Overview of the BTeV B Program

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Physics Goals

Detailed study of CP violation in the B sector

- Precise measurements of standard model parameters in the b and c quark systems

- Search for physics beyond the Standard Model

How do you do this?

-High statistics production of B_d and B_s
(B_c Λ_b and charm too!)

- Reconstruct large samples of events in some key modes, but try to save all useful data.

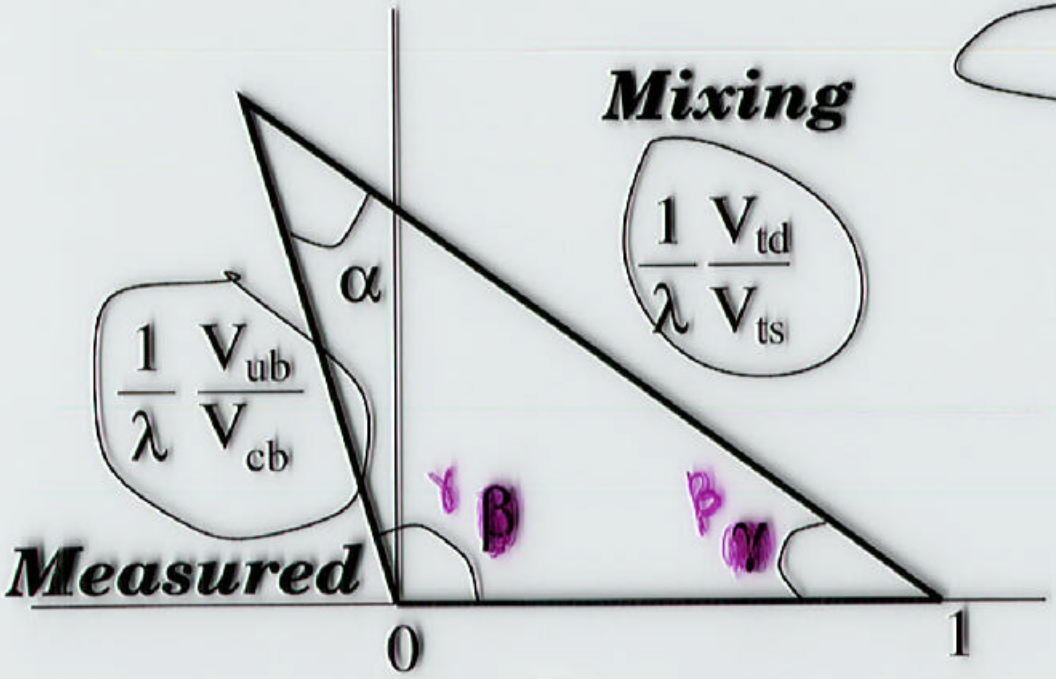
-Good triggering
-Good vertex resolution
-Boosted Heavy Flavors
-Good mass resolution
-Good Particle ID
-Have to cover a lot, really well.

A case study $B^0 \rightarrow \rho\pi$

-Want to over-constrain CKM, look for new Physics.

- Need to make lots of measurements

bd triangle



Key Modes

α	$B^0 \rightarrow \rho\pi$
γ	$B_d \rightarrow D K^*$
β	$B_d \rightarrow J/\Psi K_s^0$

A challenge $B^0 \rightarrow \rho\pi$

$B^0 \rightarrow \rho\pi$ - is rare (about 1 / 36000 B^0 decays)

- Contains a π^0, charged π's too.
- and to extract α you need to do a time resolved ***Dalitz*** analysis (Snyder and Quinn)

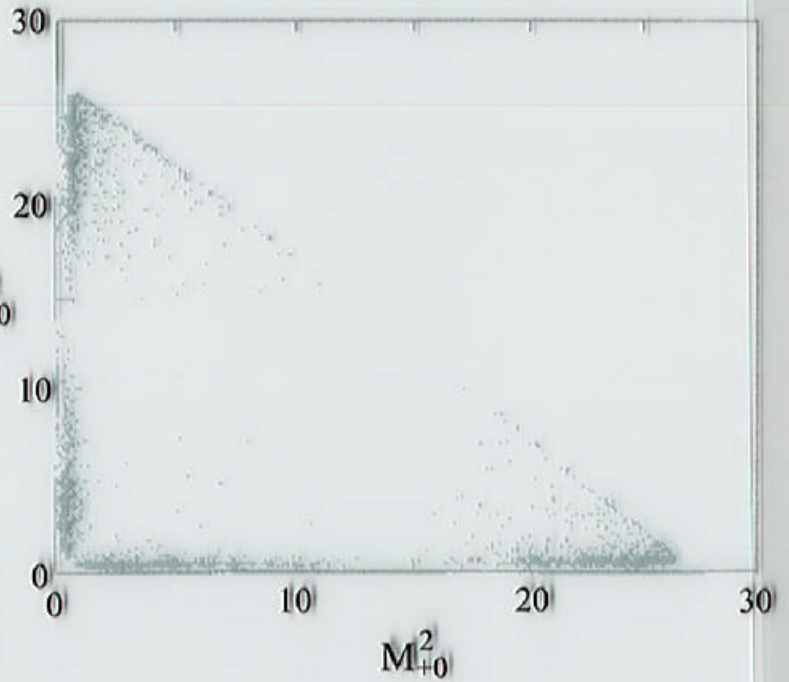
$B^o \rightarrow \rho\pi$ Decay Modes

Decay Mode	Decay Amplitudes
$\sqrt{2}A(B^+ \rightarrow \rho^+\pi^o)$	$=S_1 = T^{+o} + 2P_1$
$\sqrt{2}A(B^+ \rightarrow \rho^o\pi^+)$	$=S_2 = T^{o+} - 2P_1$
$A(B^o \rightarrow \rho^+\pi^-)$	$=S_3 = T^{+-} + P_1 + P_o$
$A(B^o \rightarrow \rho^-\pi^+)$	$=S_4 = T^{-+} - P_1 + P_o$
$2A(B^o \rightarrow \rho^o\pi^o)$	$=S_5 = T^{+-} + T^{+-} - T^{+o} - T^{o+} - 2P_o$

Γ^{ij}(Tree Amplitude) P_k(Penguin)

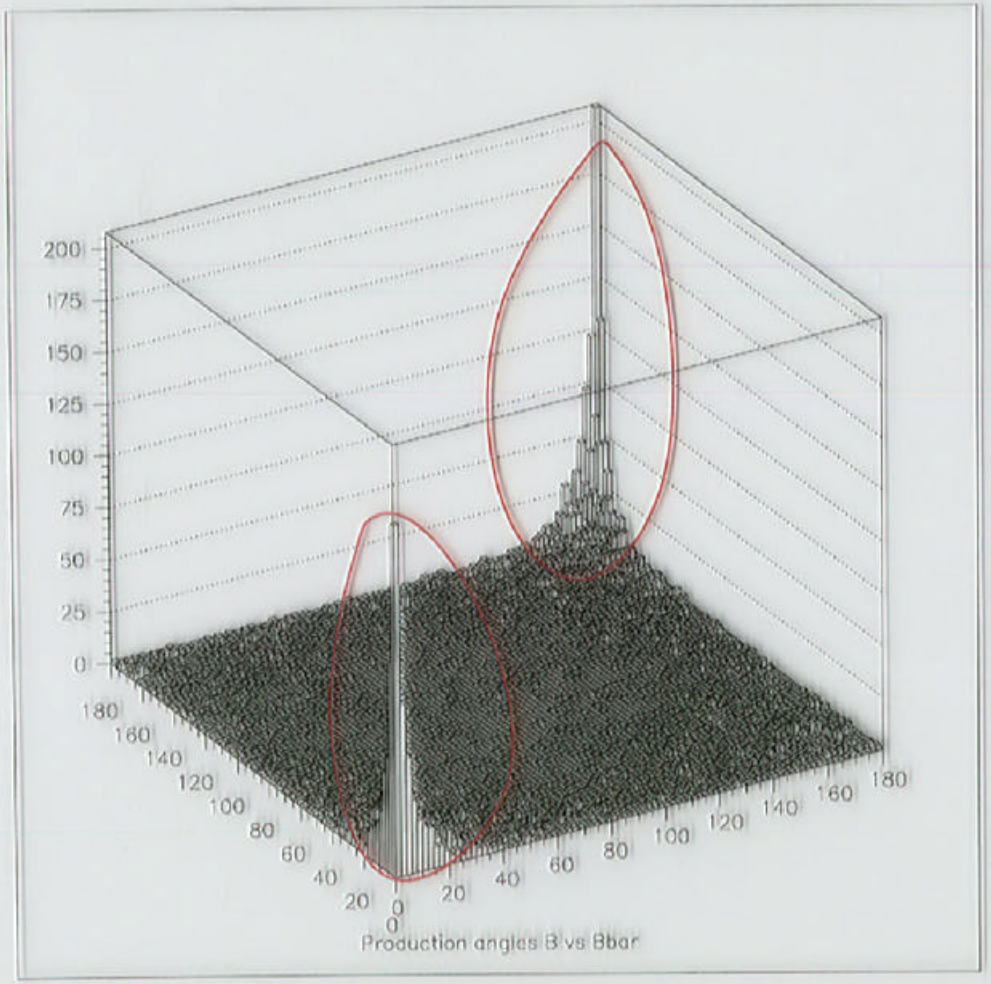
Add B^0 modes, penguins cancel.

