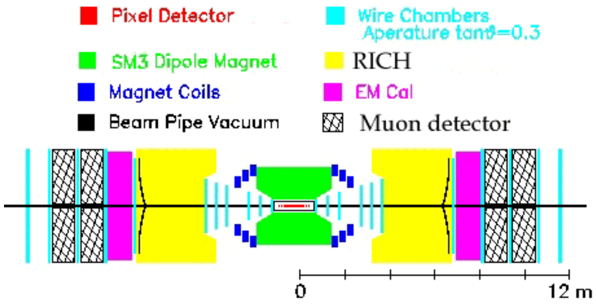
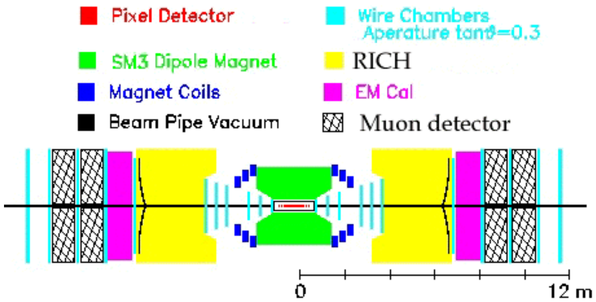


The BTeV Detector

S. Stone
July, 2000

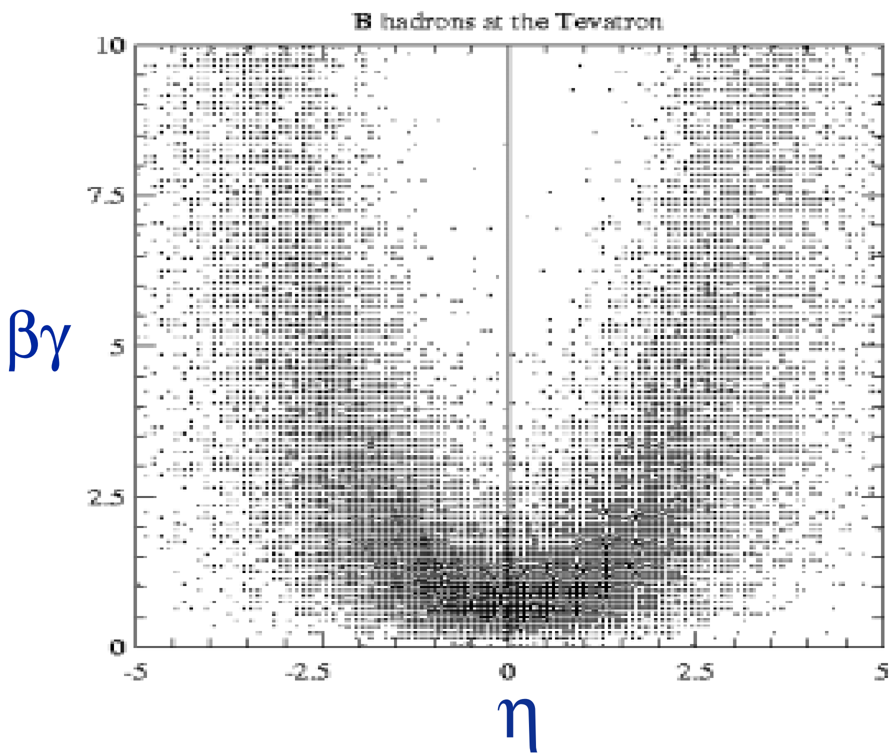
- Reasons for doing b & c decay physics at the Fermilab Tevatron:
  - Large samples of b quarks are available, with the Main Injector, the collider will produce ~4×10^{11} b hadrons per 10^7 sec at $\mathcal{L} = 2\times10^{32}$ cm^{-2}s^{-1}, $\Rightarrow$ a mean of 2 interactions/crossing, ~1.3 are "inelastic"
  - B_s & Λ_b and other b-flavored hadrons are accessible for study at the Tevatron.
  - Charm rates are ~10x larger than b rates

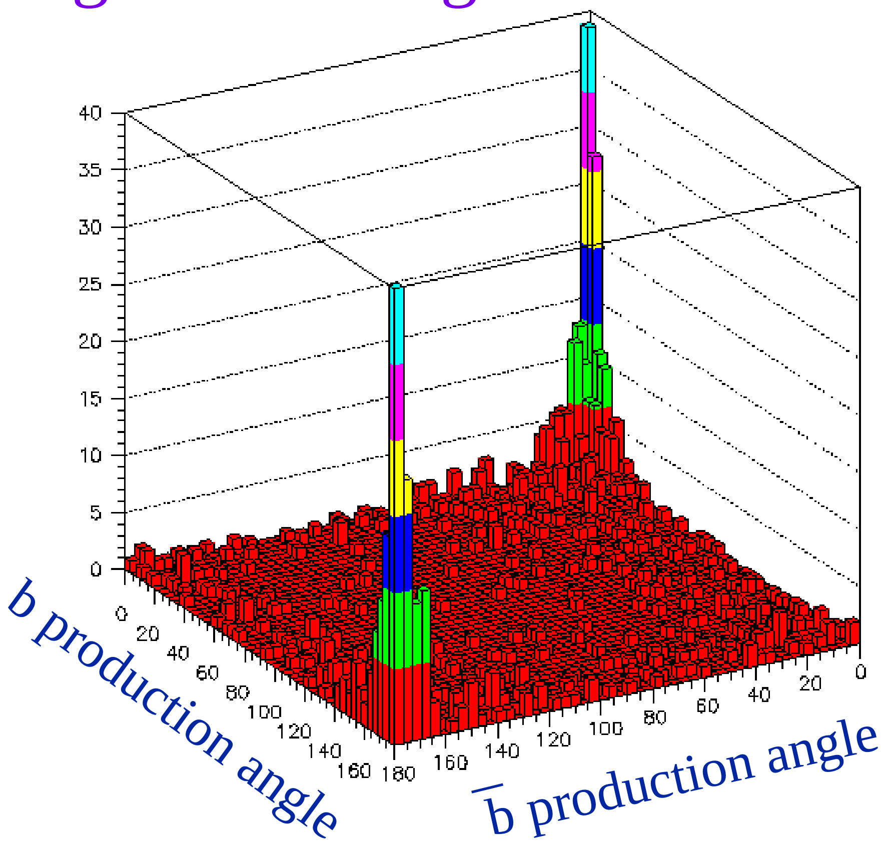


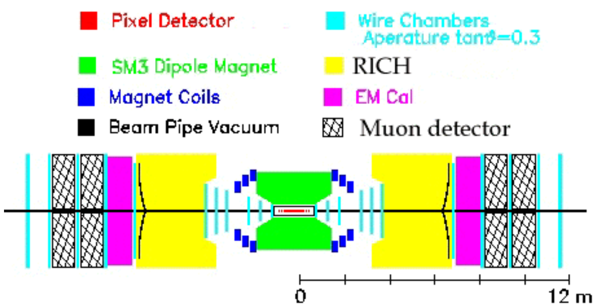
Characteristics of hadronic b production

