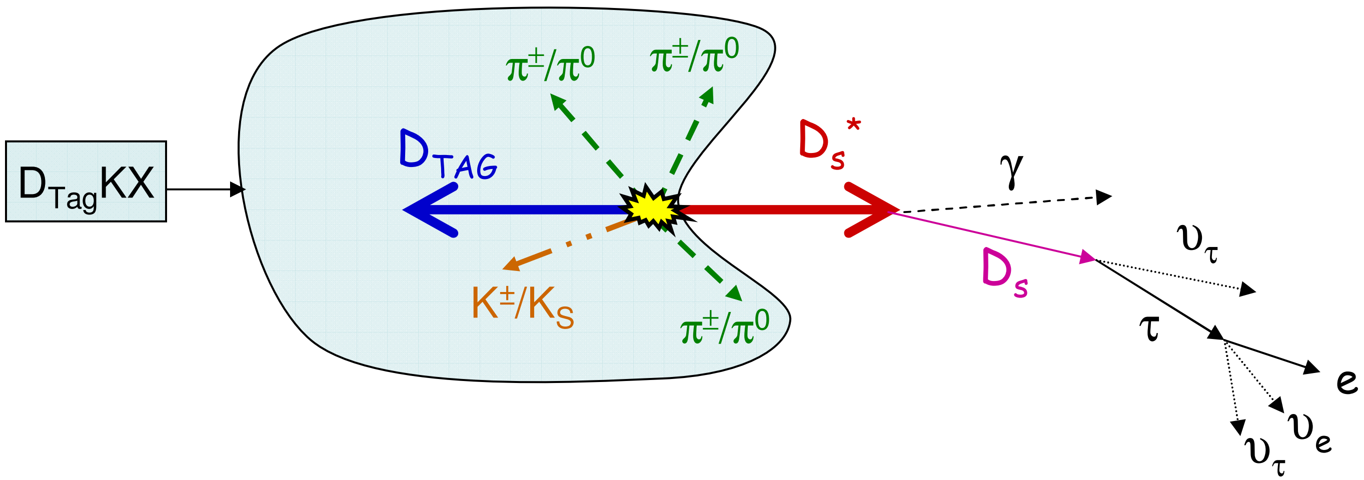
$$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \overline{\nu}_\tau$$

- **GoodPhotonLoose**
- **E_γ > 100 MeV**
- **No Overlap w/**
  - **Tag, π^0**



1. Identify Tag D Meson
2. Identify a Single Kaon ($K^\pm/K_s$) – From Fragmentation
3. Identify any Pions ($\pi^\pm/\pi^0$) – From Fragmentation
4. Identify the “Signal” Photon from $D_s^* \rightarrow D_s\ \gamma$

Event Reconstruction
Recoil Masses



A D_s^* candidate is built from the particles recoiling against it:

- D_{Tag}
- Fragmentation Kaon
- Fragmentation Pions – "X"
- **Mass Constrained Fit**
- **200 MeV Mass Window**

$$\mathbf{D_s^* = Beam - (D_{Tag} + K + X)}$$

The D_s^* candidate is combined with a "signal" photon candidate to create a D_s candidate. Correctly reconstructed events should Peak at the D_s Mass (1.968 GeV).

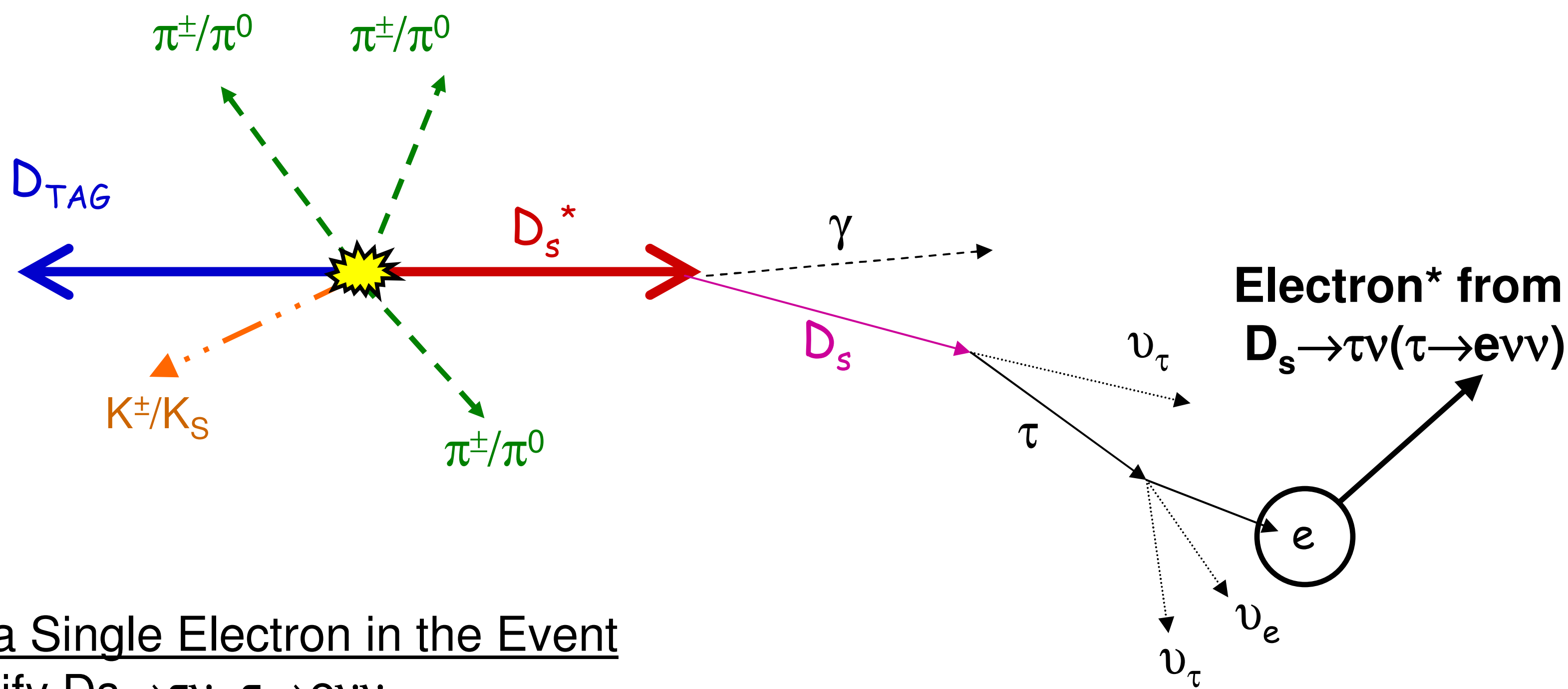
$$\mathbf{D_s = M_{Recoil} = D_s^* - \gamma}$$

$$\textbf{Extra Energy} = \sum \left(\begin{array}{c} \text{Any Photons Not Associated With Any of the} \\ \text{Reconstructed Tracks, or the Signal Photon} \end{array} \right)$$

Signal Event Selection

$$D_s^+ \to \tau^+ \nu_\tau : \tau^+ \to e^+ \nu_e \overline{\nu}_\tau$$

*Also Measuring $D_s \to K_S K$
⇒electron replaced by $K_S K$ pair



Identify a Single Electron in the Event

- Identify $Ds \to \tau\nu$, $\tau \to e\nu\nu$
- eKMVeryLoose
- No overlap w/ gammaConversionDefault
- >4 SVT Hits
- ≥12 DCH Hits

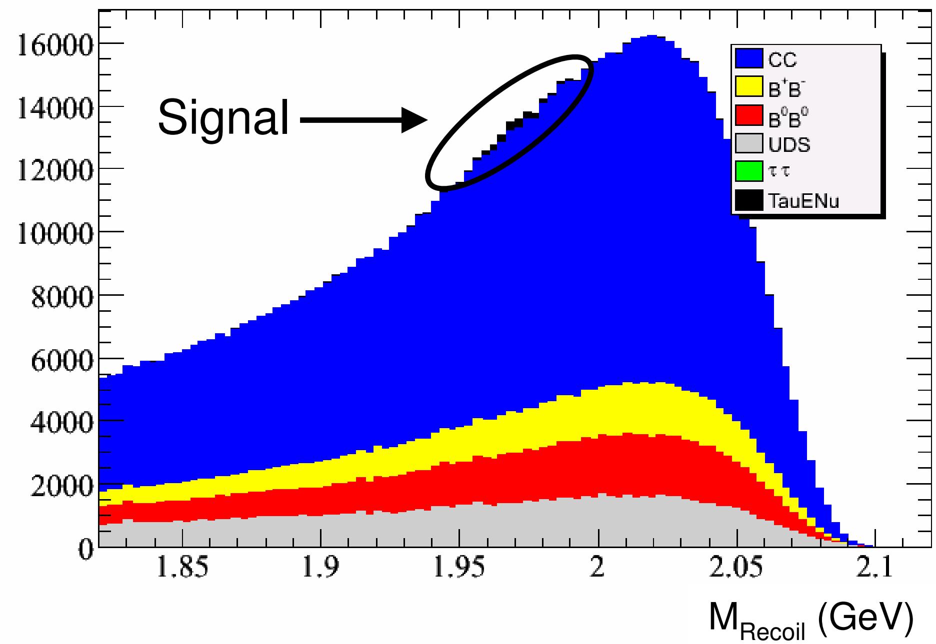
D_s Recoil Mass Spectrum
Signal Extraction

Many variables were investigated that would extract the signal. The largest discriminating variables are:

- D_s^* Kinematic Fit Probability
- CM Momentum of the D_s

Run 1-6 Monte Carlo

(Normalized to 427 fb^{-1})



- **Optimization Method for Cut Variables**
  - Optimized on MC
  - Repeated for Multiple D_s Mass Windows
    - 10-200MeV
  - Both Methods Return Similar Results

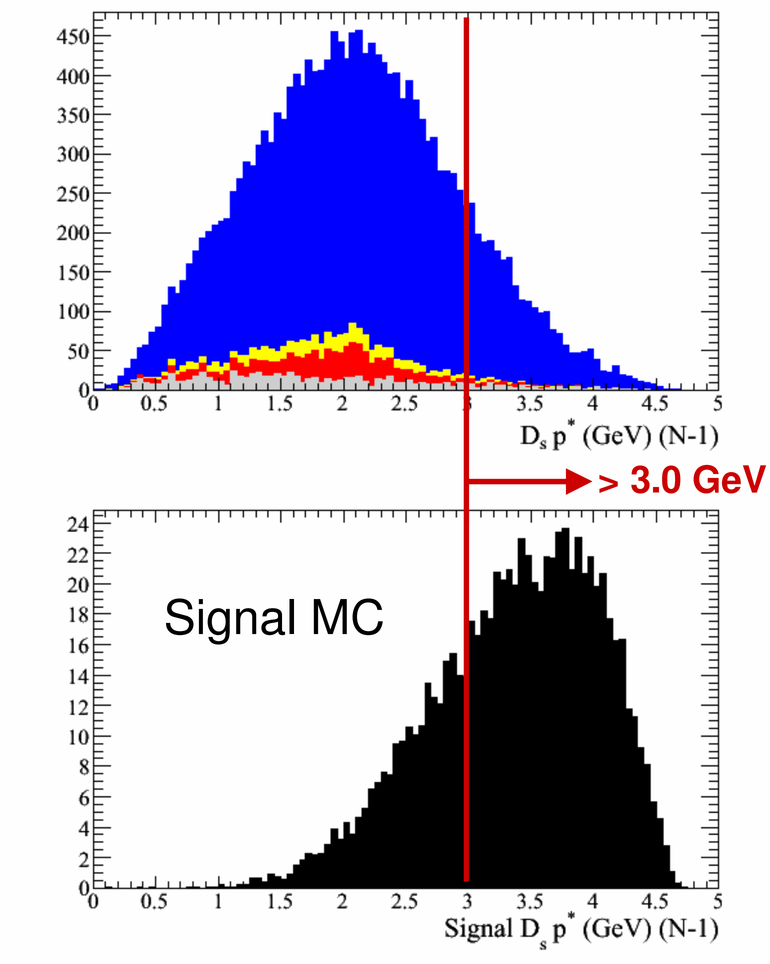
1 – Optimization Package: SprBumpHunter
  - Searches for rectangular region w/ globally optimized FOM $(S/\sqrt{(S+B)})$
  - Training/Validation Samples
    - 20:80 50:50 80:20

2 - Iterative Optimization
  - Randomly/Progressively Choose and Optimize Cut Variables according to FOM