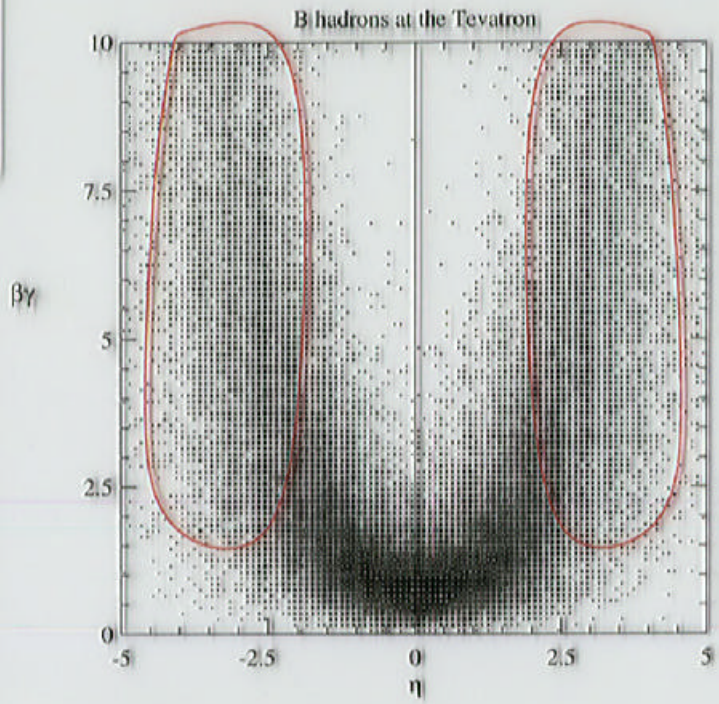
Need 2000+ events



Producing Copious B's

Lots, "Forward" and "Boosted"

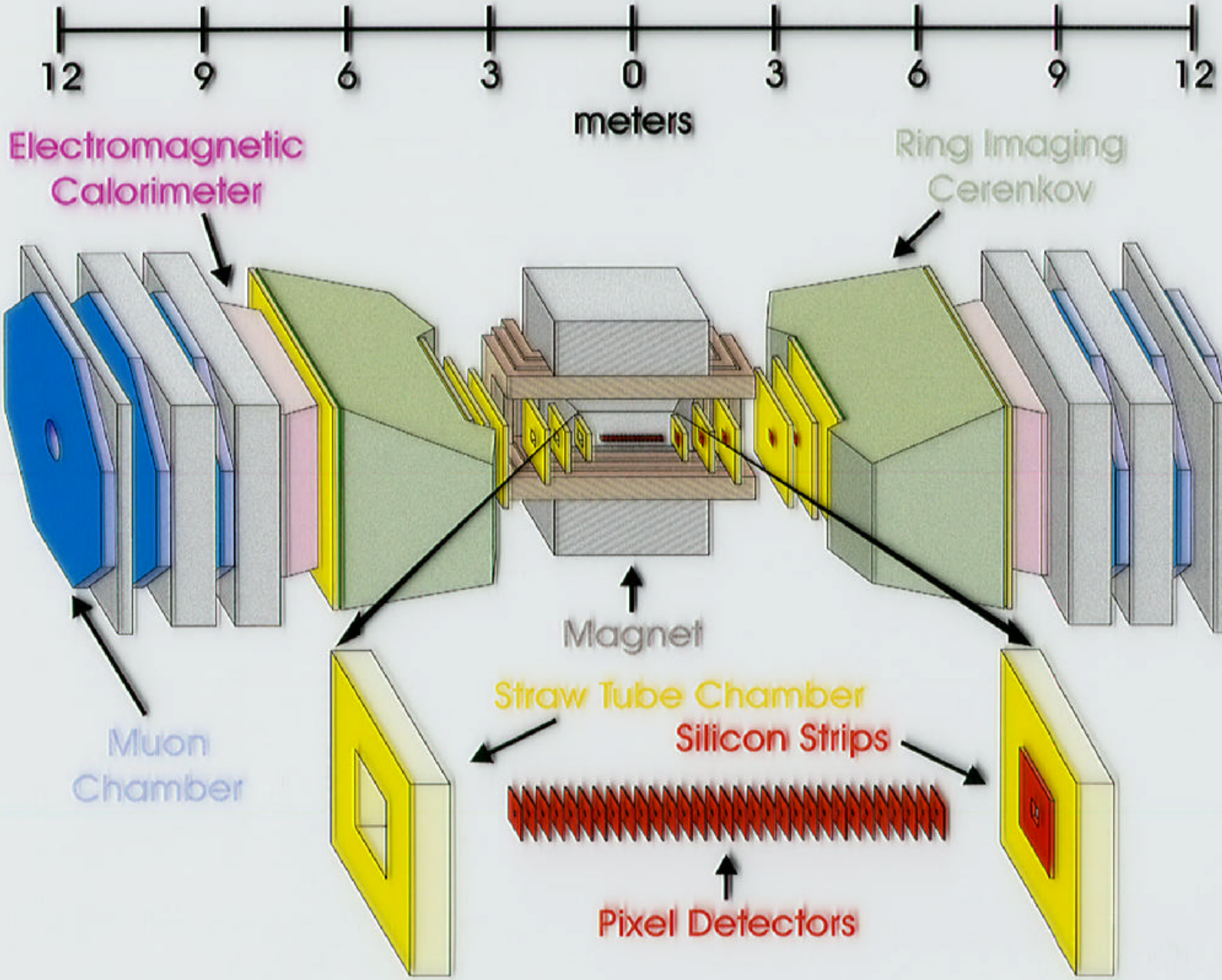




BTeV at the Tevatron

Luminosity (BTeV design)	2×10^{32} cm^{-2}s^{-1}
$b\bar{b}$ cross-section	100 μb
# of b's per 10^7 sec	4×10^{11}
$\frac{\sigma(b\bar{b})}{\sigma(total)}$	$\sim 0.15\%$
$c\bar{c}$ cross-section	> 500 μb
Bunch spacing	132 ns
Luminous region length	$\sigma_z = 30$ cm
Luminous region width	$\sigma_x, \sigma_y \approx 50$ μm
Interactions/crossing	$< 2.0 >$