The higher momentum b's are at larger η's

b production peaks at large angles with large $\bar{b}b$ correlation

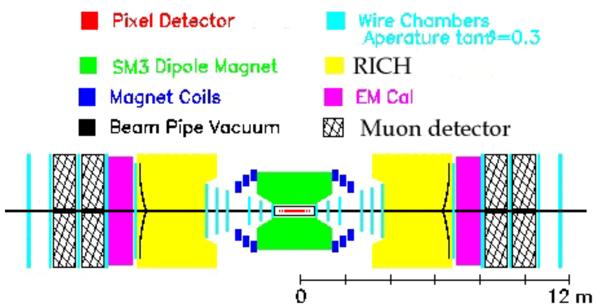






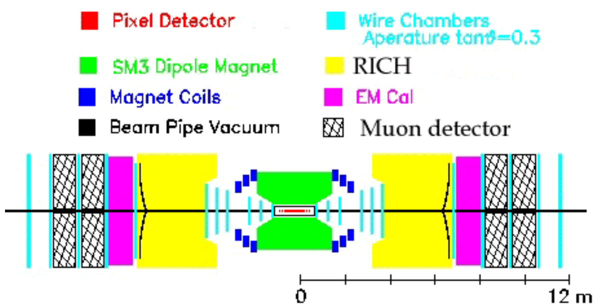
Main detector challenges

- Problems:
  - σ_b/σ_{tot} ~ 1/500
  - Background from b's can overwhelm "rare" processes
  - Large data rate just from b's - 1 kHz into detector
  - Large rates cause Radiation damage to EM calorimeter; photon multiplicities may obscure signals
- Solutions:
  - Use **detached vertices** for trigger and background rejection
  - Have excellent charged **particle identification** & lepton id
  - Deadtimeless trigger and DAQ system capable of writing kHz of events to tape
  - Use $PbWO_4$ crystal calorimeter



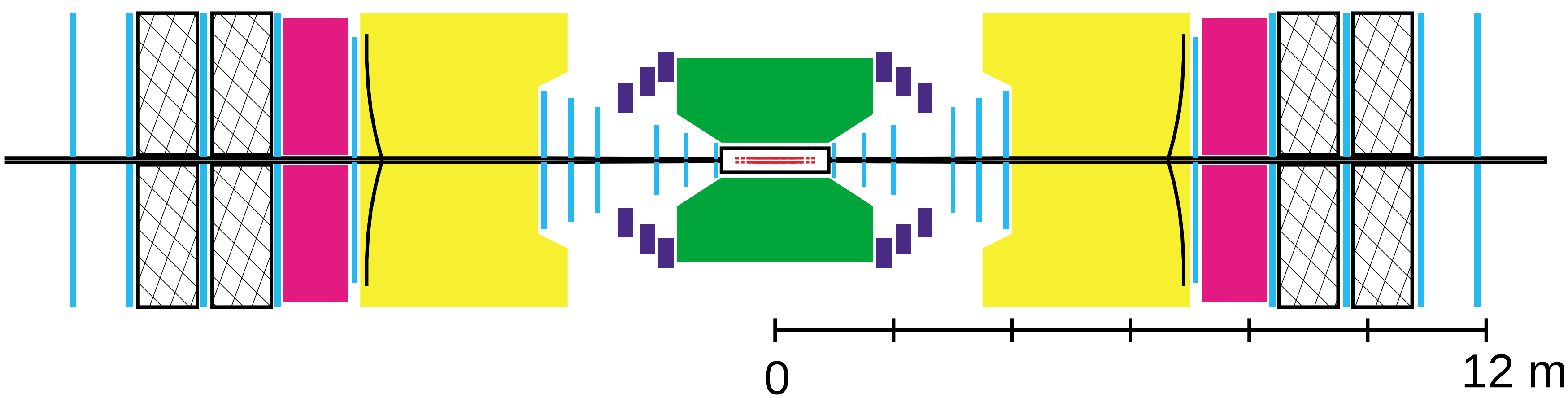
Summary of required measurements for CKM tests

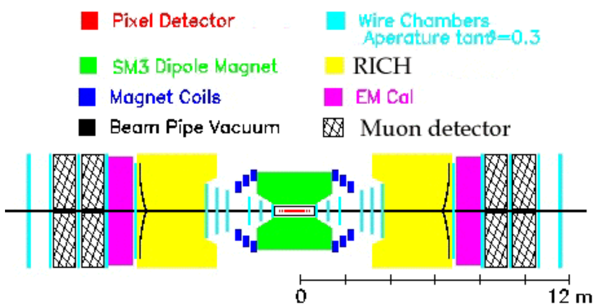
Physics Quantity	Decay Mode	Vertex Trigger	K/π sep	γ det	Decay time σ
$\sin(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\sin(2\alpha)$	$B^o \to \pi^+\pi^-$ & $B_s \to K^+K^-$	✓	✓		✓
$\cos(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\mathrm{sign}(\sin(2\alpha))$	$B^o \to \rho\pi$ & $B^o \to \pi^+\pi^-$	✓	✓	✓	
$\sin(\gamma)$	$B_s \to D_s K^-$	✓	✓		✓
$\sin(\gamma)$	$B^o \to \overline{D}^o K^-$	✓	✓		
$\sin(\gamma)$	$B \to K \pi$	✓	✓	✓	
$\sin(2\chi)$	$B_s \to J/\psi\eta'$, $J/\psi\eta$		✓	✓	✓
$\sin(2\beta)$	$B^o \to J/\psi K_s$				
$\cos(2\beta)$	$B^o \to J/\psi K^*$ & $B_s \to J/\psi\phi$				
x_s	$B_s \to D_s\pi^-$	✓	✓		✓
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\eta'$, K^+K^-, $D_s\pi^-$	✓	✓	✓	✓



The BTeV Detector

- Pixel Detector (Inside the beam pipe)
- Dipole Magnet
- Magnet Coils
- Beam Pipe
- Straw-chambers (exterior) and single-sided silicon-strips (interior)
- RICH
- $PbWO_4$ EM calorimeter
- Muon Detector