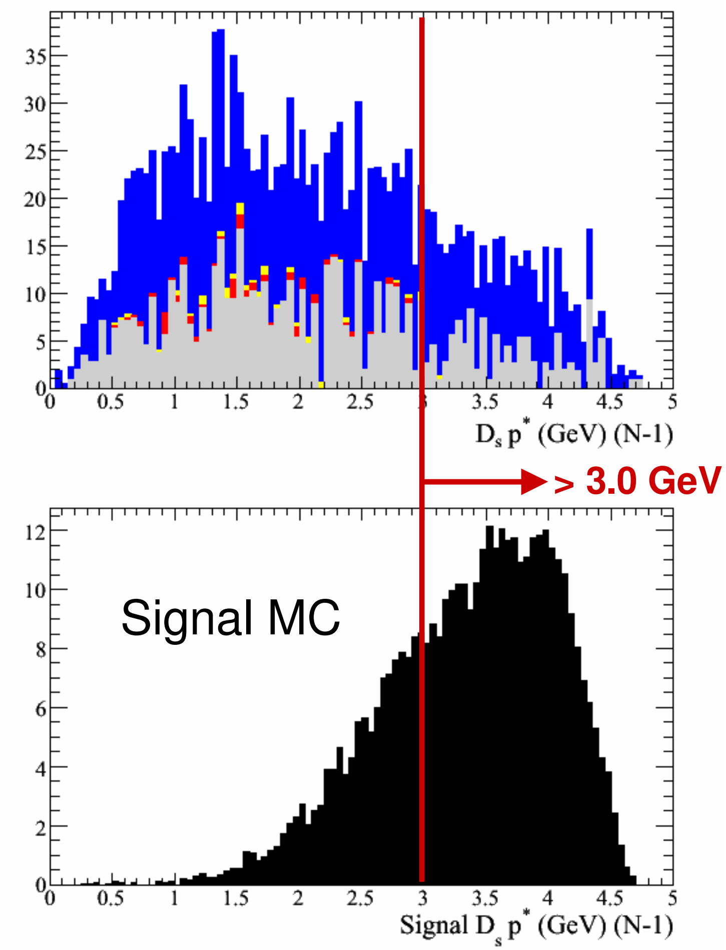
Monte Carlo - Event Selection Variables
Recoil D_s CM Momentum

ccbar Monte Carlo | B^+B^- Monte Carlo
uds Monte Carlo | B^0B^0 Monte Carlo

$$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \overline{\nu}_\tau$$



$$D_s^+ \rightarrow K_S K^+ : K_S \rightarrow \pi^+ \pi^-$$

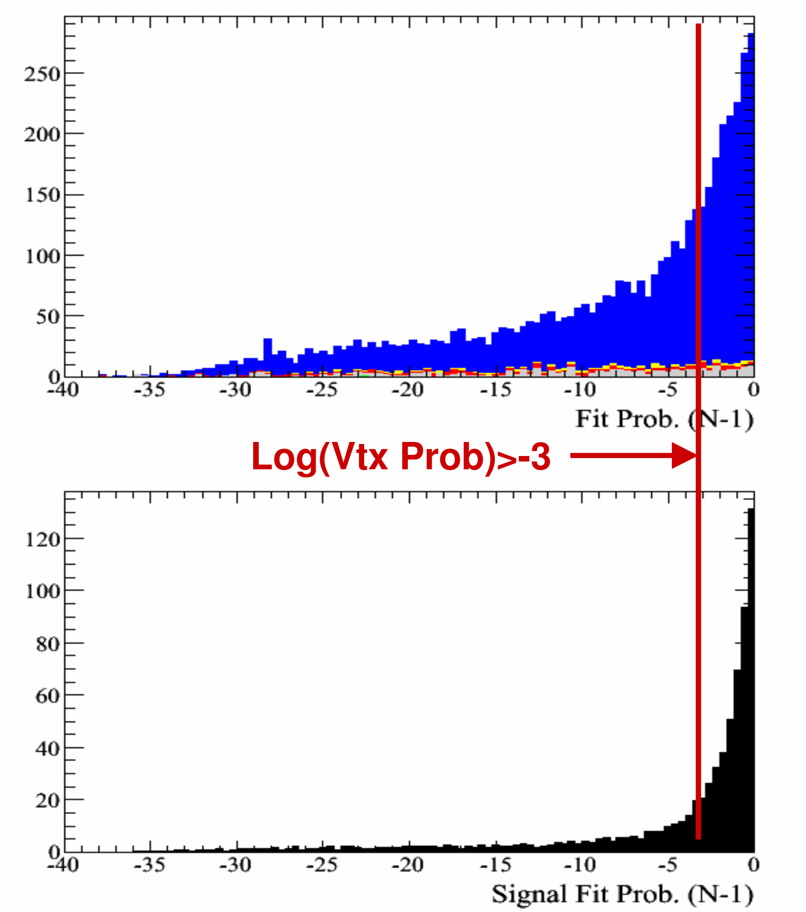


Monte Carlo - Event Selection Variables
Recoil D_s^* Kinematic Fit Probability

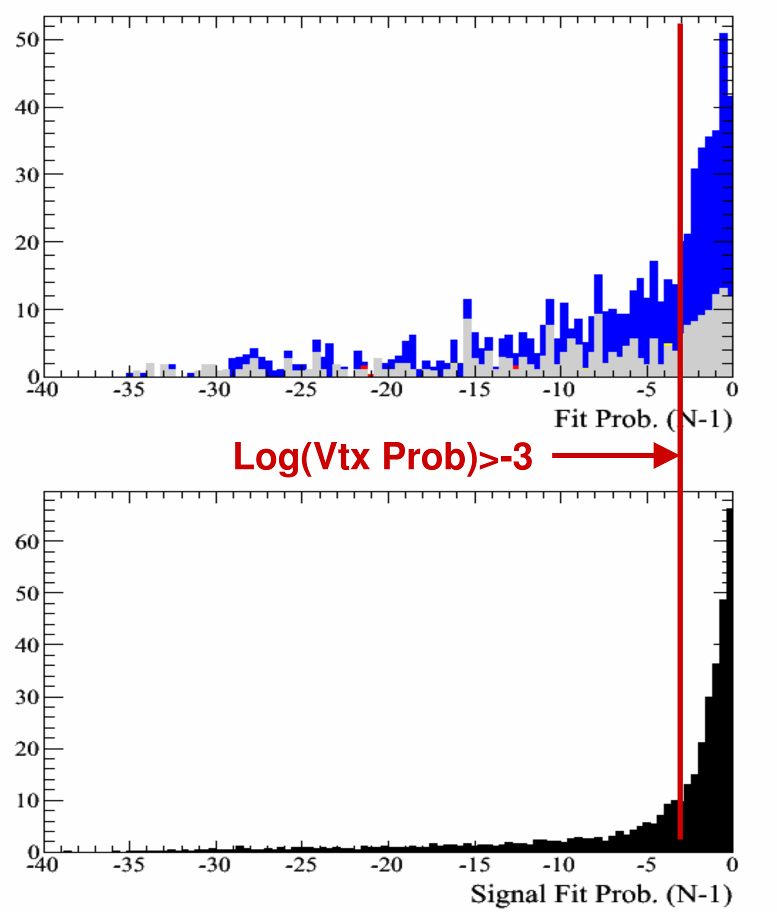
ccbar Monte Carlo — B^+B^- Monte Carlo

uds Monte Carlo — B^0B^0 Monte Carlo

$$D_s^+ \to \tau^+\nu_\tau : \tau^+ \to e^+\nu_e\bar{\nu}_\tau$$

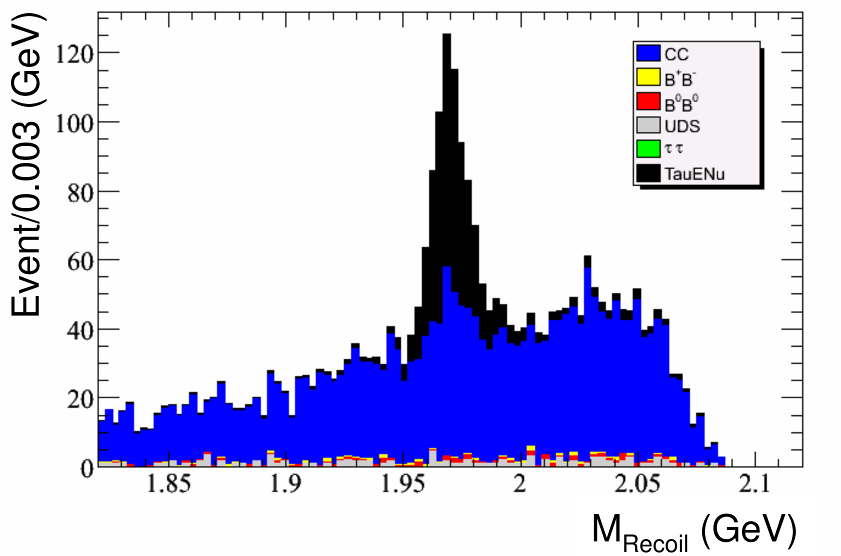


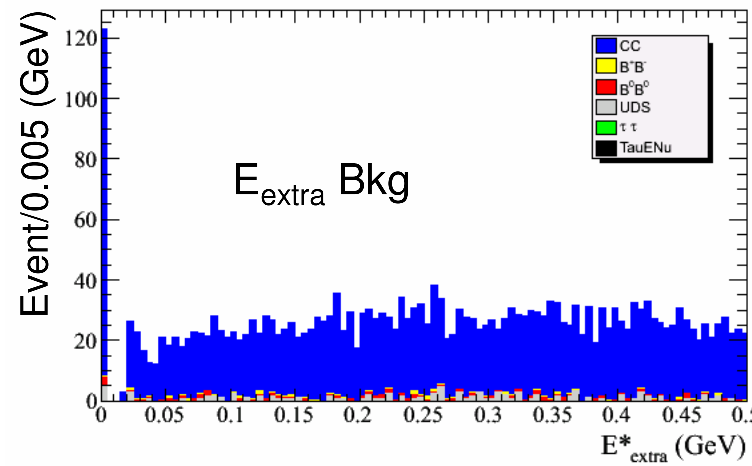
$$D_s^+ \to K_S K^+ : K_S \to \pi^+\pi^-$$

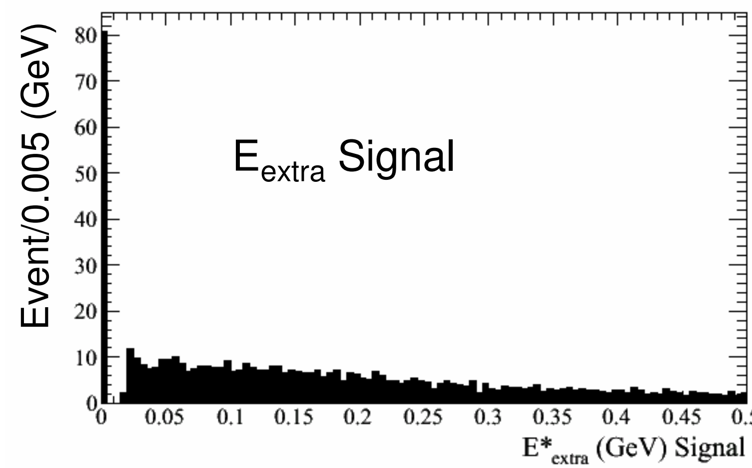


Reconstructed D_s Mass and Extra Energy
Monte Carlo - Normalized to 427 fb^{-1}

$$D_s^+ \to \tau^+ \nu_\tau : \tau^+ \to e^+ \nu_e \bar{\nu}_\tau$$



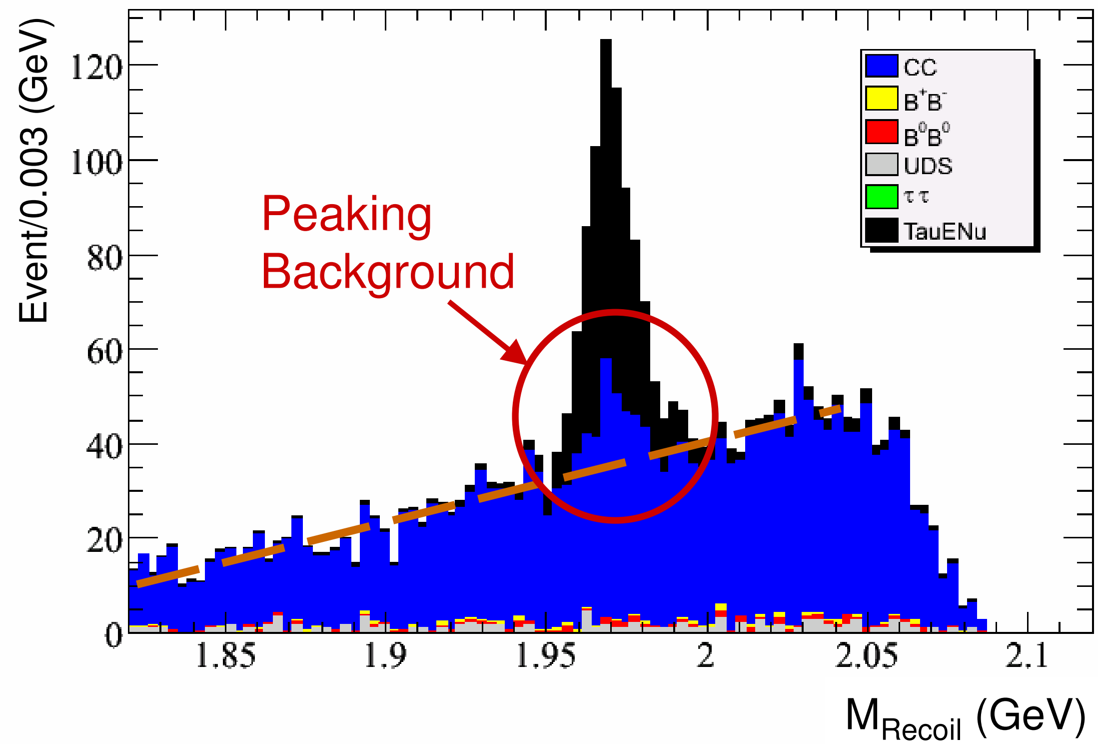




Expected MC Yields:
Total Signal = 566
Total Background = 2145
Total Peak Background = 385