BTeV Detector Layout



Tracking Pixels

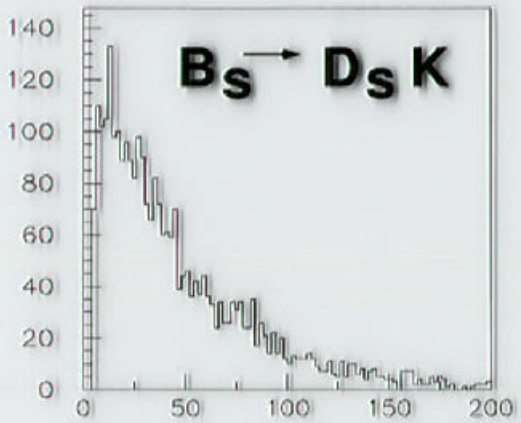
Silicon Strips, Straws

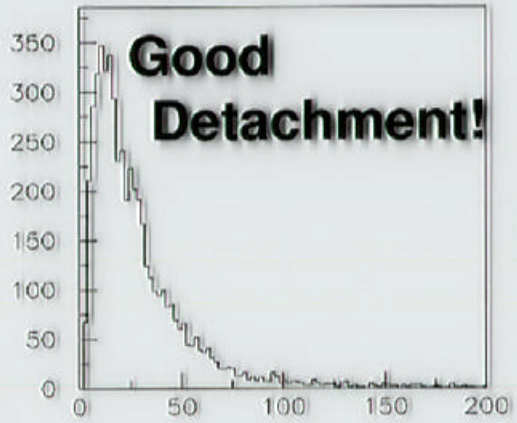
-Pixels in 1st level trigger (1/100)
(Crude Vertex, Impact)

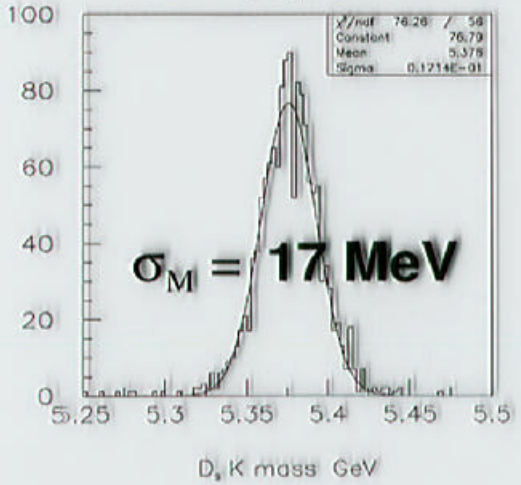
- 2nd level, add Straws, Strips (1/10)
(Better Vertex, Impact)

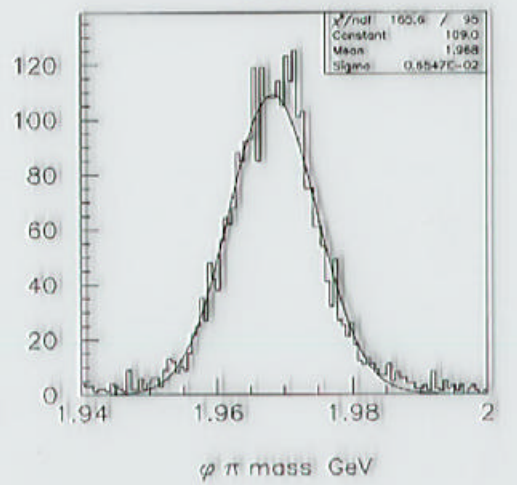
-3rd Level ~ full tracking (1/2)
(L/σ , one prongs)

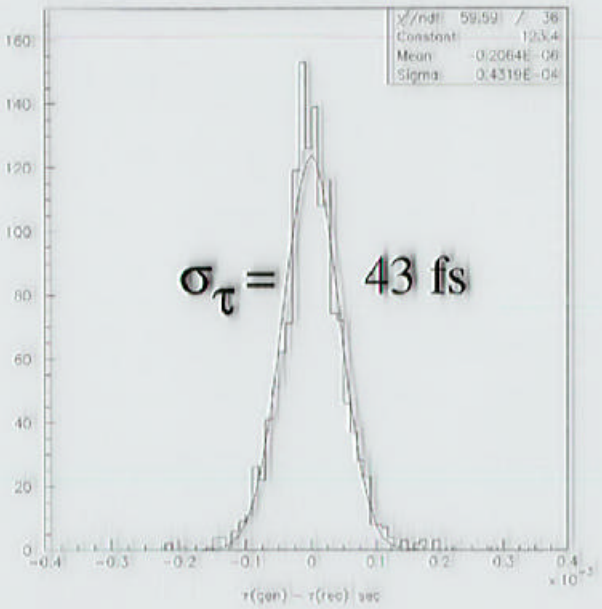
Data Rate ~4kHz (~1kHz B's)