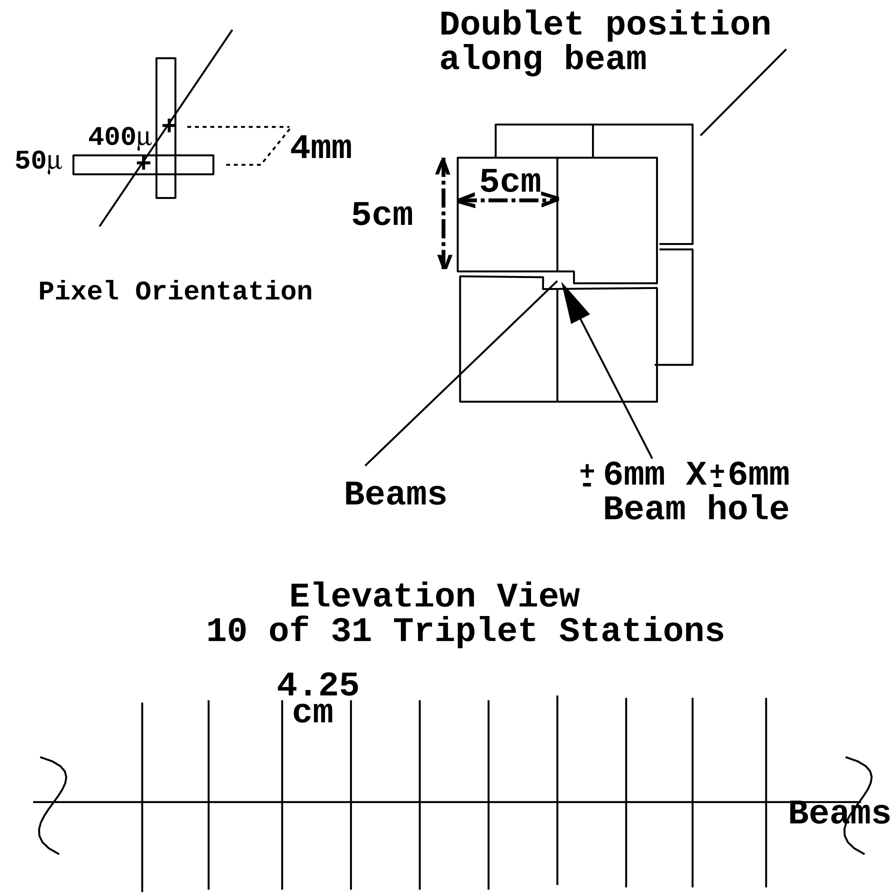


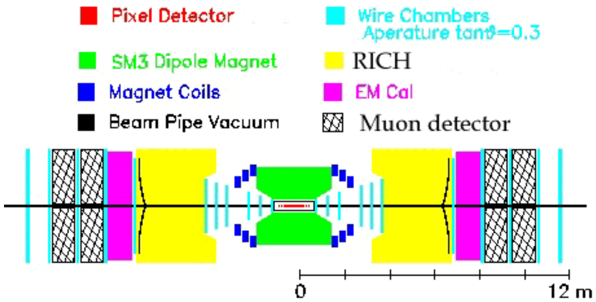


The Pixel Detector

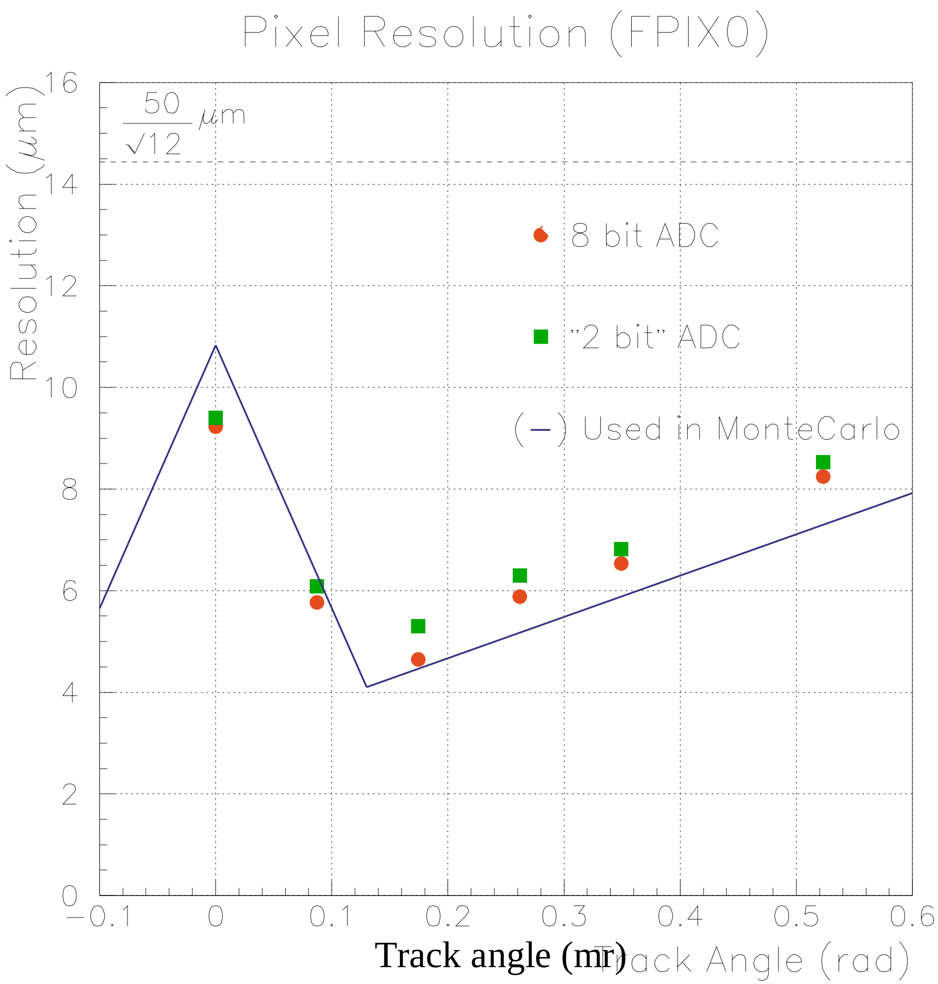
- Pixels necessary to eliminate ambiguity problems with high track density; Essential to our detached vertex trigger
- Crucial for accurate decay length measurement
- Radiation hard
- Low noise