Reconstructed D_s Mass and Extra Energy Monte Carlo - Normalized to 427 fb^{-1}

$$D_s^+ \to \tau^+\nu_\tau : \tau^+ \to e^+\nu_e\bar{\nu}_\tau$$

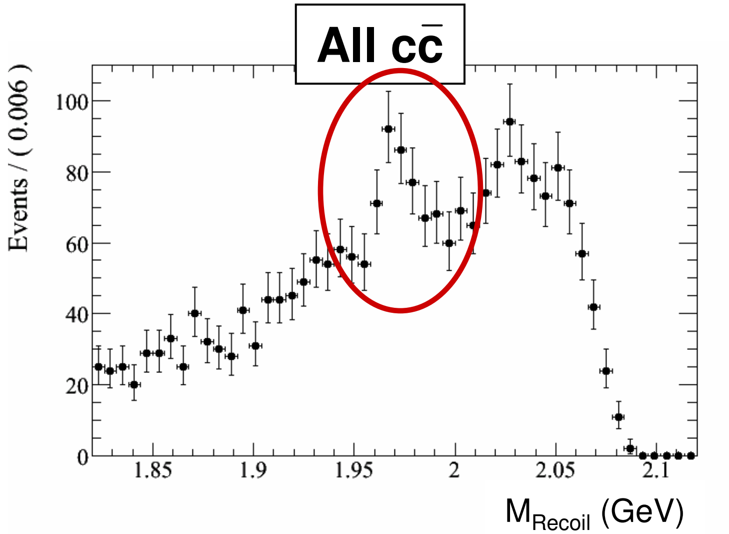


Clearly a peaking background component from cc events

What are the modes?

What are the expected yields?

Peaking Background Modes
Monte Carlo – Normalized to 427 fb^{-1}

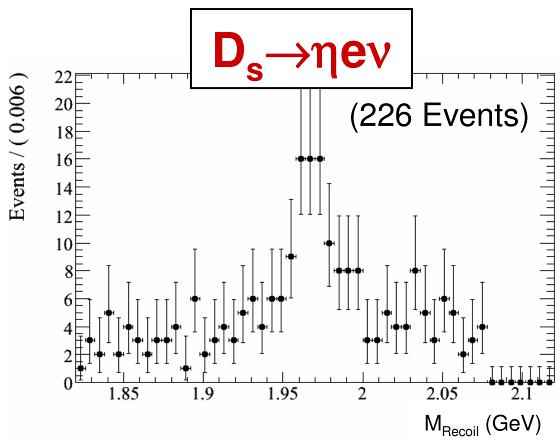


Dominant Modes
In 10MeV Mass Window Around the D_s Mass in cc sample:

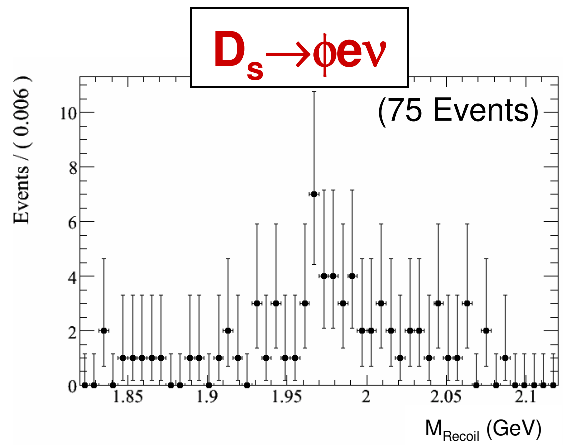
D^0
- $K\,e\,\nu$
- $K^*\,e\,\nu$

D^+
- $K^0\,e\,\nu$
- $K^{*0}\,e\,\nu$

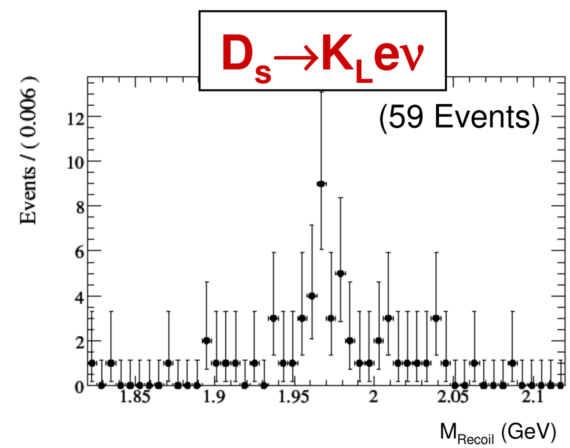
D_s
- **$\eta\,e\,\nu$**
- $\eta'\,e\,\nu$
- **$\phi\,e\,\nu$**
- **$K_L\,e\,\nu$**



BF = (2.9±0.6)%



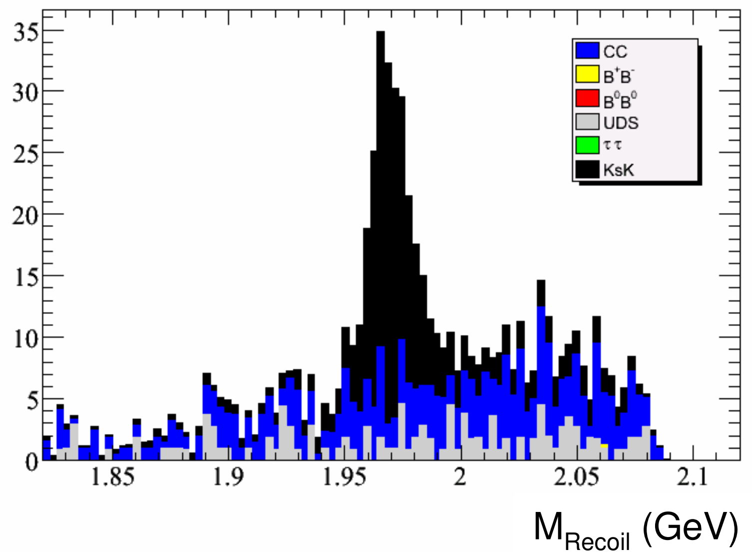
BF = (2.36±0.26)%

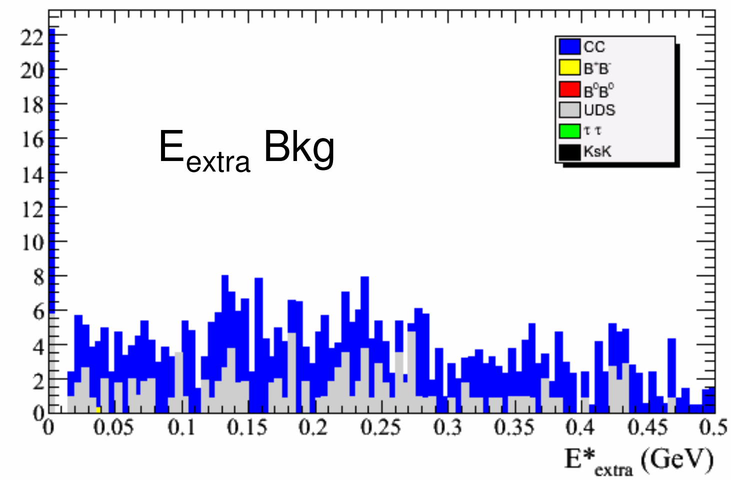


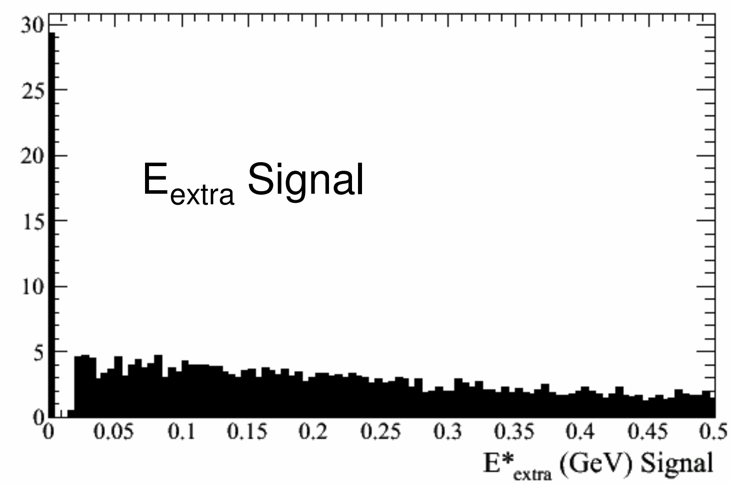
BF = (0.19±0.05)%

Reconstructed D_s Mass and Extra Energy
Monte Carlo - Normalized to 427 fb^{-1}

$$D_s^+ \rightarrow K_S K^+ : K_S \rightarrow \pi^+ \pi^-$$





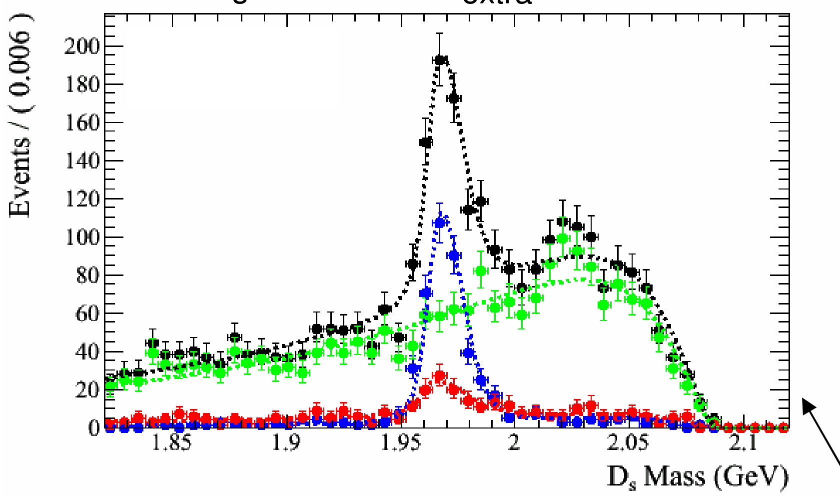


MC Yields:
Total Signal = 289
Total Background = 380

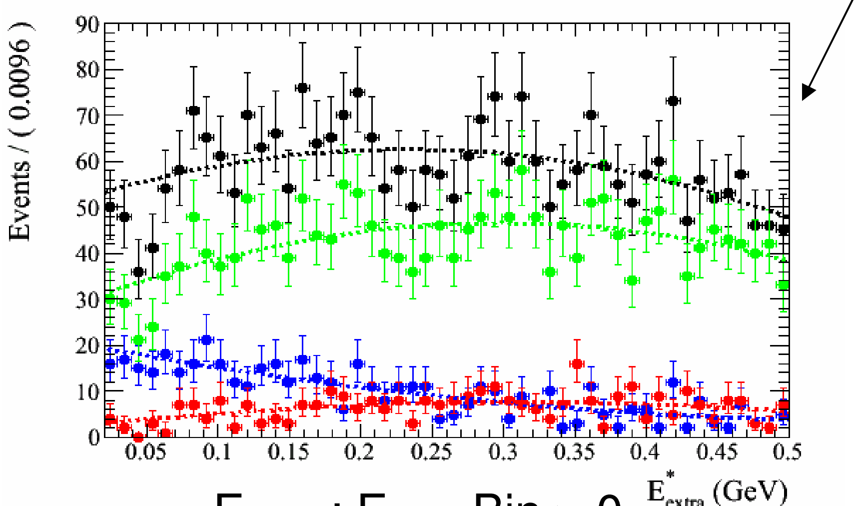
Toy Monte Carlo Study

All
Signal
Background
Peaking Backgound

D_s Mass : E_{extra} Bin > 0



2D - Fit



E_{extra} : E_{extra} Bin > 0

Signal – PDF's

- D_s Mass – Cruijff* + Novosibirsk
- E_{extra} - Poly

Background – PDF's

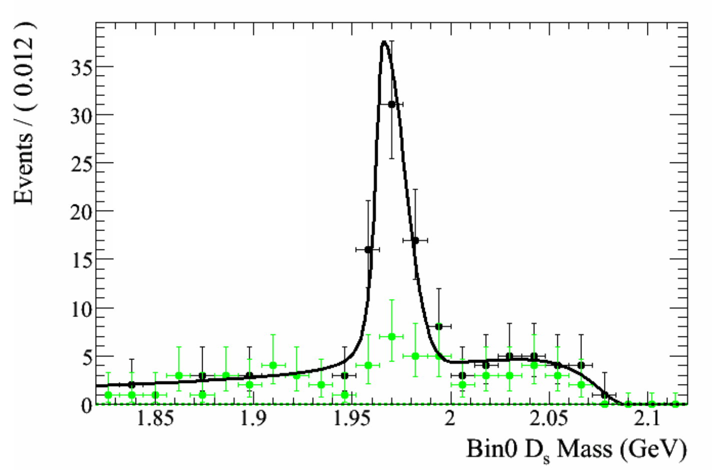
- D_s Mass - Novosibirsk
- E^{extra} - Novosibirsk