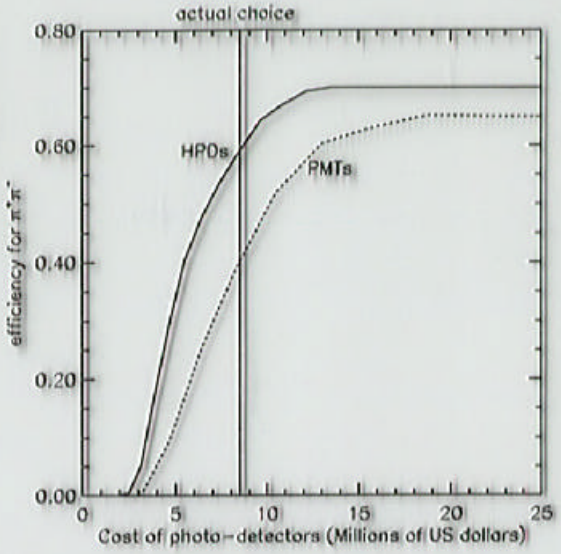






Particle ID
RICH

1888 HPD's give 4σ
π–K sparation for 60%
$B \rightarrow \pi\pi$ efficiency

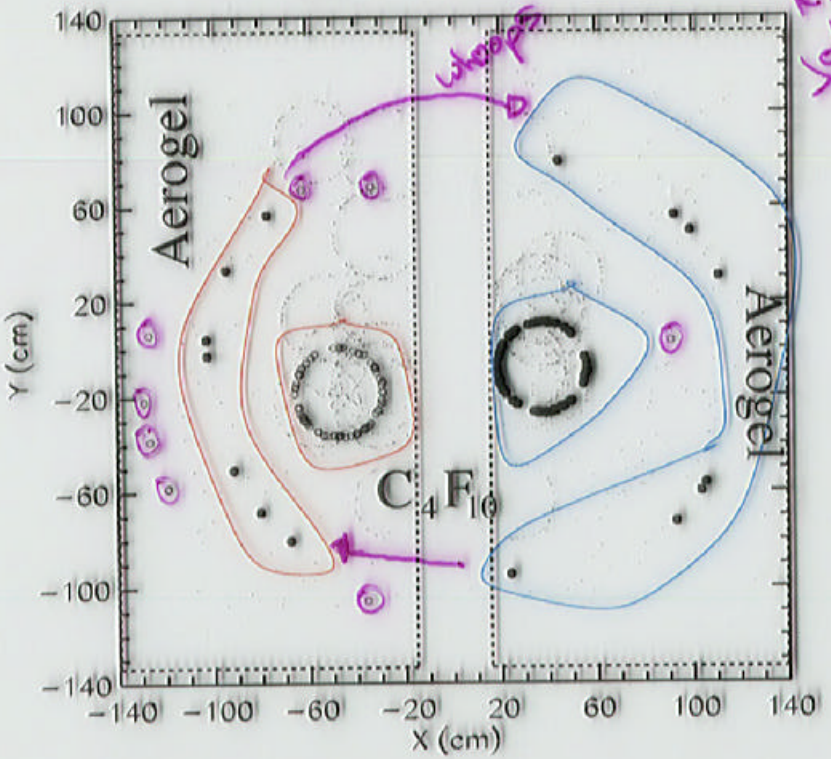


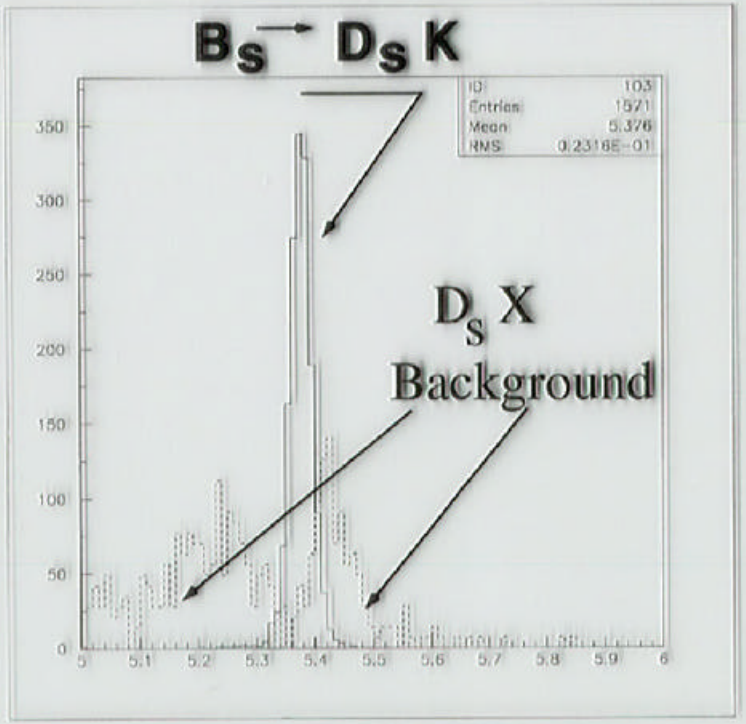
- Use Aerogel and C_4F_{10}

- pion - kaon separation from 3 GeV to 70 GeV

$B \rightarrow \pi\pi$

Rich does better job than I do!