The BTeV Baseline Pixel Detector

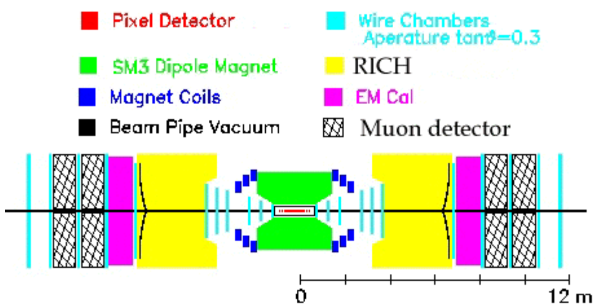




Pixel Test Beam Results

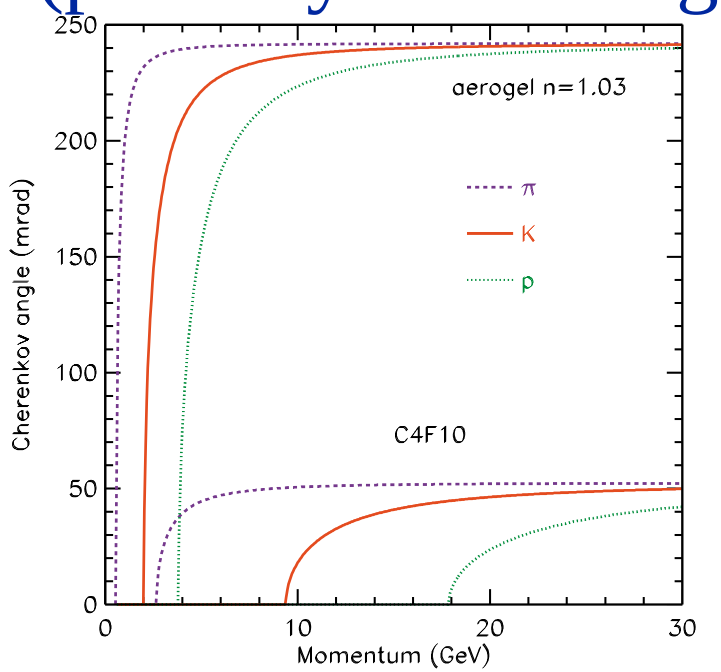


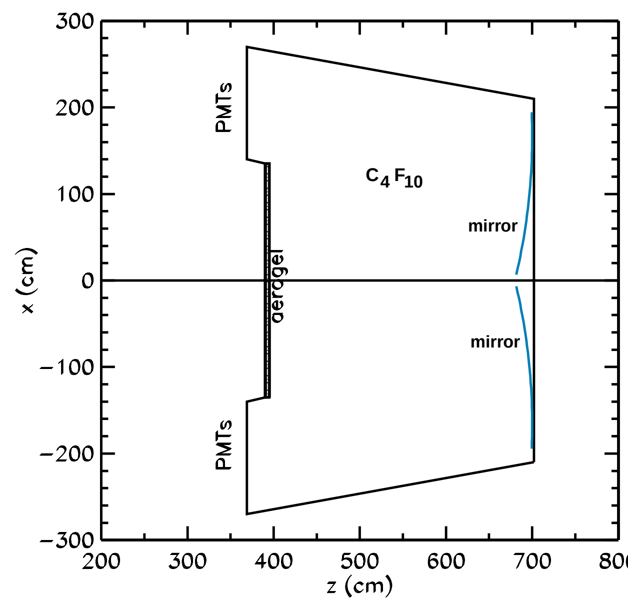
- **Solid curve** is a piece wise linear fit to a simulation based on a detailed Monte Carlo

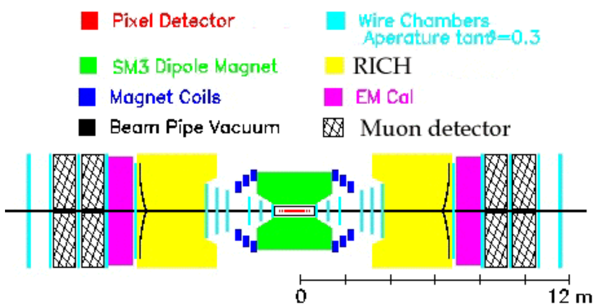


Ring Imaging CHerenkov

- Goal is π/K/p separation from 3 - 70 GeV/c
- Use C_4F_{10} gas radiator and hybrid photodiodes (possibly also aerogel radiator)