Peaking Background – PDF's

- D_s Mass – Cruijff* + Novosibirsk
- E_{extra} - Poly

J. Cruijff

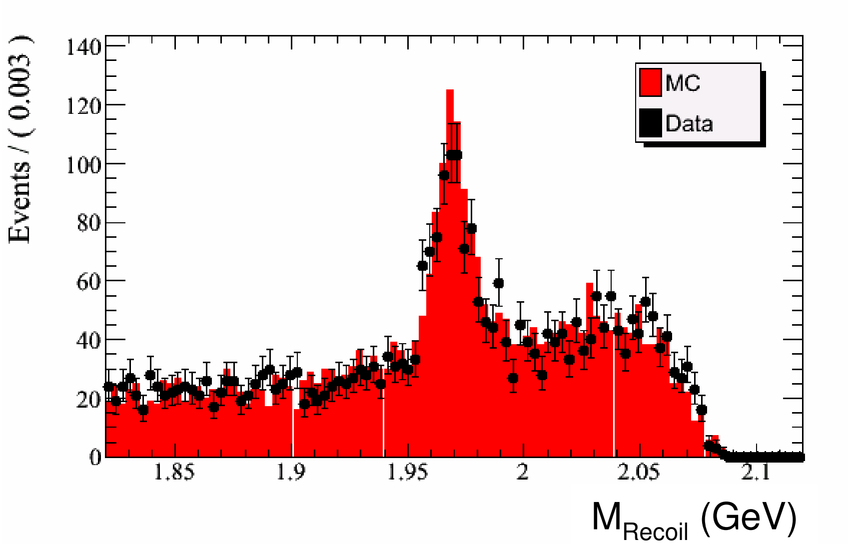
D_s Mass : E_{extra} Bin = 0

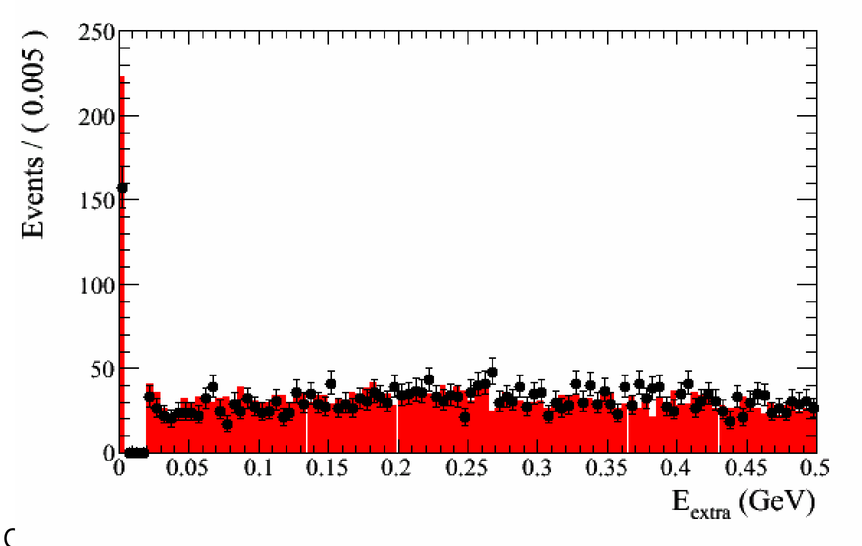


*Cruijff PDF – Crystal Ball w/ Separate Left and Right Sides

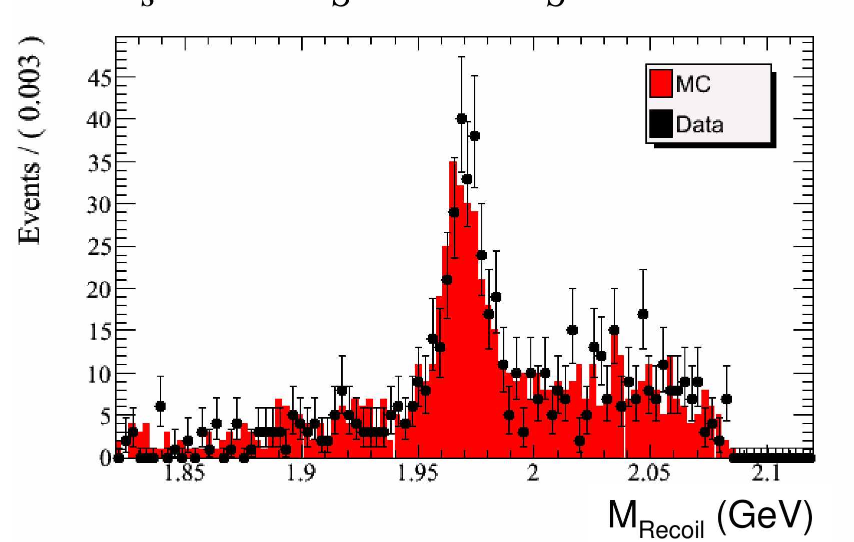
Data vs MC - D_s Recoil Mass & Extra Energy
Runs 1-6 On-Peak 427 fb^{-1}

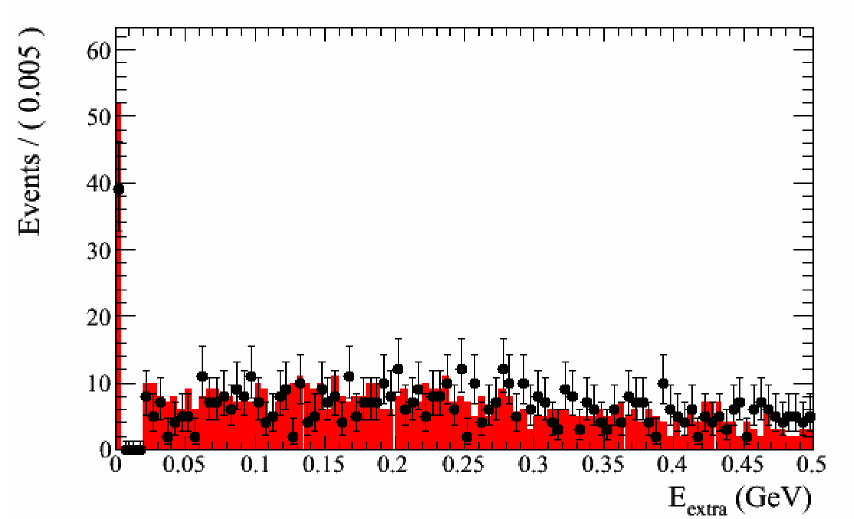
$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau$





$D_s^+ \rightarrow K_S K^+ : K_S \rightarrow \pi^+ \pi^-$

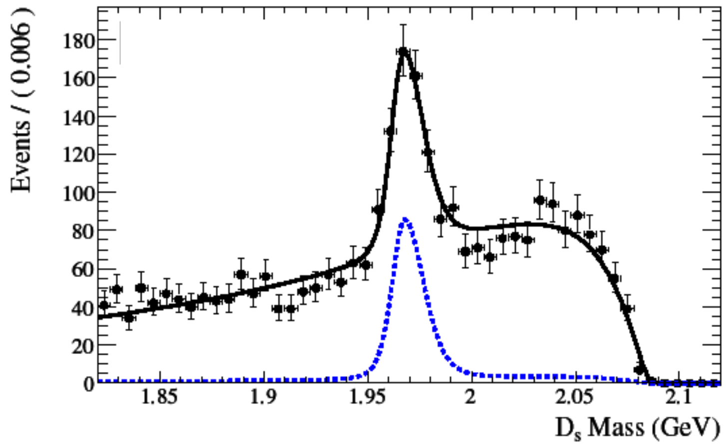


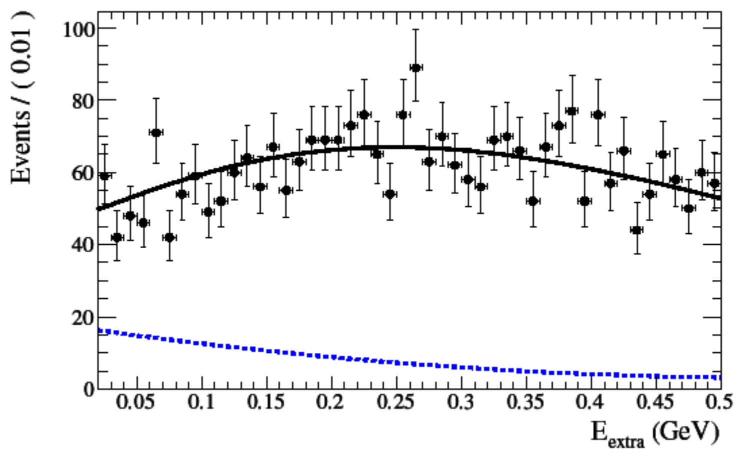


Fits to Data

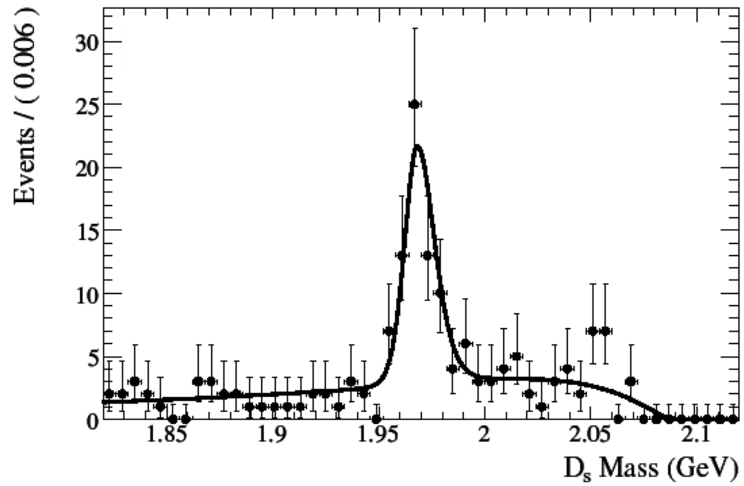
$$D_s^+ \rightarrow \tau^+ \nu_\tau : \tau^+ \rightarrow e^+ \nu_e \overline{\nu}_\tau$$

D_s Mass : E_{extra} Bin > 0





D_s Mass : E_{extra} Bin = 0



The solid curve is the fit to data.
The dashed curve is the signal contribution.