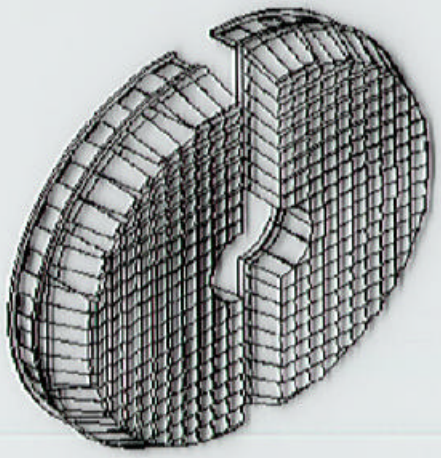


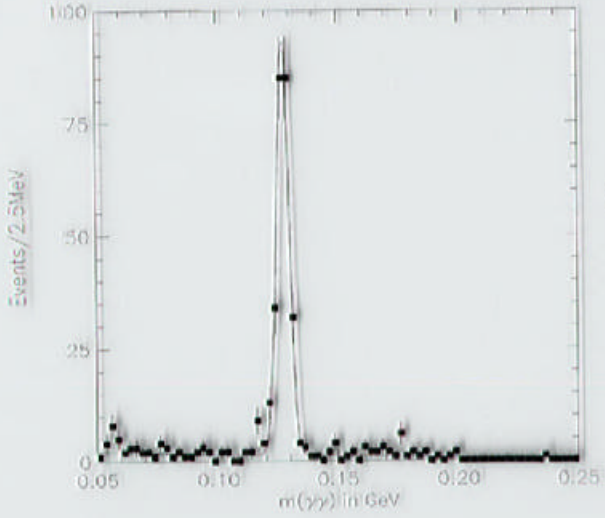


Photon Reconstruction

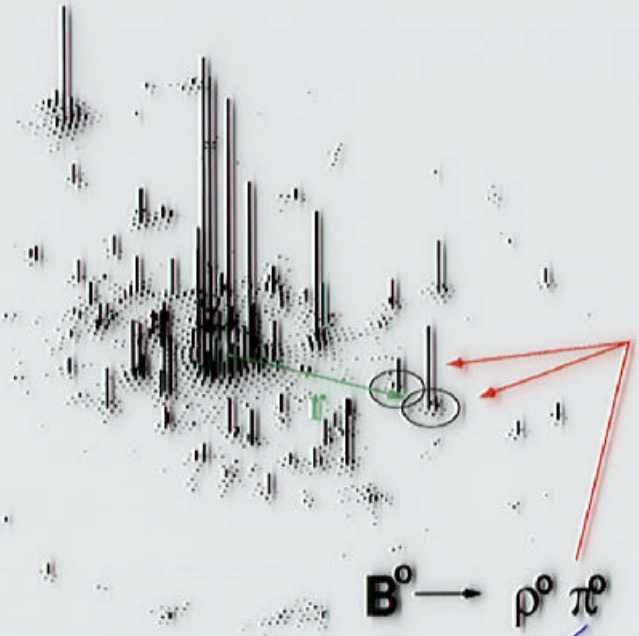
EM Cal

24000 $PbWO_4$ Crystals

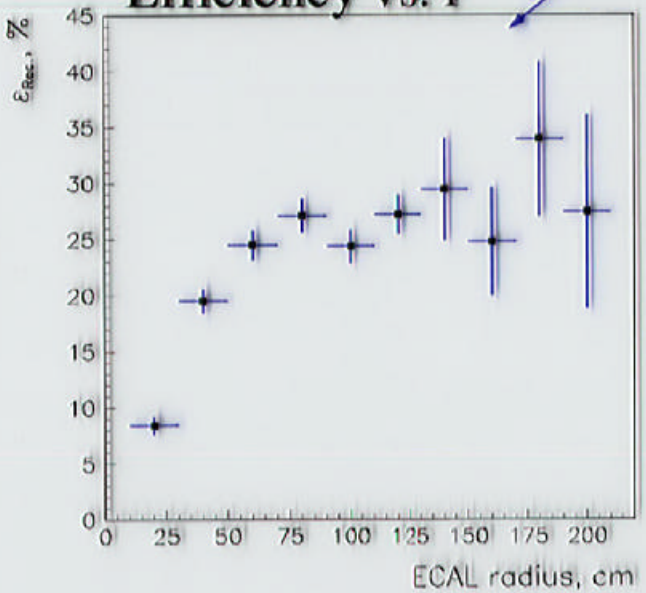




$\sigma_{M(\pi^0)} = 2.6$ MeV



Efficiency vs. r

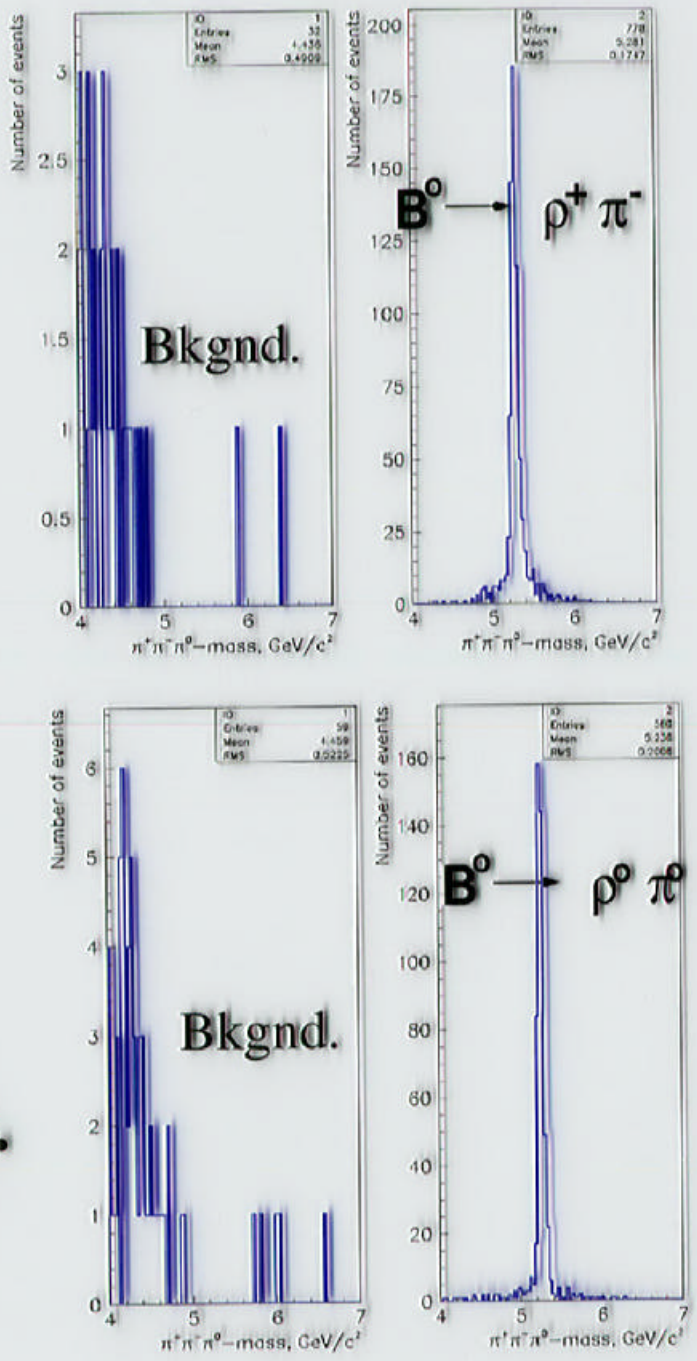


Putting it all together

$B^0 \to \rho\,\pi$ Yields

Quantity	$\rho^{\pm}\pi^{\mp}$	$\rho^0\pi^0$
Branching ratio	2.8×10^{-5}	0.5×10^{-5}
Efficiency	0.0044	0.0036
Trigger efficiency (Level 1)	0.6	0.6
Trigger efficiency (Level 2)	0.9	0.9
S/B	4.1	0.3
Signal/10^7 s	9,400	1,350
ϵD^2	0.10	0.10
Flavor tagged yield	940	135

2 years of running for 2000 ev.

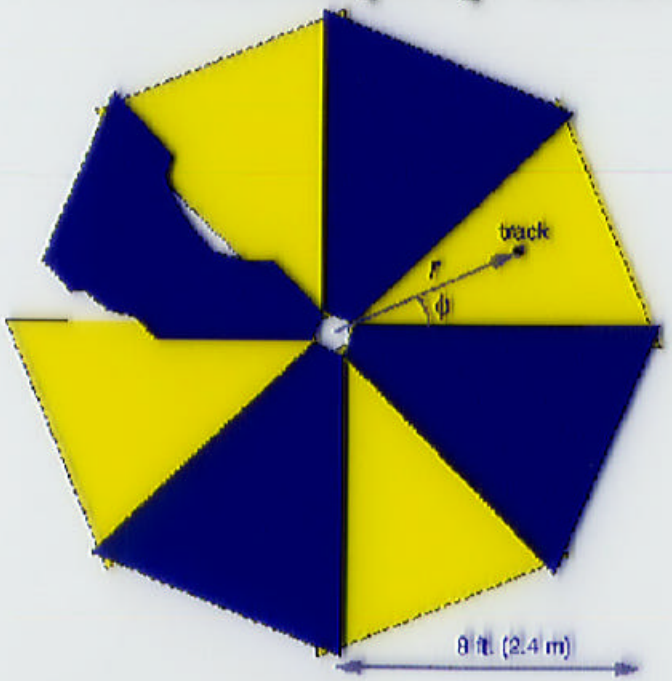


Muon System

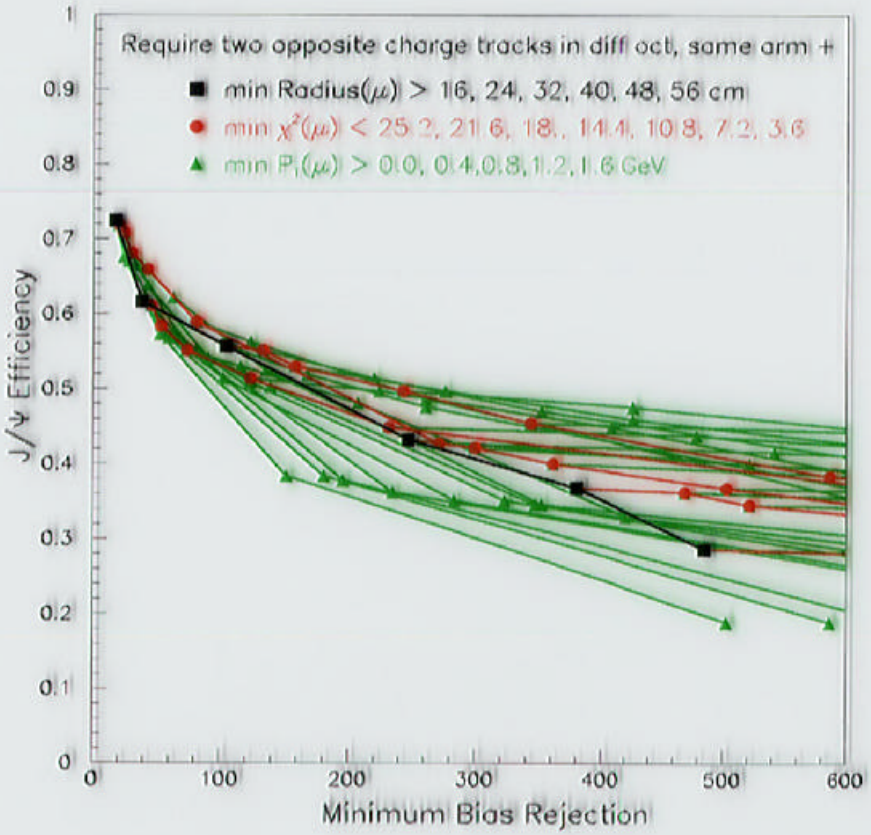
-Extra and complimentary trigger for J/Ψ

-ID for rare modes and semileptonics
(EM cal does electron ID)

-Magnetized Toroids
~73000 prop tubes



Arranged in octagons



Some BTeV estimates compared to the LHC

Info from Val Gibson talk, Sheldon Stone, CERN-TH/2000-101, & BTeV Proposal

$10^{34}/cm^2s$

Process	Comparison	BTeV	LHCb	ATLAS	CMS	e^+e^-
$B^o \to \pi^+\pi^-$ [1]	Yield/$10^7 s$	24k (2.4K tag)	12k	2.3k (tag)	0.9k(tag)	36(tag)
$B^o \to J/\Psi K_s$ [2]	Yield/$10^7 s$	80k	88k	165k	433k	~27k
$B^o \to \rho\pi$ 2 chgd. π	Yield/$10^7 s$	11k	3.3k	-	-	
$B_s \to D_s^{\pm} K^{\mp}$	Yield/$10^7 s$	13k	6k	-	-	
$B_s \to D_s^{\pm}\pi^{\mp}$	Yield/$10^7 s$	103k	86k	3.5k	4.5k	
$B_s \to D_s^{\pm}\pi^{\mp}$	X_s Reach/$10^7 s$	75	75	46	42	
$B_s \to J/\Psi\eta^{(\prime)}$	Yield/$10^7 s$	9k	-	-	-	
$B_s \to J/\Psi\Phi$	Yield/$10^7 s$	-	370k(5 yrs)	300k(3 yrs)	600k (3 yrs)	
$B_s \to J/\Psi(\Phi$ or $\eta^{(\prime)})$	$\sigma \sin(2\chi)/10^7 s$	0.033	0.03(5 yrs)	0.05(3 yrs)	0.03(3 yrs)	

Not at e+e-!