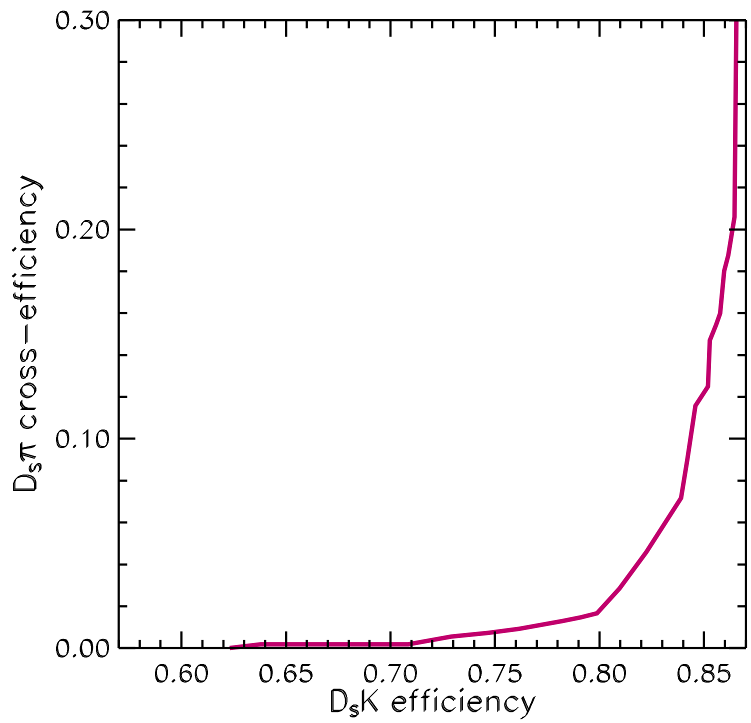


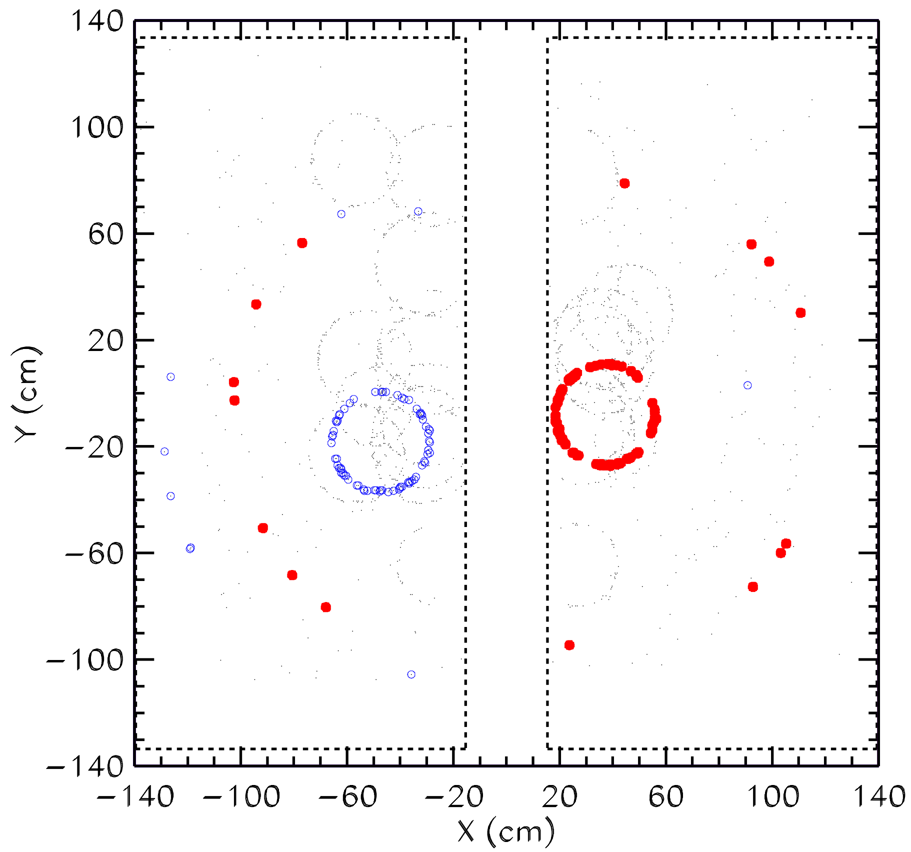


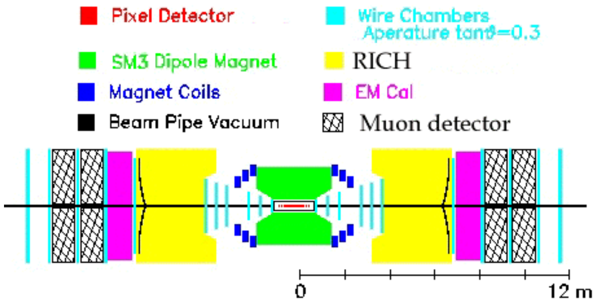
Particle Identification

◆Excellent P. I. D.

◆Rings from $B^0 \rightarrow \pi^+ \pi^-$, & rest of crossing



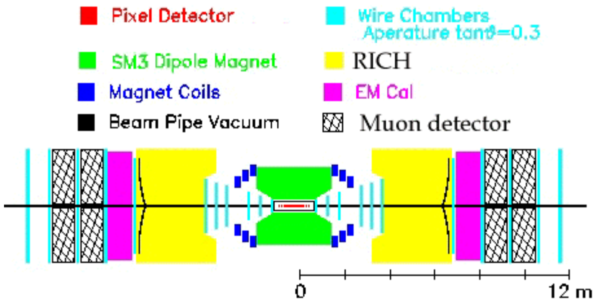


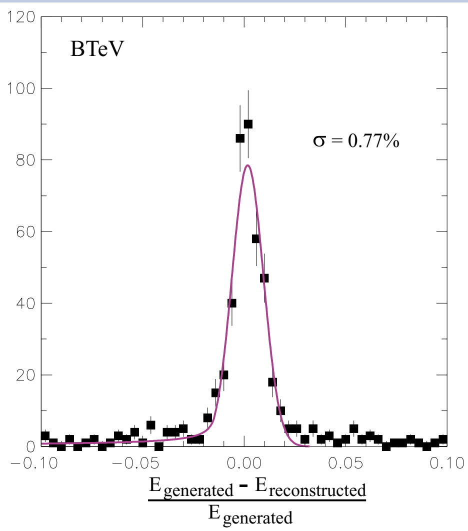


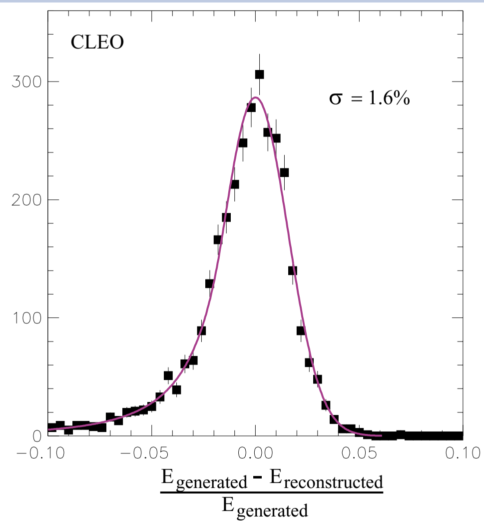
The $PbWO_4$ EM Calorimeter

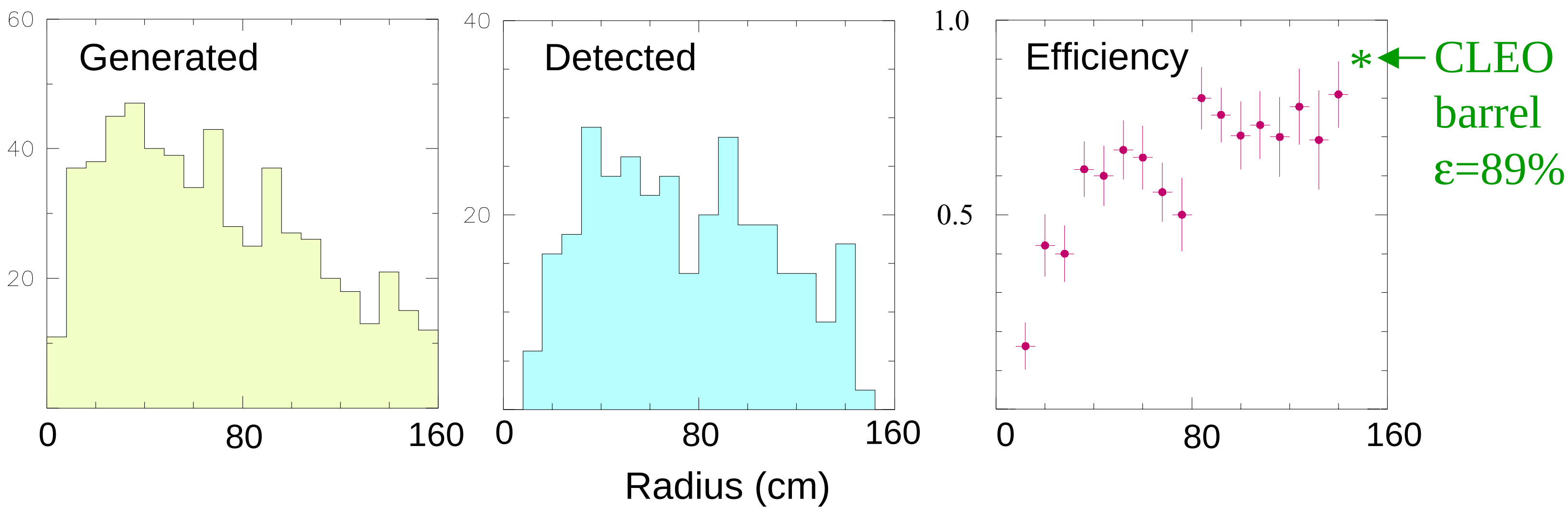
- Crystal technology developed by CMS. They will use 80,000 crystals
- Our baseline uses similar size crystals as CMS endcaps 26 x 26 x 220 mm^3, total of 2x11,850
- Crystals are radiation hard
- Scintillation is fast, 99% of light emitted < 100 ns
- We will use phototube readout since we are not in a magnetic field