Total Yields:

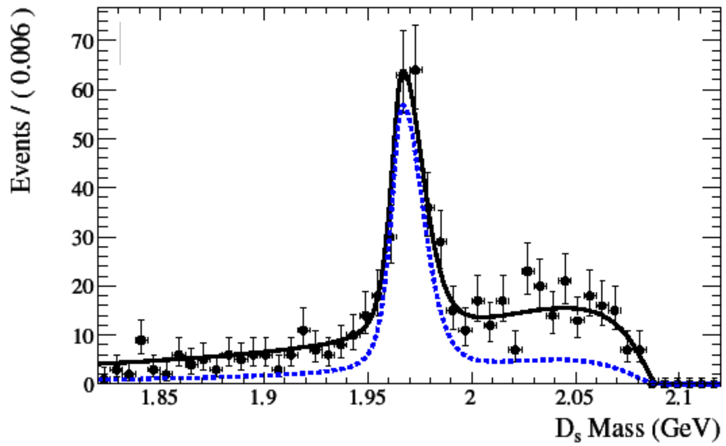
$N_{Sig} = 448 \pm 36$

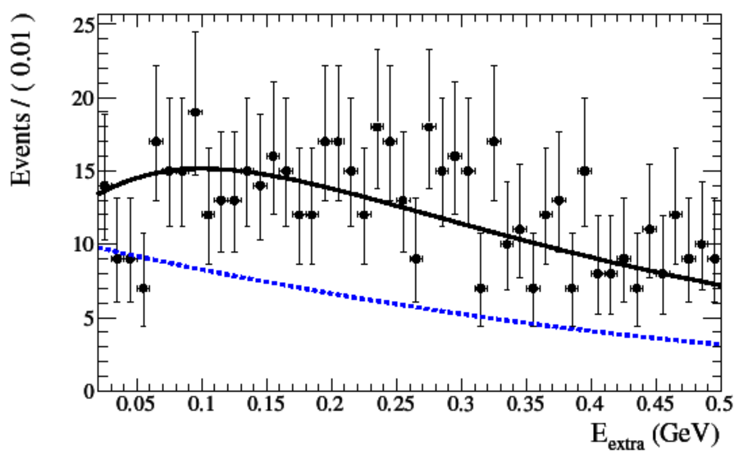
$N_{Bkg} = 2264 \pm 58$

Fits to Data

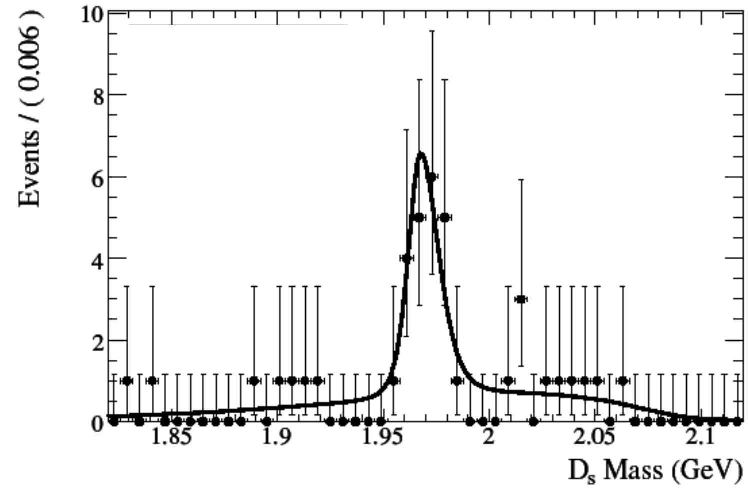
$$D_s^+ \to K_S K^+ : K_S \to \pi^+ \pi^-$$

D_s Mass : E_{extra} Bin > 0





D_s Mass : E_{extra} Bin = 0



The solid curve is the fit to data.
The dashed curve is the signal contribution.

Total Yields:

$N_{Sig} = 332.5 \pm 27.7$

$N_{Bkg} = 305.5 \pm 27.5$

Systematics Uncertainties

$$\frac{B(D_s \to \tau\nu_\tau)}{B(D_s \to K_s K)} \Rightarrow \frac{B(K_s \to \pi^+\pi^-)}{B(\tau \to e\nu_e\nu_\tau)} \frac{N_{\tau\nu}}{N_{K_s K}} \frac{\varepsilon^{K_s K}_{Cuts}}{\varepsilon^{e}_{Cuts}} \frac{\varepsilon^{K_s K}_{PID}}{\varepsilon^{e}_{PID}} \frac{\varepsilon^{K_s K}_{Trk}}{\varepsilon^{e}_{Trk}}$$

Sources of Systematic Errors:

Branching Fraction Errors

World Averages From PDG

Tracking Efficiency: MC corrected to Match Data

Cut Variables Used (MC vs Data) vs Mode

Particle Identification: Is the Electron a True Electron…

PDF Shapes: What effects do the PDF parameters have on NSig

Source	Value
$B(D_s \to K_s K)$	**6.0%**
$B(K_s \to \pi\pi)$	**0.1%**
$B(\tau \to e\nu\nu)$	**0.3%**
Selection Variables	**3.0%**
Particle Identification	**0.82%**
Tracking	**2×0.34%**
$\tau\nu$ PDF Variables	**+7.69% -4.73%**
$K_s K$ PDF Variables	**+4.86% -0.63%**

The uncertainty on the PDF variables for $D_s \to \tau\nu_\tau$ dominate, followed by the uncertainty on the $D_s \to K_s K$ branching fraction. The uncertainties on the tracking and $K_s \to \pi\pi / \tau \to e\nu_e\nu_\tau$ are negligible.

Results

$B(D_s \to \tau\nu) = (4.54 \pm 0.53 \pm 0.40 \pm 0.28)$ %

$f_{D_s} = (233.6 \pm 13.6 \pm 10.4 \pm 7.1)$ MeV
(Tot. Error = 7.9%)

Errors: Statistical ± BaBar Systematic ± PDG Systematic

Results from $D_s \to \mu\nu_\mu$ measurements:

CLEO-c: (257.6±10.3±4.3) MeV
(Tot. Error = 4.3%)

Belle: (275±16±12) MeV
(Tot. Error = 7.3%)

Results from $D_s \to \tau\nu_\tau$ measurements:

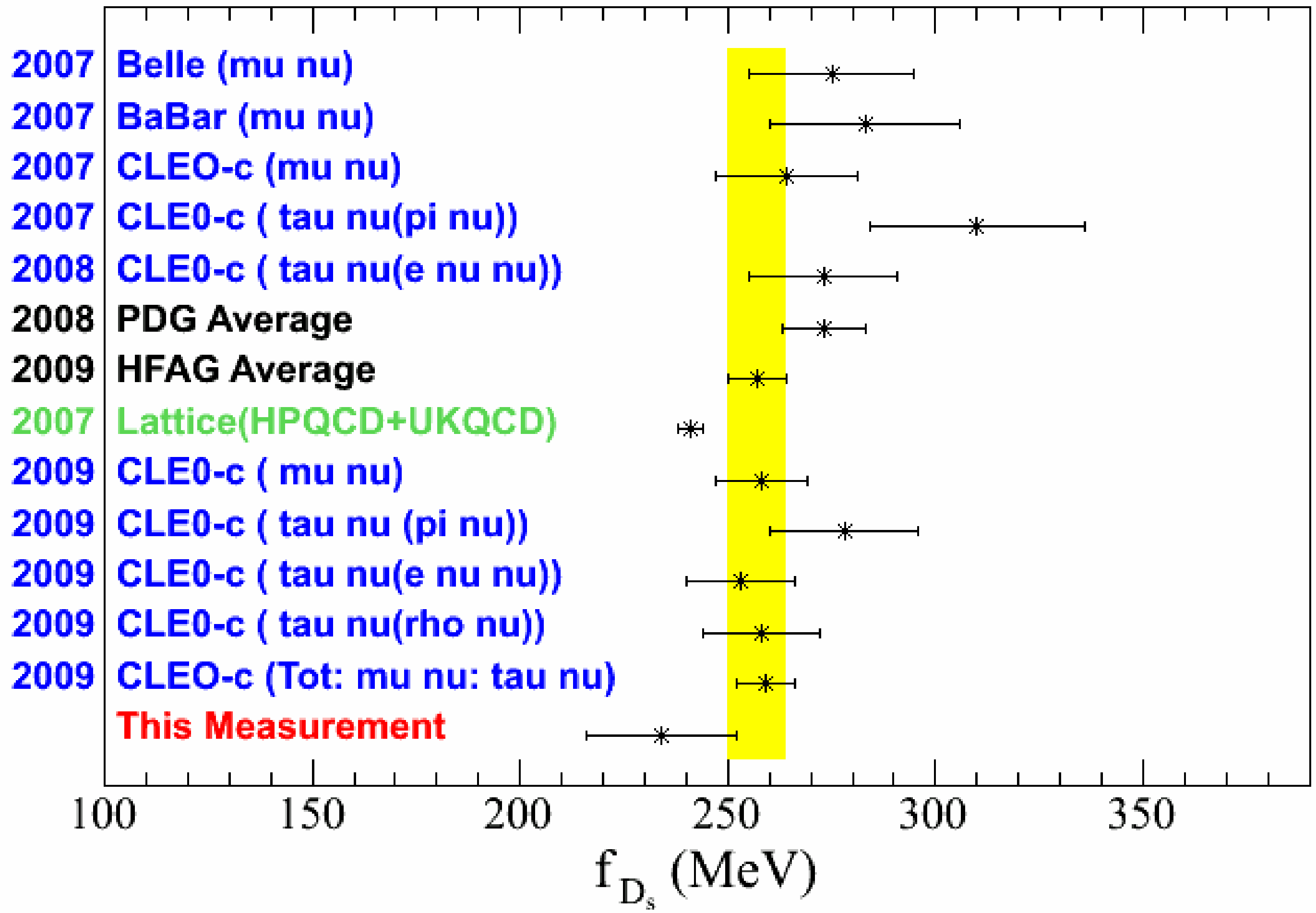
CLEO-c: ($\tau \to \pi\nu_\tau$) (278.0±17.5±4.4) MeV
(Tot. Error = 6.6%)

CLEO-c: ($\tau \to e\nu_e\nu_\tau$) (252.6±11.2±5.6) MeV
(Tot. Error = 4.9%)