[1] $\sigma_{e^+e^-} = 1.1nb$, $\varepsilon = .3$, $\varepsilon D^2 = .3$, $B = 0.5\times10^{-5}$

[2] $(10^7/2\times10^9)\times4$ of BaBar "start" sample

BTeV does very well!

For Icarus

$B^- \to \bar{D}^0 K^-$

BTeV ($10^7 s$): 300evts

e^+e^- ($10^7 s$ @ $10^{34}/cm^2 s$): 6evts

$B = 1.7\times10^{-7}$, $\varepsilon = 0.5$

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In Conclusion

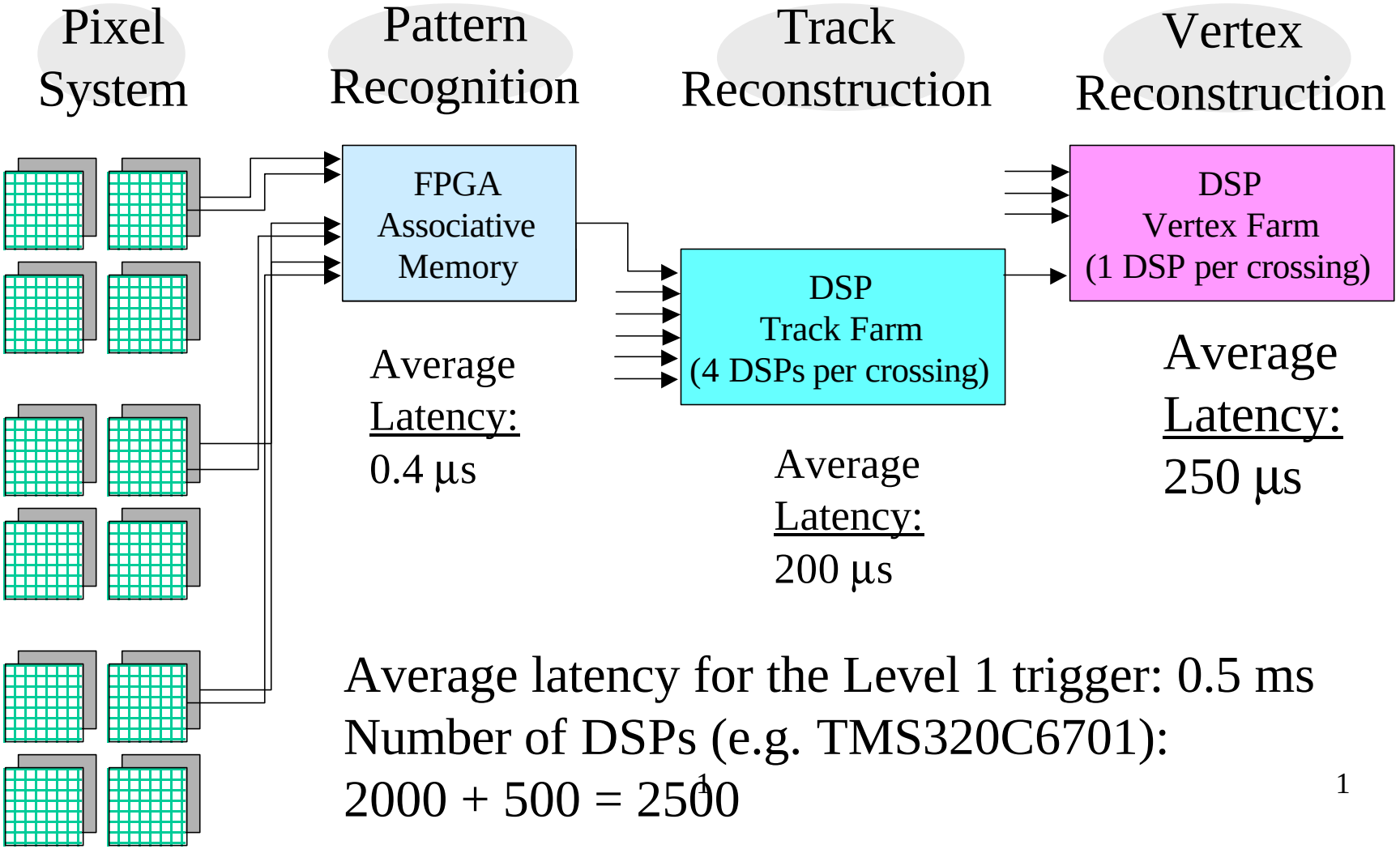
- BTeV is a state of the art detector well suited to the detailed study of CP violation in the B sector

- The trigger is designed to be efficient and flexible (can't predict everything)

-The particle ID and calorimetry will make BTeV very versatile

-Our studies show that we will be competitive with LHC experiments

Block Diagram of Level 1



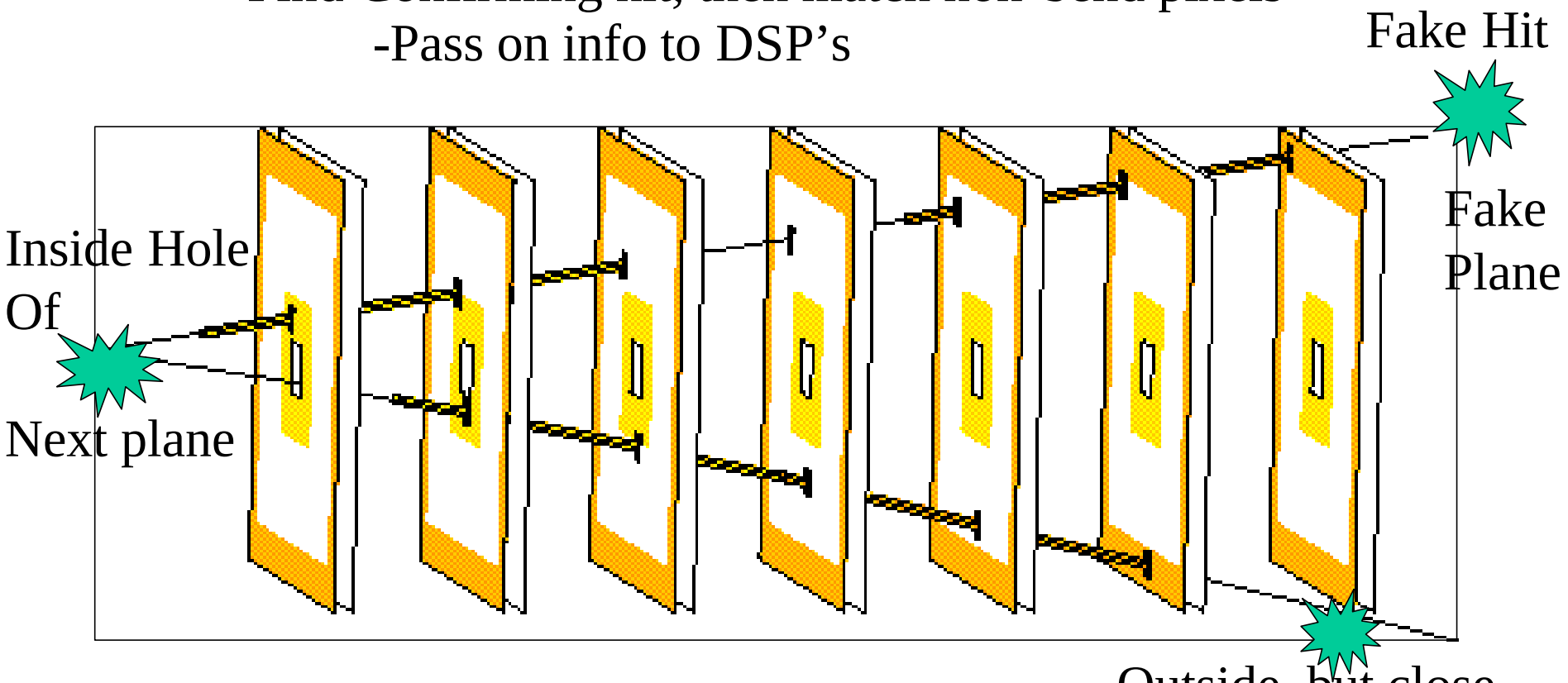
Average latency for the Level 1 trigger: 0.5 ms