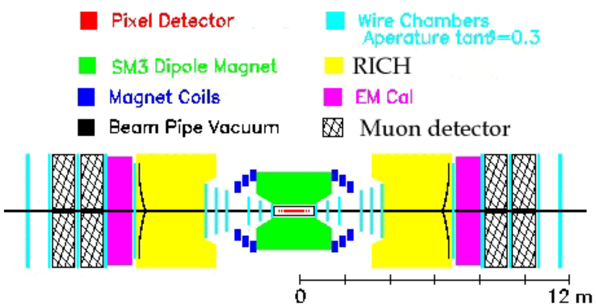
Ex: Efficiency for $B \to K^*\gamma$





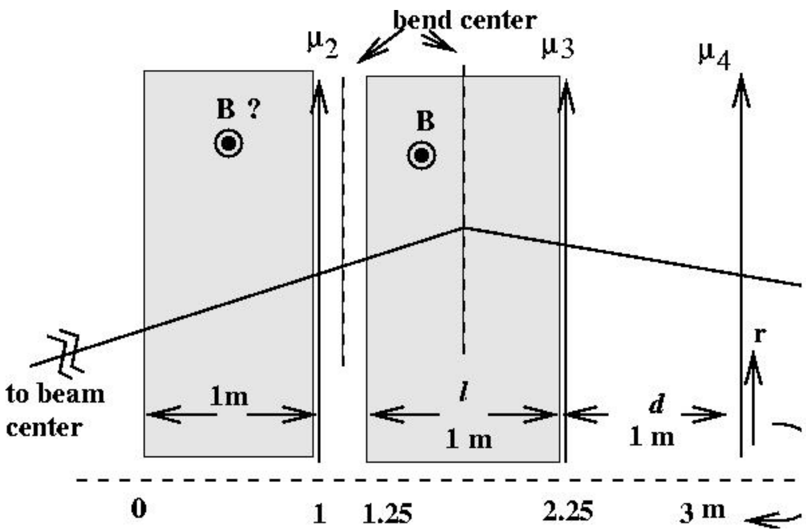


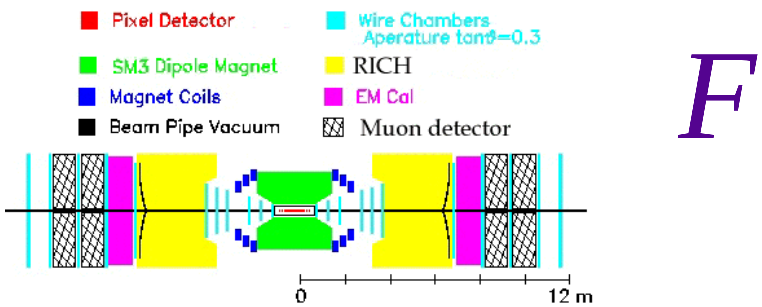




The Muon Detector

- Goals:
  - Identifies muons
  - Triggers on di-muons in level 1; provides a method of checking detached vertex triggering efficiency
- Design: Two torroids with three sets of position detectors



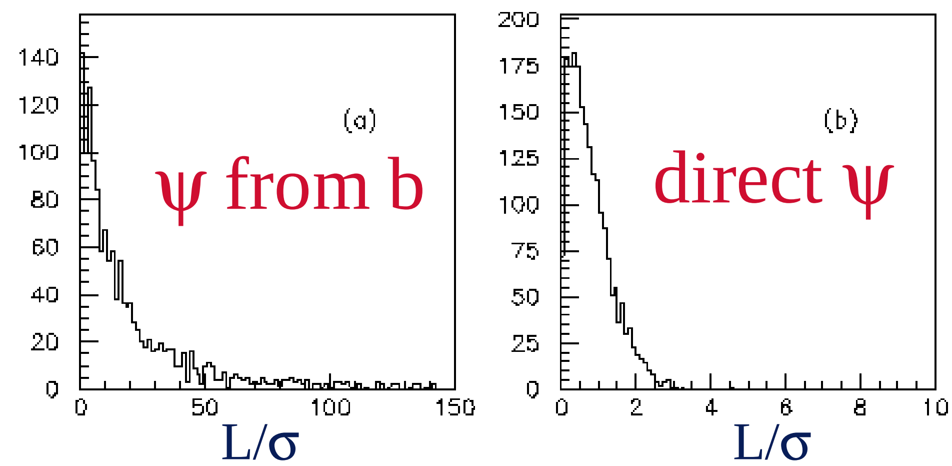


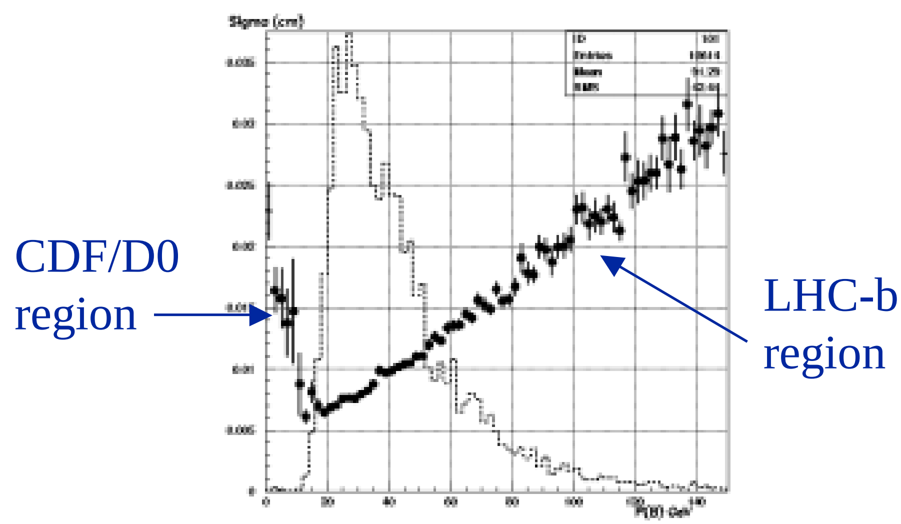
Fundamentals: Decay Time Resolution

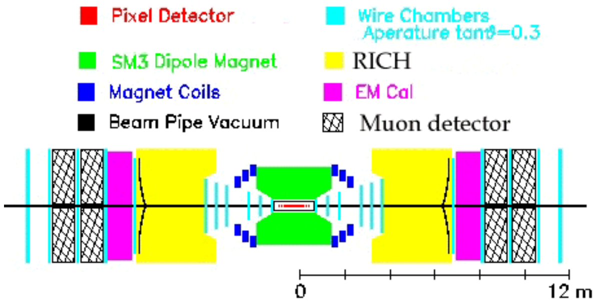
- Excellent decay time resolution
  - Reduces background
  - Allows detached vertex trigger
- The average decay distance and the uncertainty in the average decay distance are functions of B momentum:

$<L> = \gamma\beta c\tau_B$

$= 480\ \mu m \times p_B/m_B$

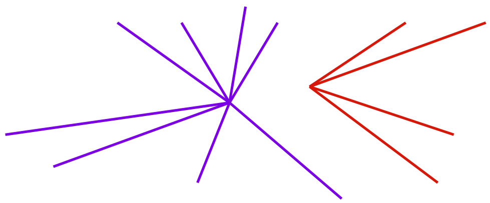


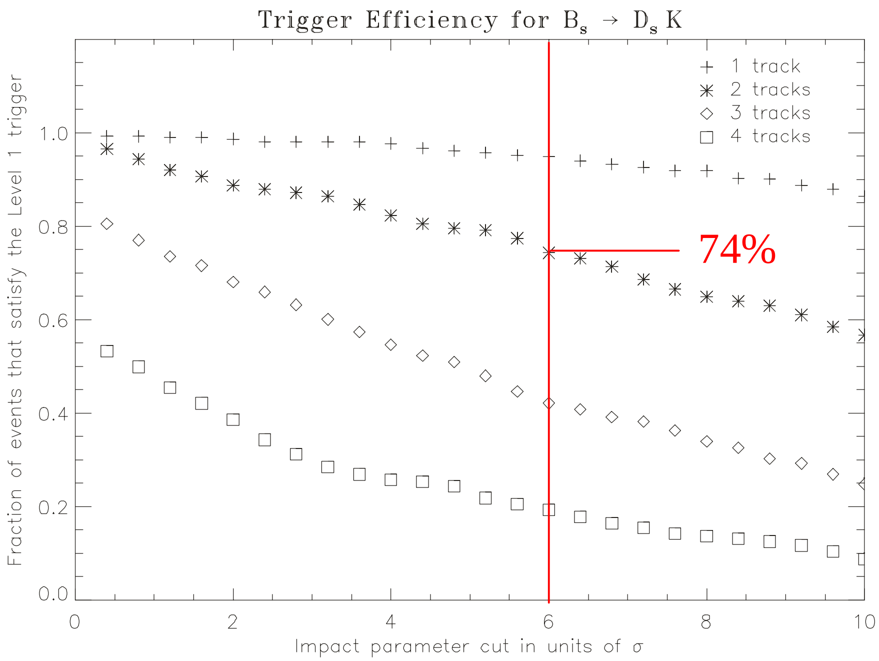


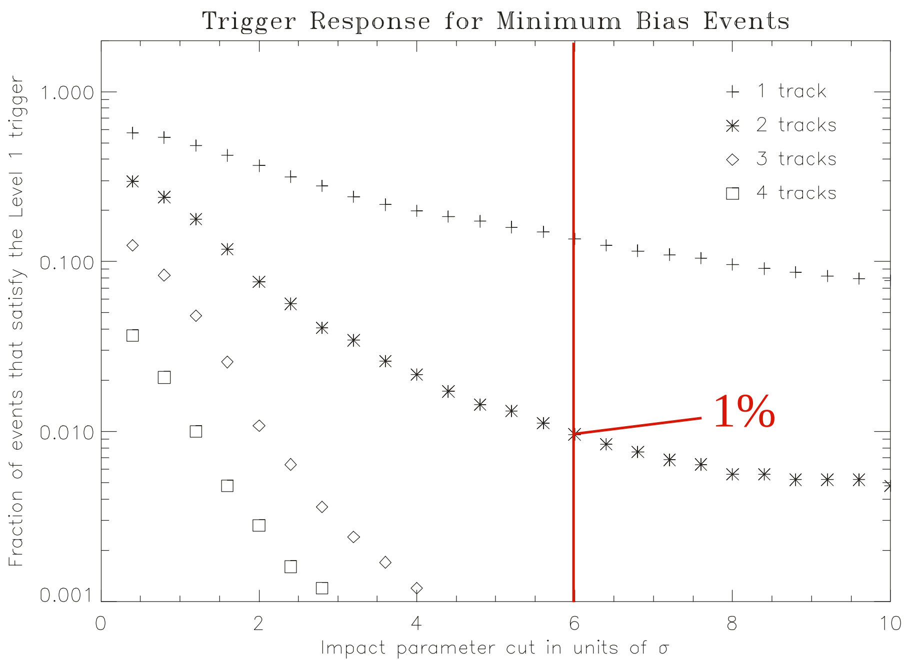


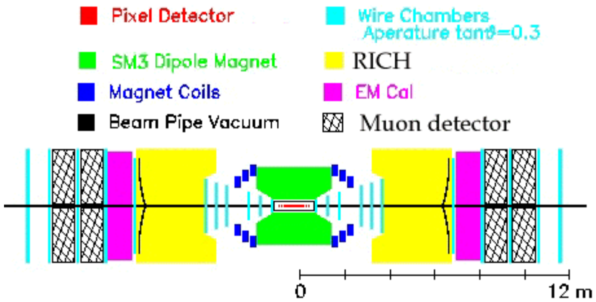
Pixel Trigger Overview

- **Idea: Finds the primary vertex and identifies tracks which miss it, and calculates the significance of detachment, b/σ(b).**