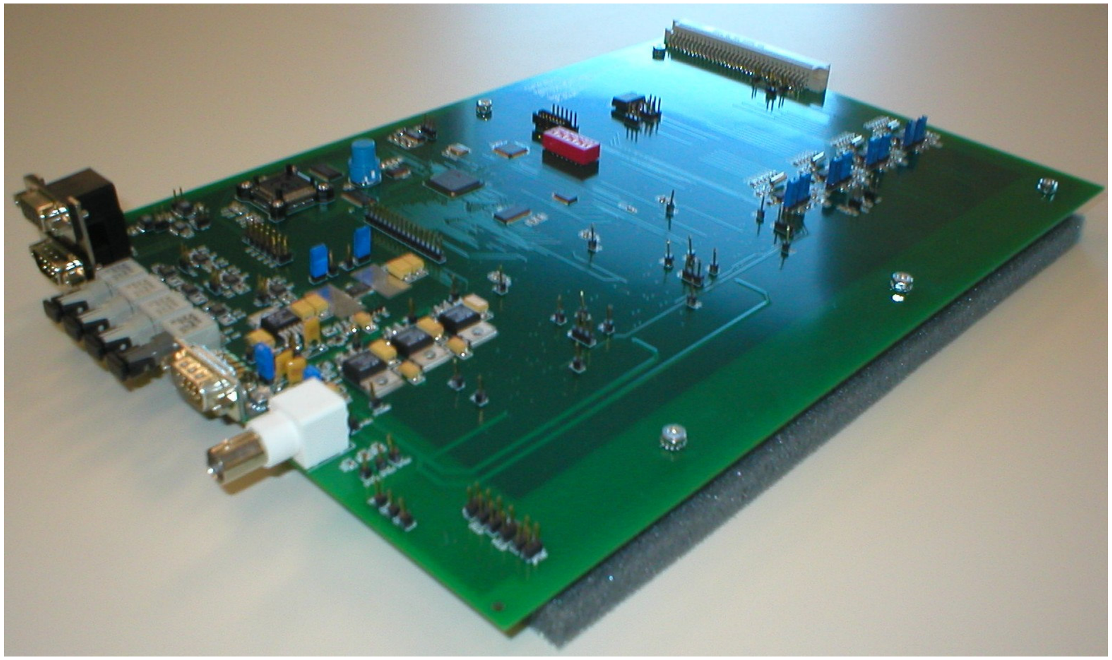
Errors: Statistical ± Systematic

Backup
Slides

Summary of f_{D_s} Results

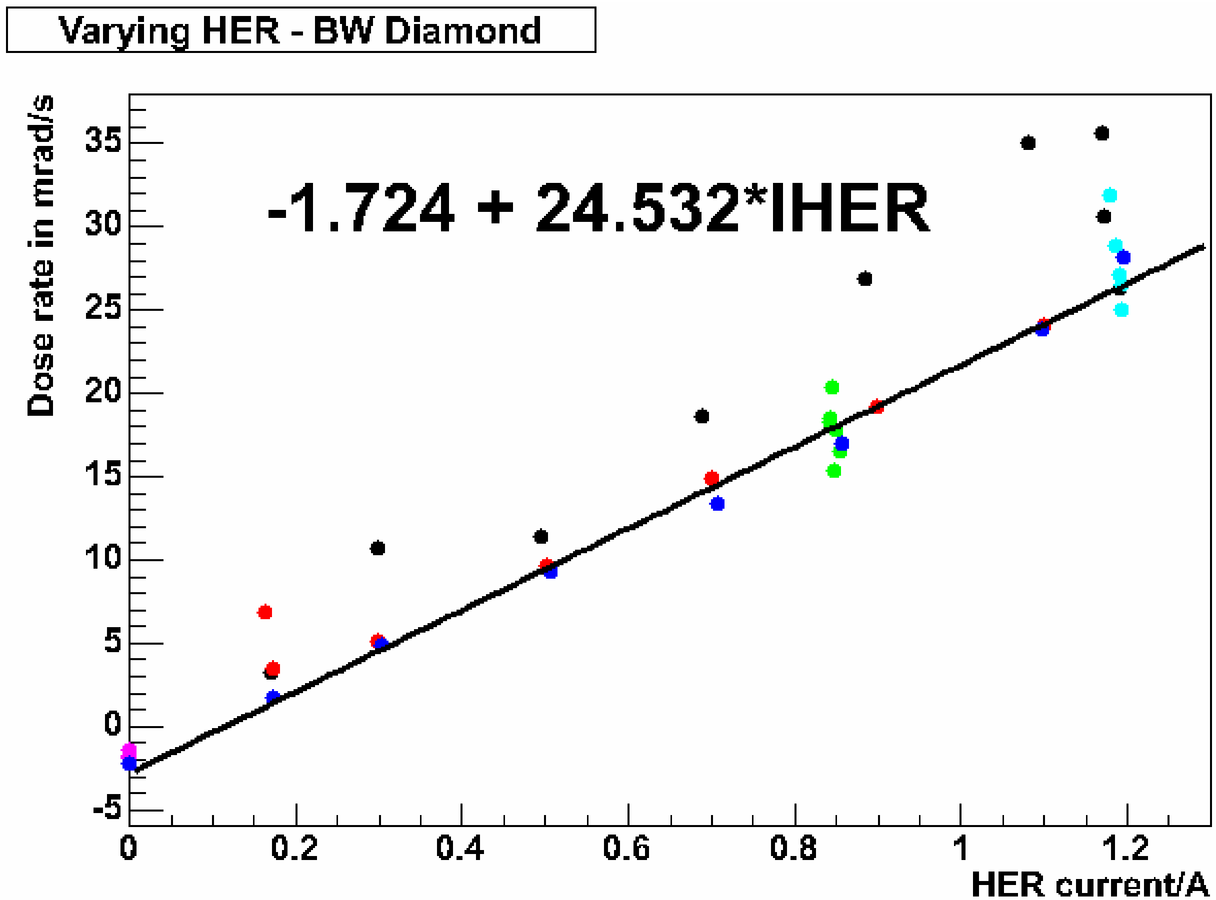


SVTRad Electronics



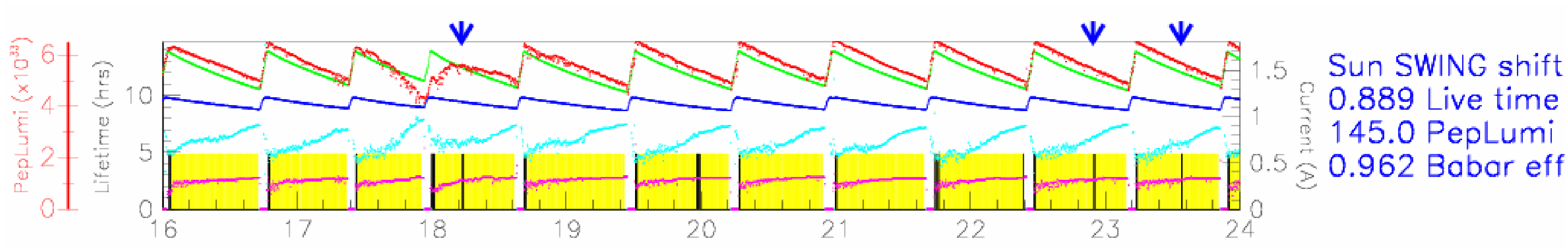
- DC Coupled Readout
- ≈ 1ms Sampling Rate
- Monitors Total (Leakage + Radiation) Current
- Large Leakage Current Subtraction with Temperature Corrections (2 Thermistors per Diode)
- 1nA ≈ 5 mRad/s
- Trigger Beam Dumps When Dose Rate Exceeds Maximum Allowed
- Dose Rates Read Out via CANBUS

Expected background as a function of currents and luminosity

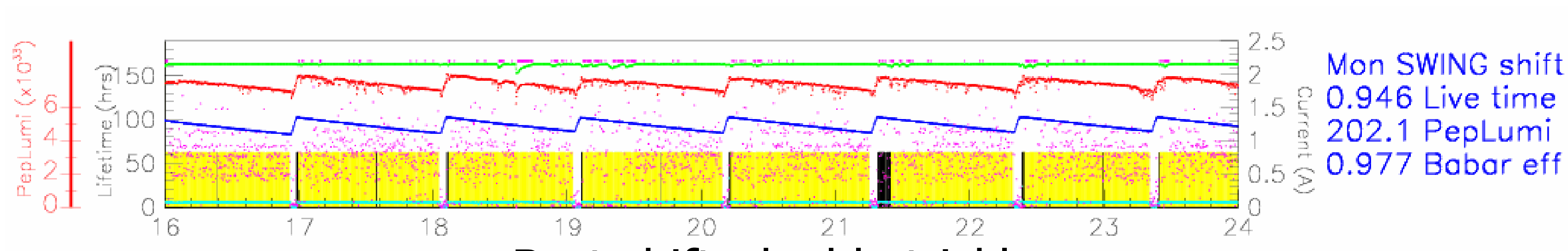


Run 4 Progress: Trickle Injection (IV)