Number of DSPs (e.g. TMS320C6701):

2000 + 500 = 2500

BTeV Pixel Trigger (FPGA)

-Form Hit Clusters, sort by quadrant (More Parallel)
-Search “In out” and “Out in” in precision bend view
-Start near pipe and near edge – Use Beam/Material constraints
-Find Confirming hit, then match non-bend pixels
-Pass on info to DSP’s



Approach reduces combinatorics too

BTeV Pixel Trigger (DSP Part A)

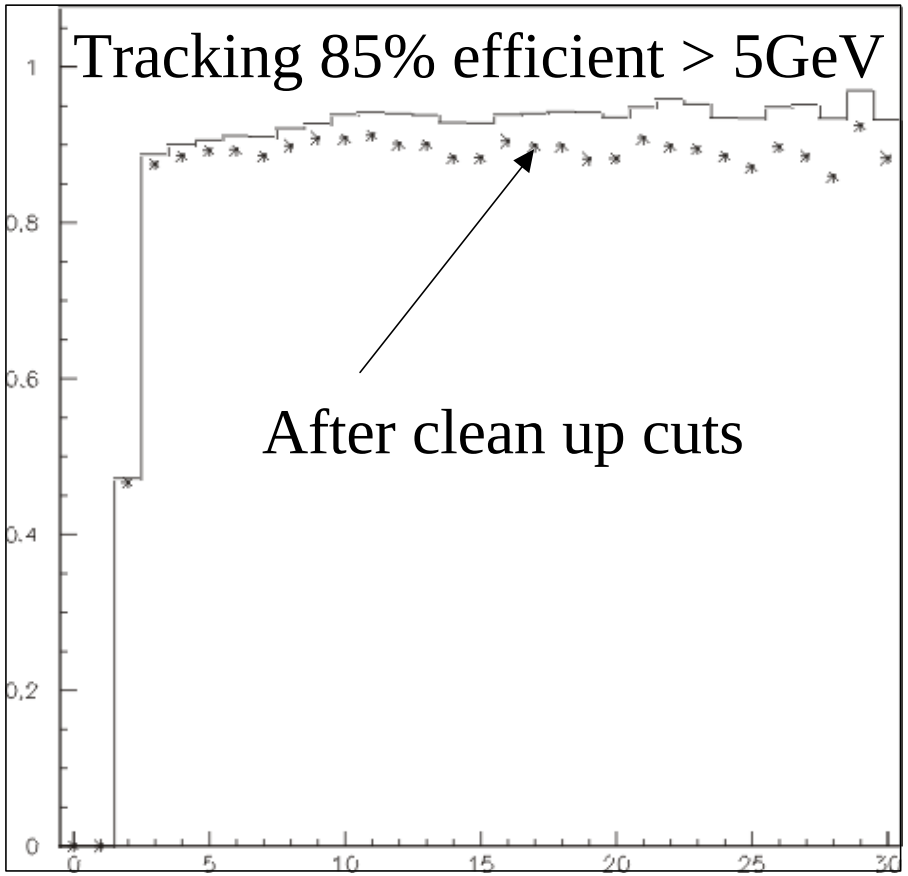
DSP's Form tracks form segments found by FPGA's

-BTeVGEANT contains hadronic interactions, γ conversions, δ-rays

-Pixel hits have non-Gaussian tails (derived from test beam data)

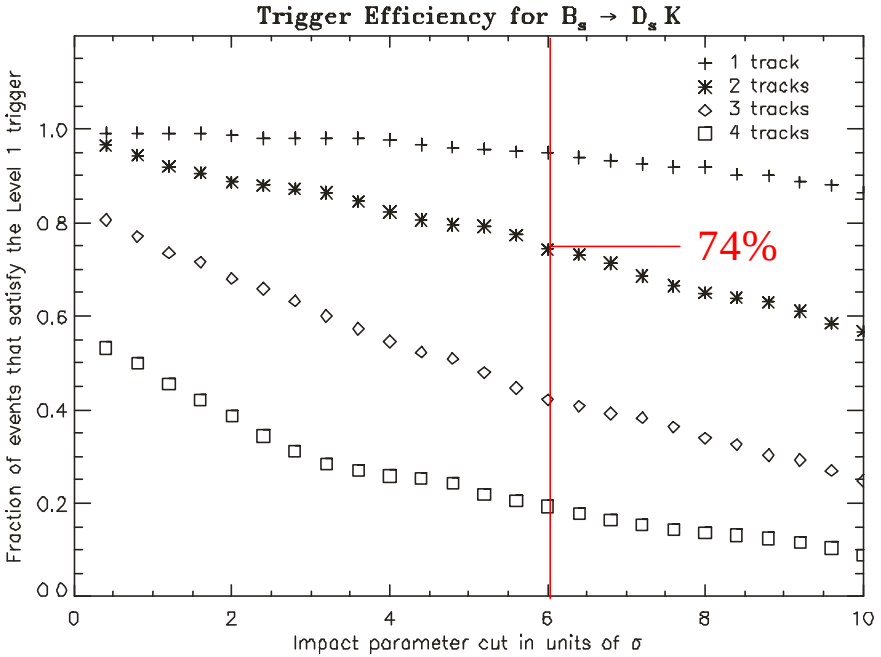
-Average of 2 interactions per crossing

Tracks get passed to Vertex DSP



Momentum of tracks in fiducial

BTeV Pixel Trigger (DSP Part B)



Keep ~50% of B's

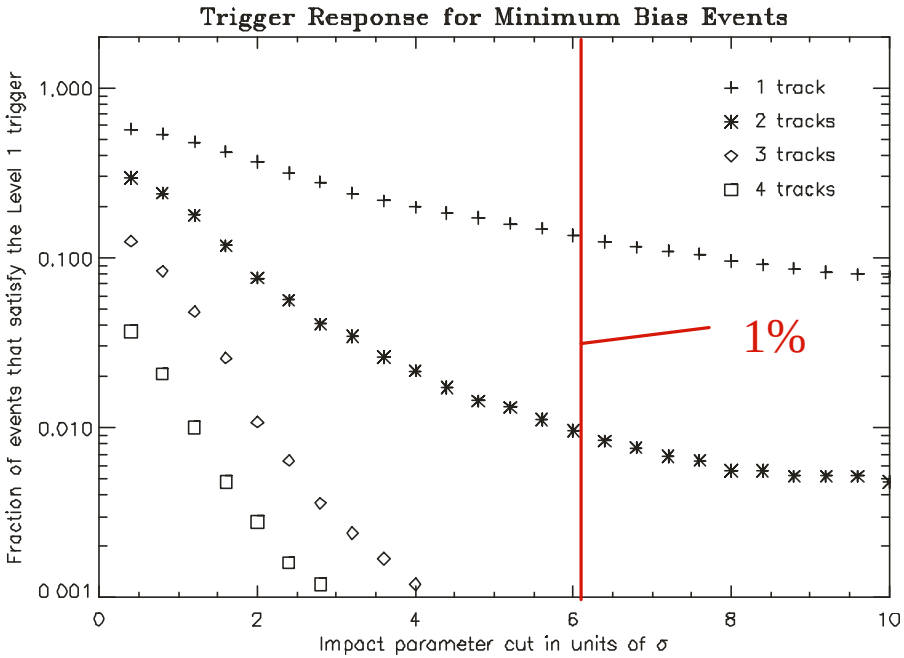
Reject 99% of min bias

-Form Verticies

-Require 2 tracks:

a) Within 2mm of primary

b) > 6 "errors" of impact



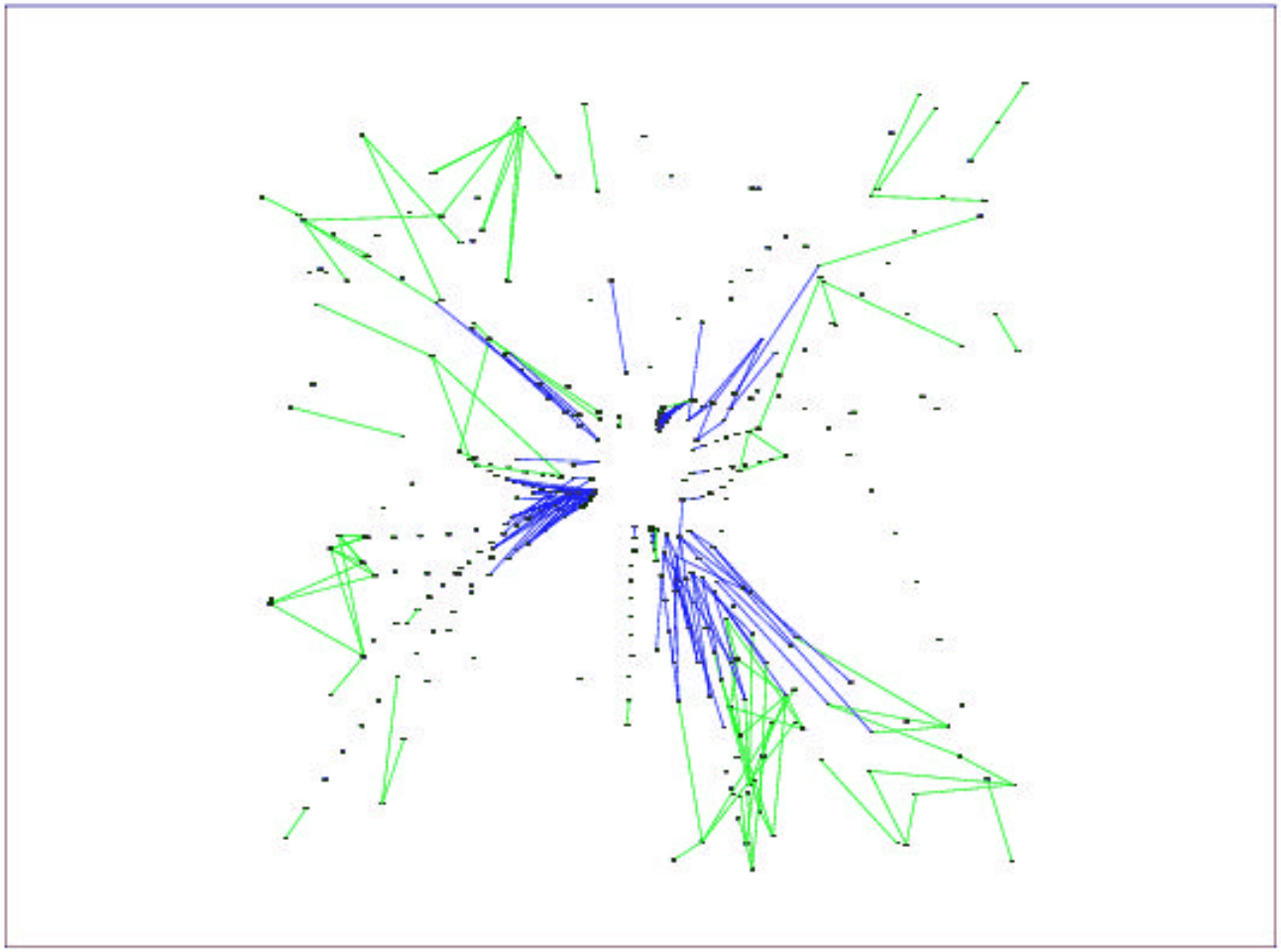
L1 Trigger Performance

State	efficiency(%)	state	efficiency(%)
$B \rightarrow \pi^+\pi^-$	63	$B^o \rightarrow K^+\pi^-$	63
$B_s \rightarrow D_sK$	71	$B^o \rightarrow J/\psi\ K_s$	50
$B^- \rightarrow D^oK^-$	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

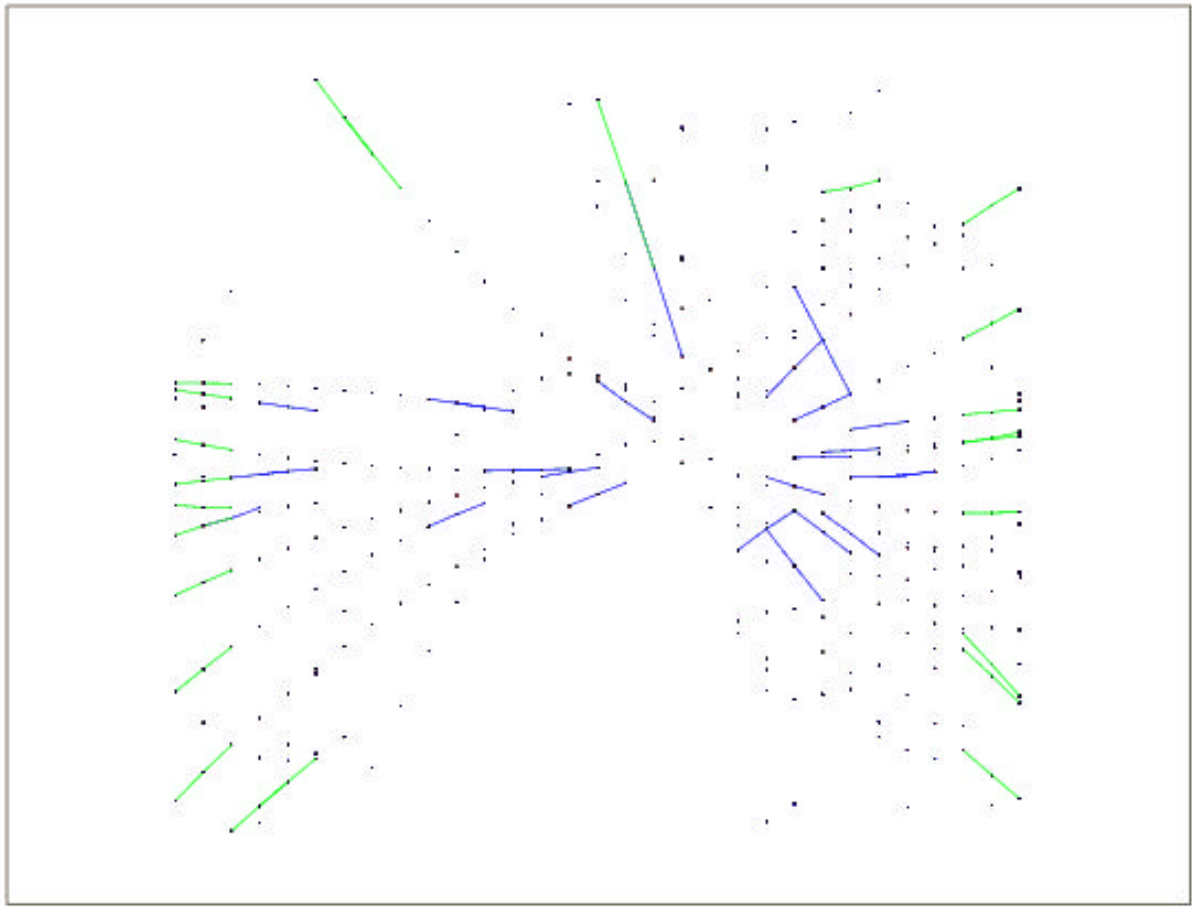
Refinements and Recoveries in Level 2 and Level 3

Cleaning Up Segments: The Movie



Pixel hits after 1st segment finding

Cleaning Up Segments: The Sequel



This is the most Dramatic change..