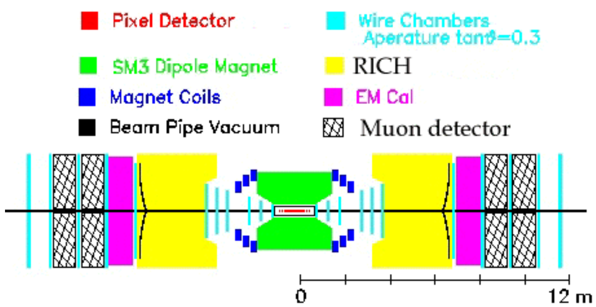


L1 Trigger Performance

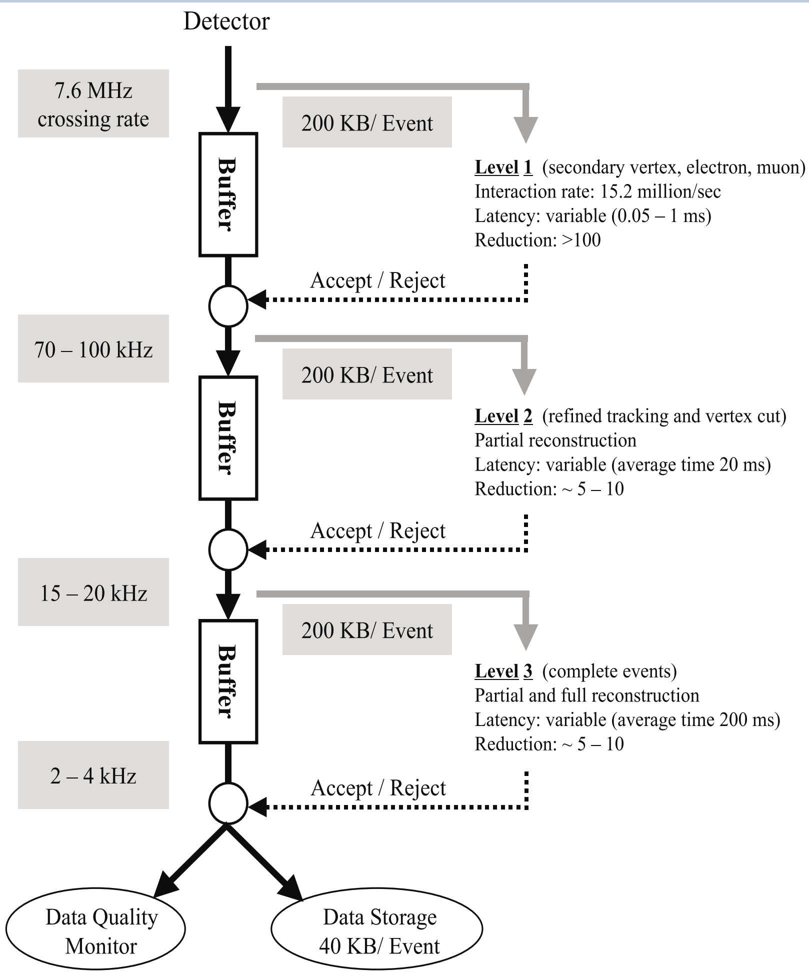
- For a requirement of at least 2 tracks detached by more than 6σ, we trigger on only 1% of the beam crossings and achieve the following efficiencies for these states after the other analyses cuts:

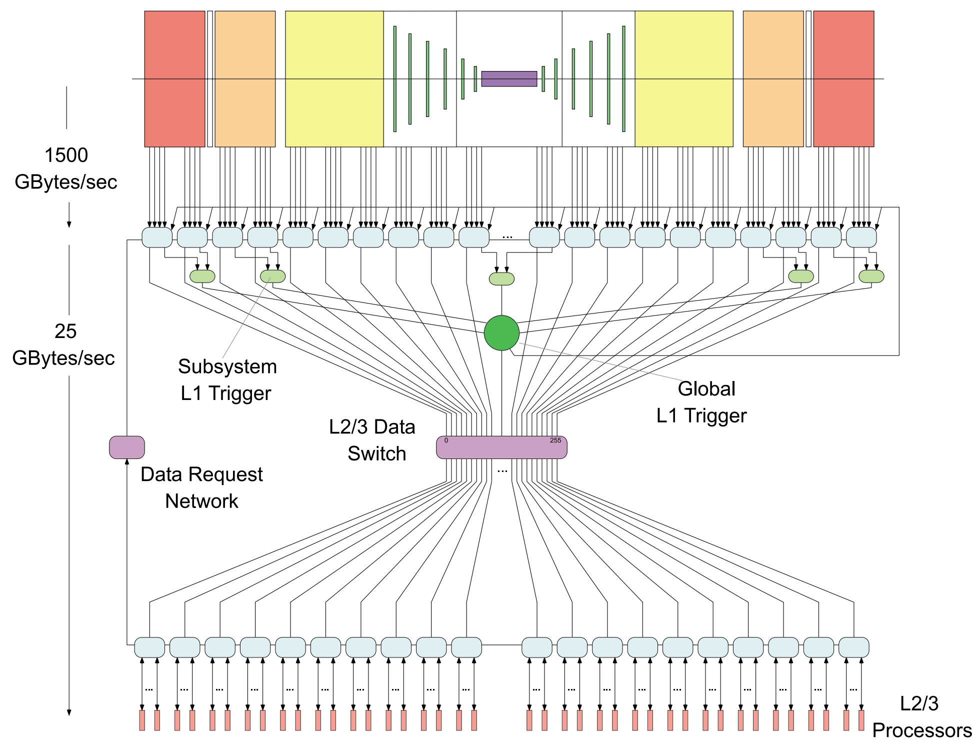
State	efficiency(%)	state	efficiency(%)
$B \rightarrow \pi^+\pi^-$	63	$B^o \rightarrow K^+\pi^-$	63
$B_s \rightarrow D_s K$	71	$B^o \rightarrow J/\psi\, K_s$	50
$B^- \rightarrow D^o K^-$	70	$B_s \rightarrow J/\psi K^*$	68
$B^- \rightarrow K_s \pi^-$	27	$B^o \rightarrow \rho^o \pi^o$	56

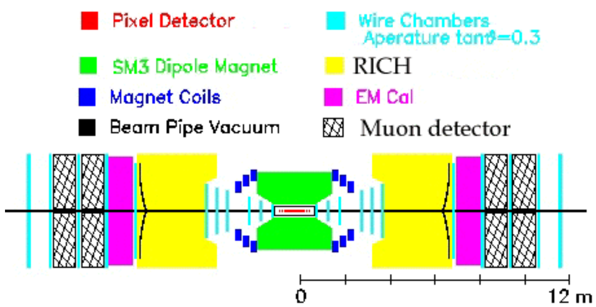
- Full GEANT simulations including pattern recognition done for trigger


Pixel Detector
Wire Chambers
Aperature tanθ=0.3
SM3 Dipole Magnet
RICH
Magnet Coils
EM Cal
Beam Pipe Vacuum
Muon detector
0
12 m

DAQ Scheme


Detector
7.6 MHz
crossing rate
200 KB/ Event
Buffer
Level 1 (secondary vertex, electron, muon)
Interaction rate: 15.2 million/sec
Latency: variable (0.05 – 1 ms)
Reduction: >100
Accept / Reject
70 – 100 kHz
200 KB/ Event
Buffer
Level 2 (refined tracking and vertex cut)
Partial reconstruction
Latency: variable (average time 20 ms)
Reduction: ~ 5 – 10
Accept / Reject
15 – 20 kHz
200 KB/ Event
Buffer
Level 3 (complete events)
Partial and full reconstruction
Latency: variable (average time 200 ms)
Reduction: ~ 5 – 10
2 – 4 kHz
Accept / Reject
Data Quality
Monitor
Data Storage
40 KB/ Event


1500
GBytes/sec
25
GBytes/sec
Subsystem
L1 Trigger
Global
L1 Trigger
L2/3 Data
Switch
Data Request
Network
L2/3
Processors



The Status of BTeV

- BTeV submitted a preliminary technical design report in May of 1999 and a full proposal in May of 2000.
- BTeV is an approved experiment, Fermilab E897.
- More information can be found at http://www-btev.fnal.gov