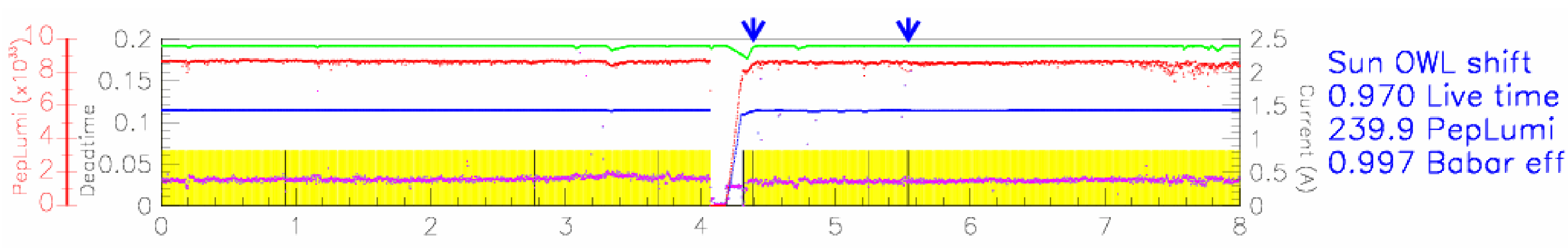
Best shift, no trickle



Best shift, LER only trickle

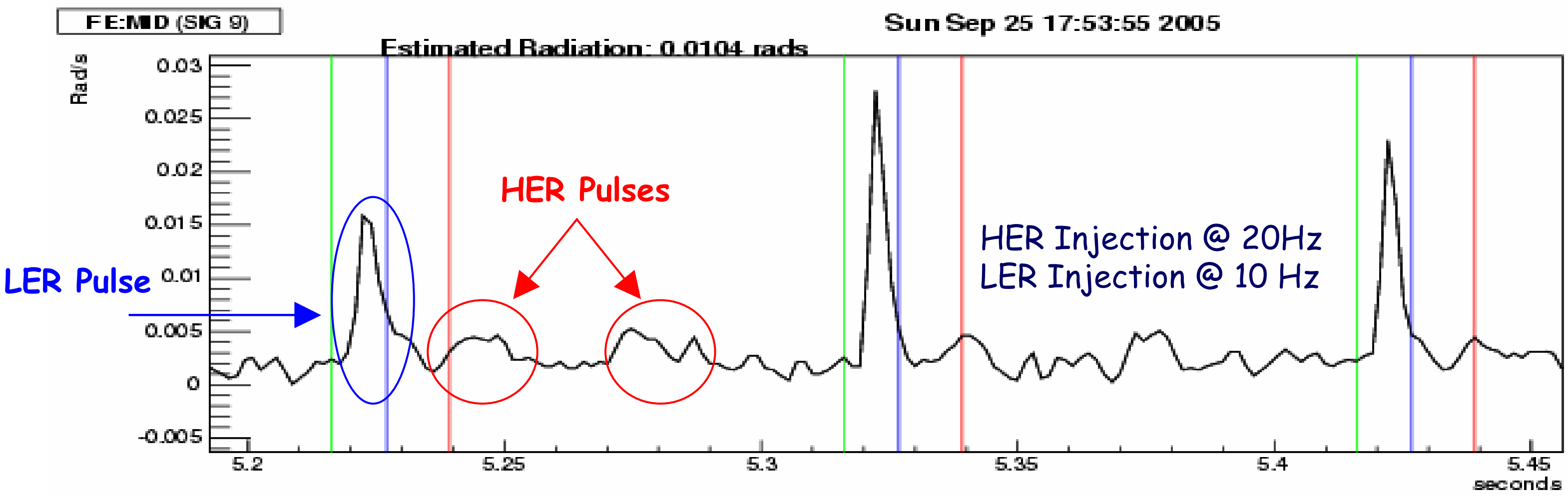


Best shift, double trickle

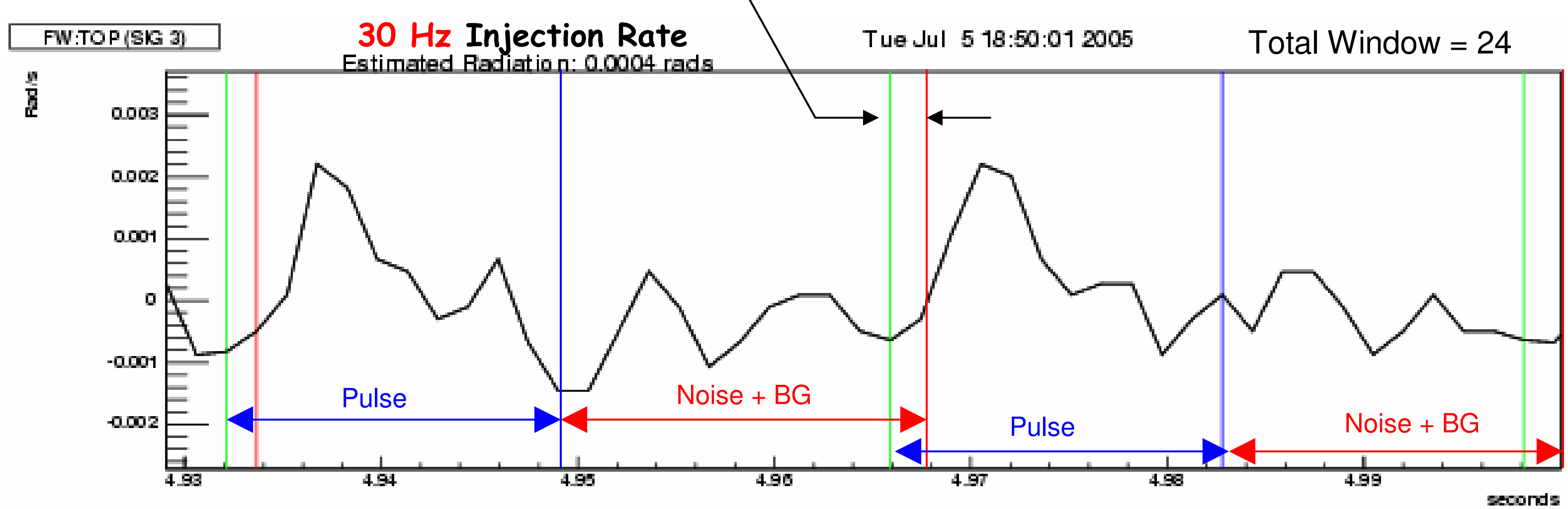


Trickle Monitoring Limitations

- Integration will Include HER Pulse if Window (Number of Data Samples) too Wide

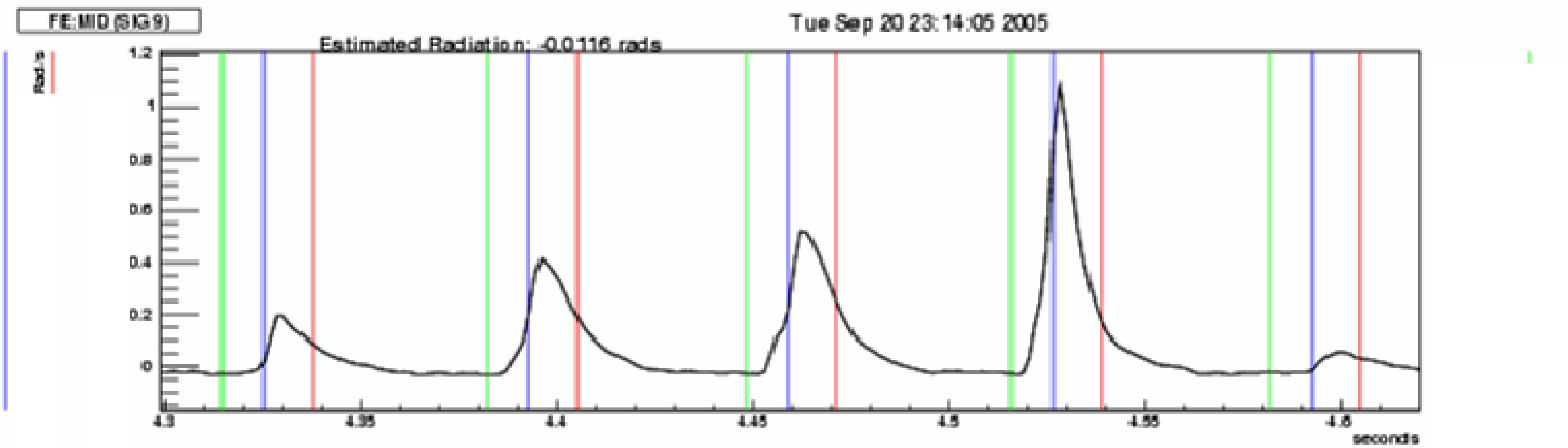


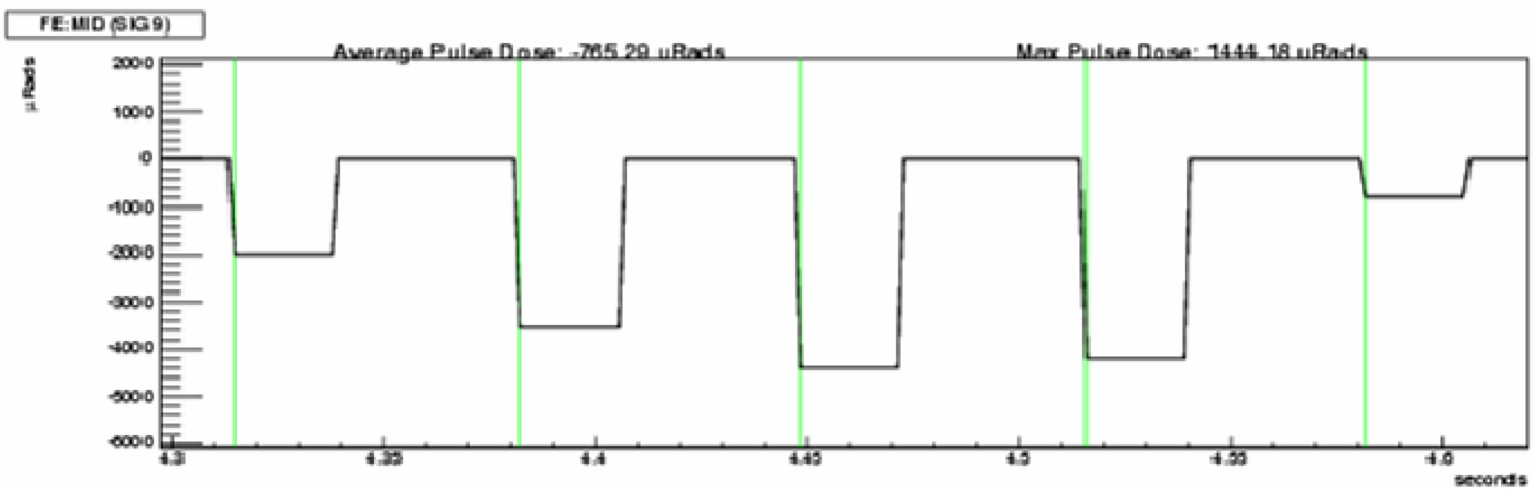
- Integration Overlaps next Pulse if Total Window > 22 Data Samples



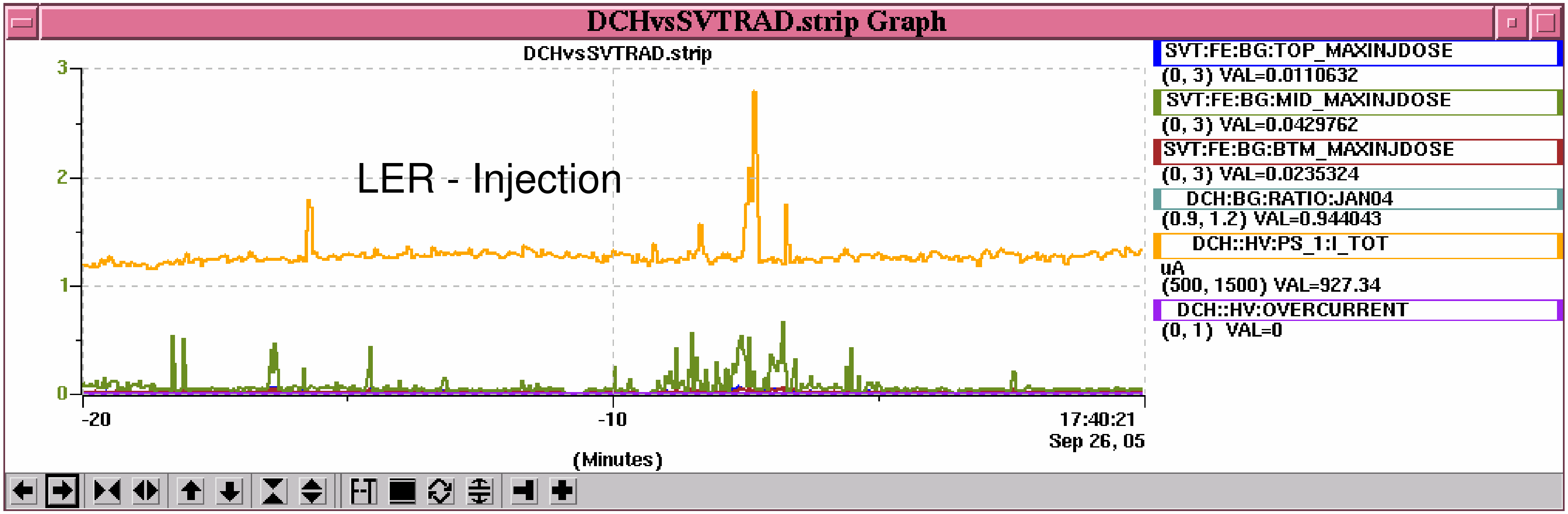
Bad Injection - Pulse Width

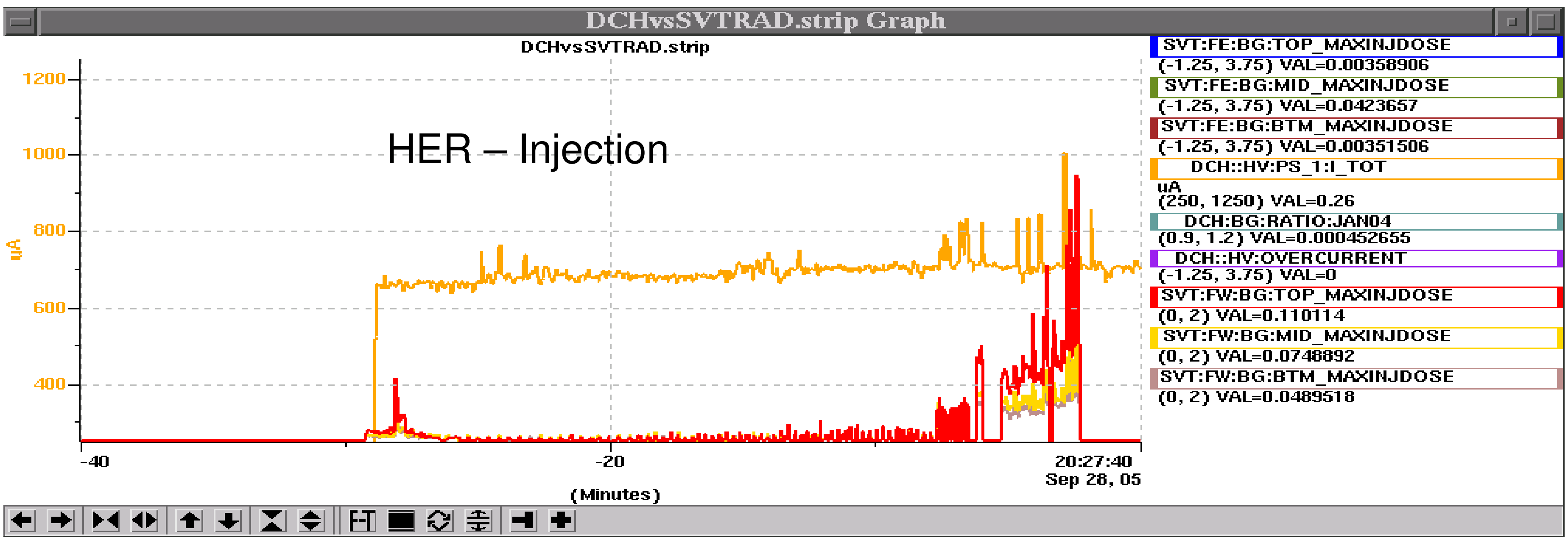
- Wide Pulses - Overlaps both Pulse and Noise + BG Windows
- Causes Large Negative Injection Dose Readings



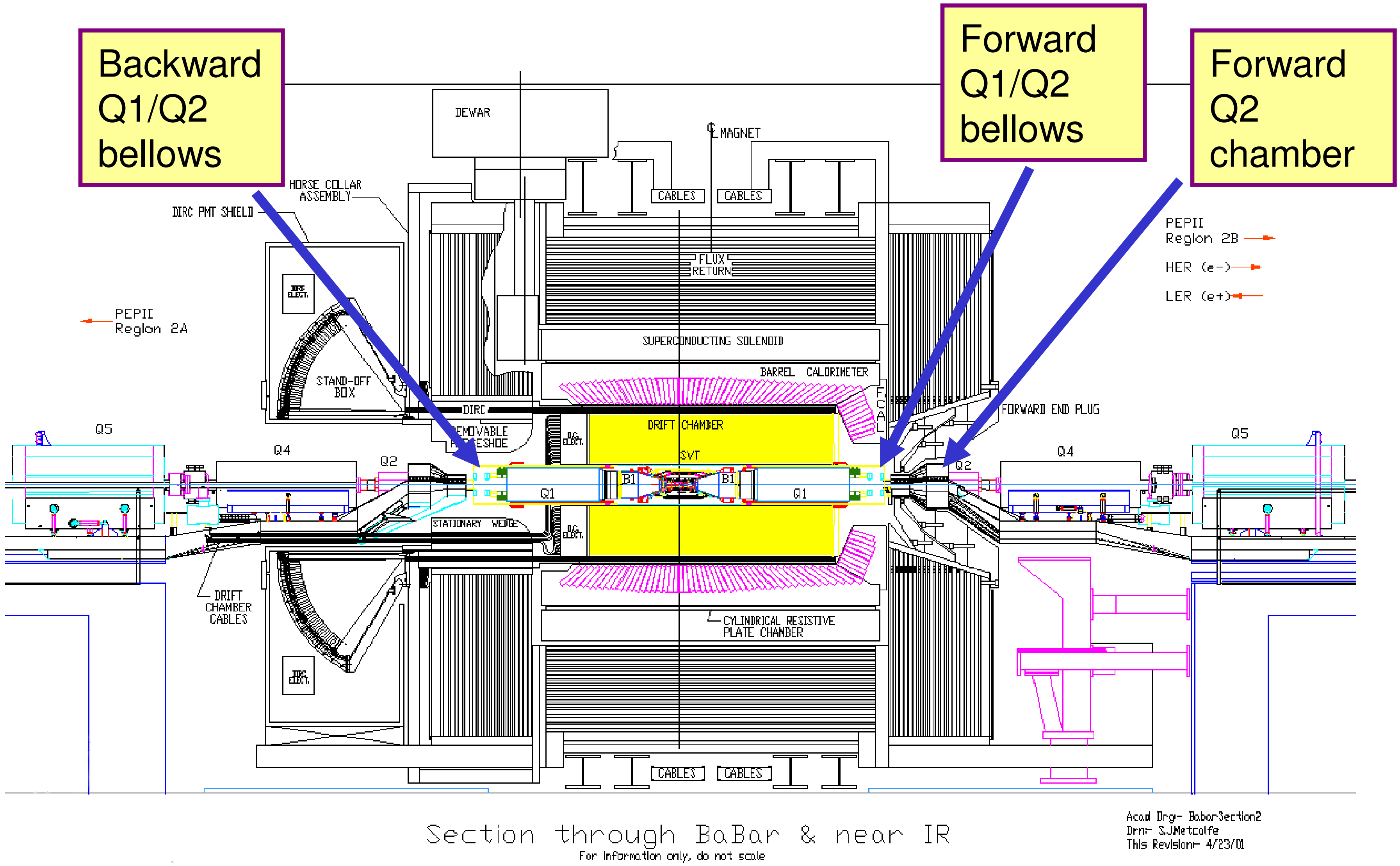


DCH Overcurrents and SVTRAD Max Inj Dose





Side view of BaBar

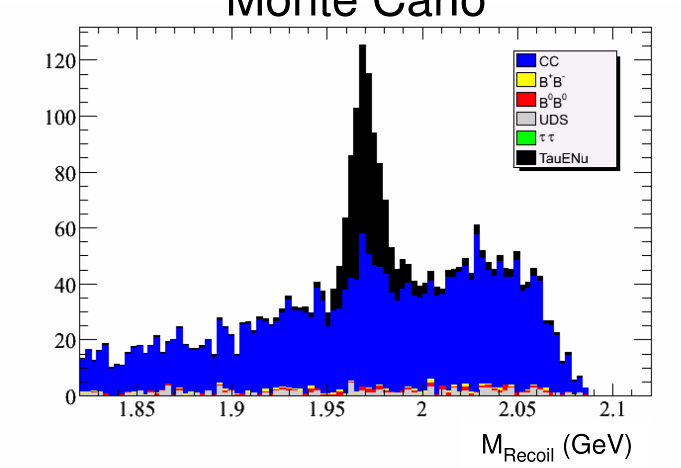


Bellows Conclusion

- **The design flaw in the RF seal made a weak point in the system – it allowed voltage to develop between the RF seal and the Cu under the tiles**
- **When the beam currents got high enough some form of an arc damaged this tile – the tile is made of SiC 40% and AlN 60%**
- **The damaged tile could not hold off as much voltage as before and hence the maximum beam currents were limited**

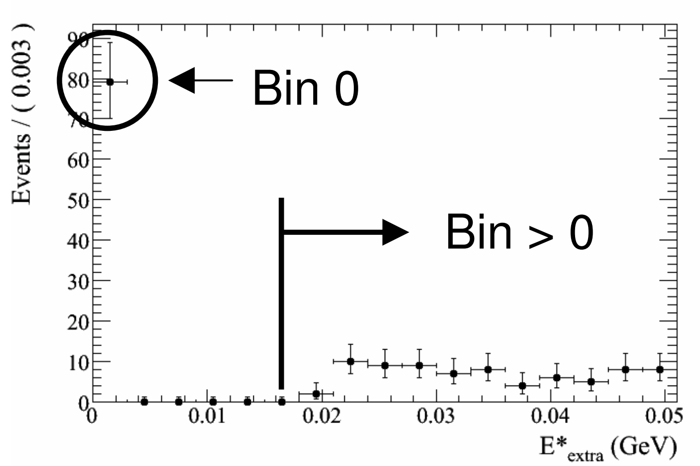
Yield Extraction - D_s Mass Fit Procedure

Monte Carlo



Signal & Bkg MC

E_{extra} (0.0→0.05 GeV)



Separating E_{extra} Bin 0 and Bin > 0 Due to Discontinuity at Bin 0

Use a 1-D (D_s Mass) Fit for Bin 0

Use a 2-D (D_s Mass & E_{extra}) Fit for Bin > 0

Fit Components

Signal

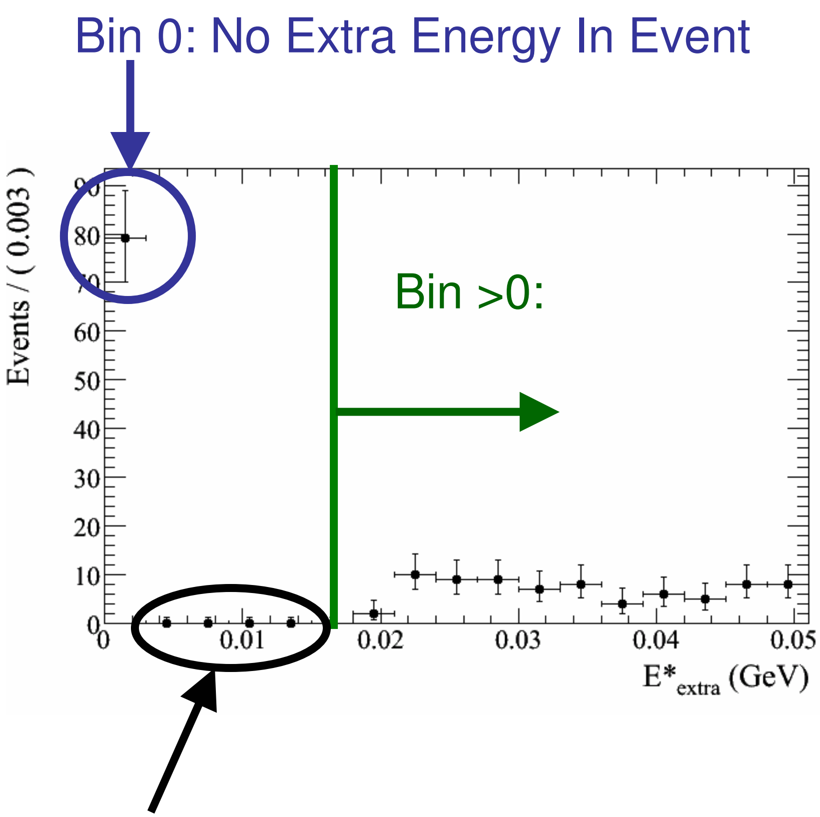
Background

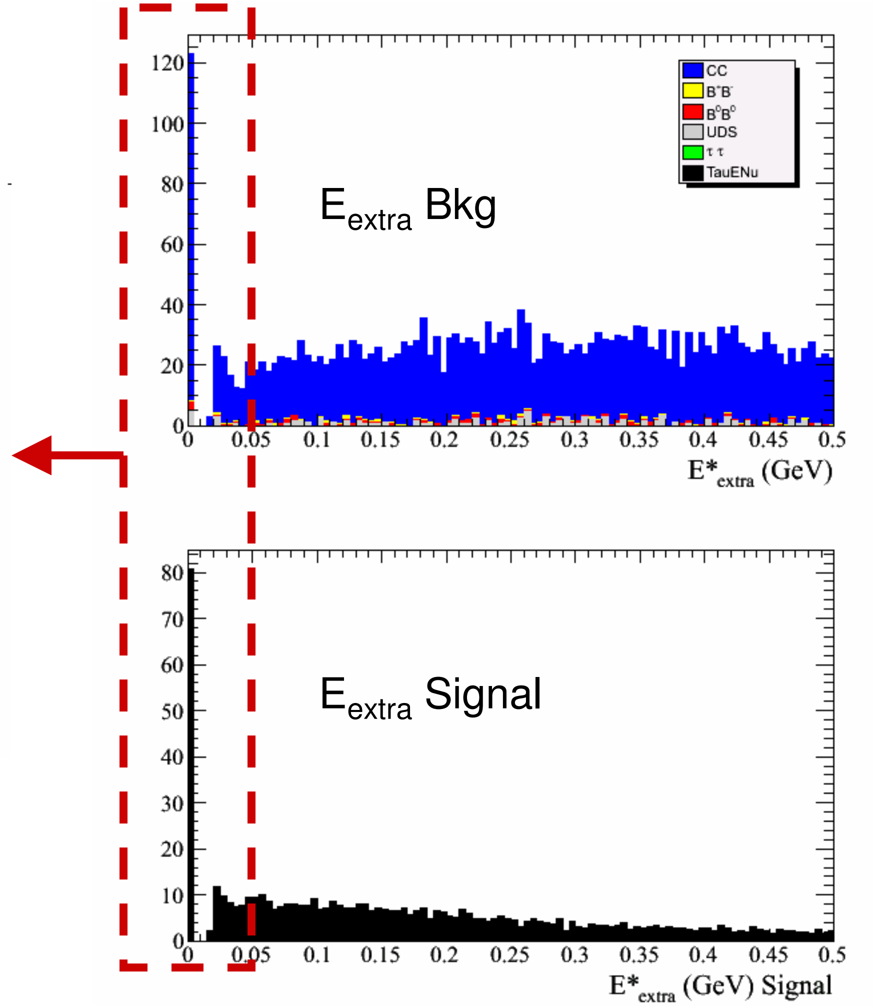
Peaking Background

Fit to Data:

- PDF Parameters fixed to MC
- E_{extra} Bkg Shape Taken from Data Sidebands
- Float N_{Sig} and N_{Bkg}
    - N_{PBkg} Held Constant

Closer Look at Extra Energy
Monte Carlo - Normalized to 427 fb^{-1}





The Gap in between bin 0 and the first data point above zero at 0.02 GeV is due to the minimum energy required for photon candidates.

Systematic Errors – Cut Variables & PDF Shapes

The cut variable systematic is found by comparing the ratio of Monte Carlo and data events for $D_s \to \tau\nu_\tau$ and $D_s \to K_s K$.

$$M_{N-1} \quad M_{All} \quad D_{N-1} \quad D_{All}$$

M = # Evts Monte Carlo
D = # Evts Data
All = All Cuts Applied
N-1 = All Cuts Applied Except 1

$$R_{Mode} = \frac{M_{N-1}/M_{All}}{D_{N-1}/D_{All}} \qquad \frac{R_e}{R_{K_s K}} \approx ?$$

$$\sigma_{CutVar} = \left| 1 - \frac{R_{D_s \to \tau\nu}}{R_{D_s \to K_s K}} \right|$$

$$\sigma_{CutVar} = 3.0\,\%$$

The PDFs used to extract the yields have many parameters that are found from fits to Monte Carlo. These parameters are fixed in the fit to data. The systematic error is found by varying these parameters by $\pm 1\sigma$ and evaluating the variation of the number of fitted events. Each parameter can shift the number of events up or down, resulting in asymmetric errors.

$\tau\nu$ PDF Variables	**+7.69% -4.73%**
$K_s K$ PDF Variables	**+4.86% -0.63%**

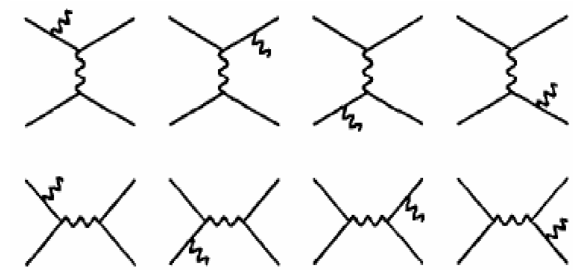
Systematic Errors – Particle Identification

The Electron PID Efficiency is Measured in Radiative Bhabha Events

- Very Clean

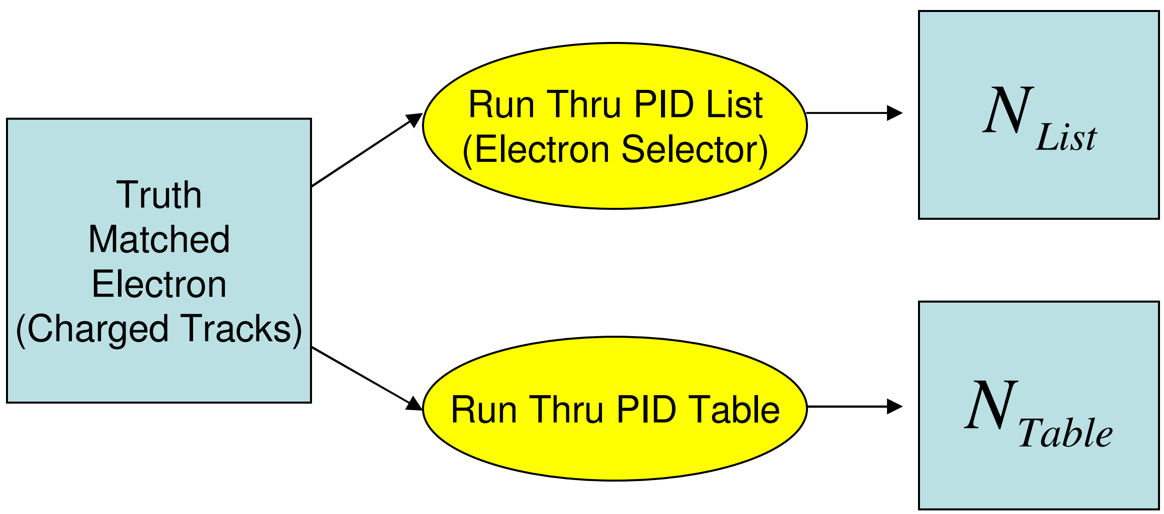
This Analysis Contains Multihadron Events

- Results in Higher Occupancies (Calorimeter)
- Translates to Lower PID Efficiency



Bhabha Scattering

$$C = \frac{N_S^{PID\,Table}}{N_S^{MC}} + \sigma_{Stat}^{PID\,Table} + \sigma_{Environment}$$



$$\sigma_{Environment} = \frac{N_{List} - N_{Table}}{N_{List}}$$

$\sigma_{Tot} = 0.82\%$

PID Table - Function of Momentum and Angle

Conclusion

- Measured BF and Extracted f_{D_s}
  - $B(D_s \to \tau\nu) = (4.54 \pm 0.53 \pm 0.40 \pm 0.28)$ %
  - $f_{D_s} = (233.6 \pm 13.6 \pm 10.4 \pm 7.1)$ MeV
  - Result within 1σ of CLEO-c & LQCD
- BAD 1994
- Journal Draft – BAD 2252
  - Intended for PRD-RC
  - Currently in RC
  - Hope to Go to CWR Soon