CDF - Secondary vertex trigger

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for the CDF Collaboration

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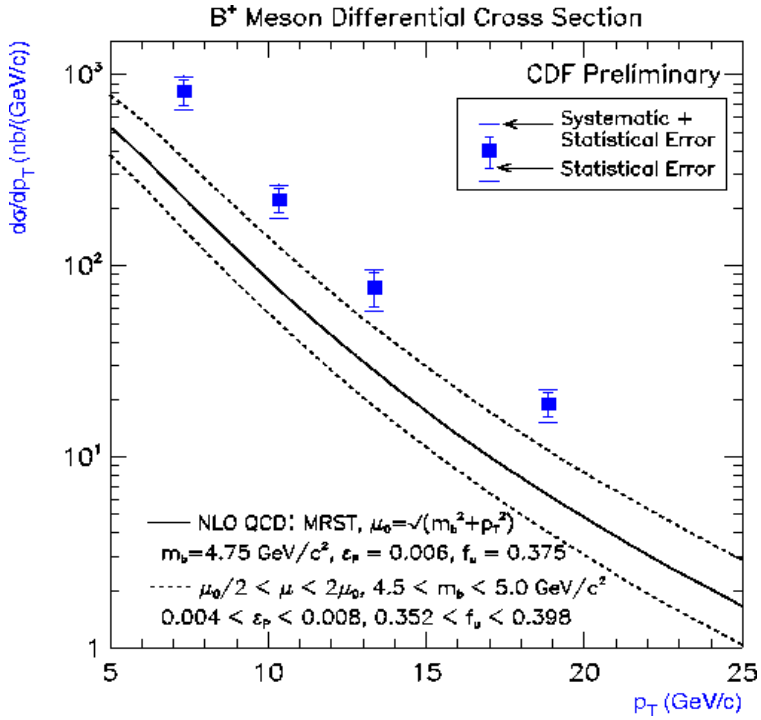
- Why an impact parameter trigger at Hadron Colliders
- How implement a such a trigger
- Performances and Physics results

Why B Physics at hadron colliders

- ✓ High cross section:
  - o $\Upsilon(4S) \approx 1$ nb (only B^0, B^+)
  - o $Z^0 \approx 7$ nb
  - o $p\bar{p} \approx 100$ μb
- ✓ Many B hadron species produced:
  $B^{\pm}$, B^0, B_s, B_c, Λ_b, Ξ_b



but

large $p\bar{p}$ inelastic cross section $\sigma_{tot} \approx 100$ mb

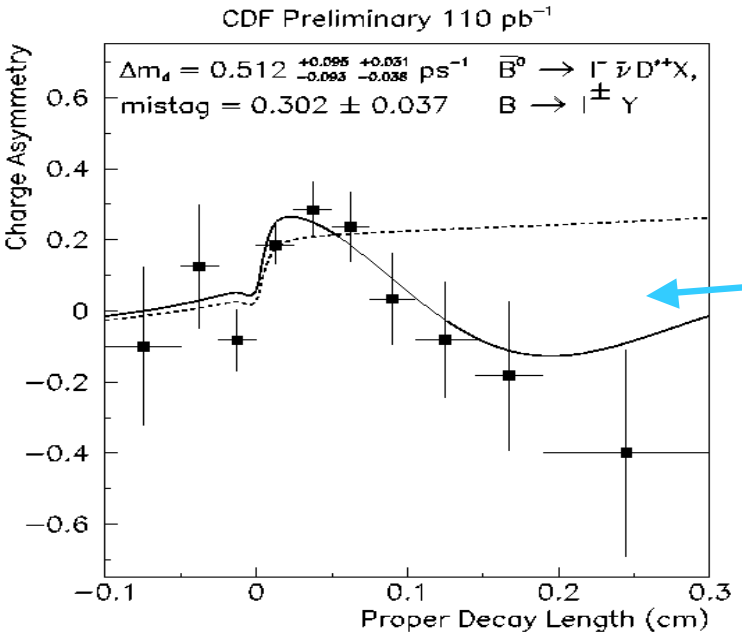
Need specialized triggers

B physics in the old era

Many B physics measurements,i.e: $\sin 2\beta$, Δm_d

Lepton-based triggers:

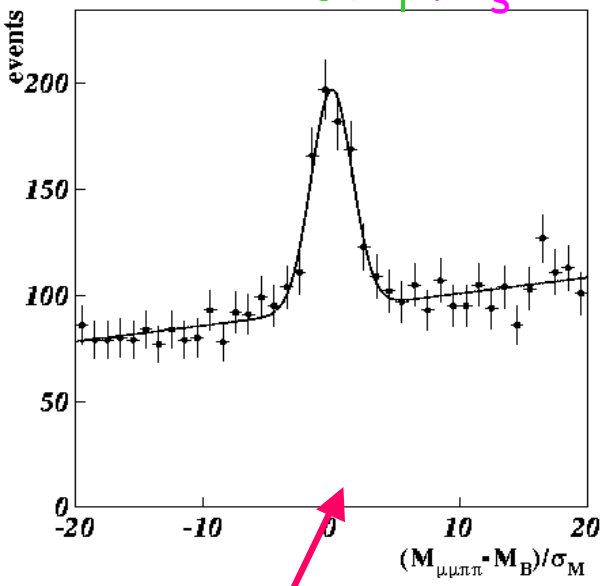
- J/ψ (mainly $\mu\mu$) in the final state
- semileptonic decays:
  low BR and neutrino presence



$B^0 \rightarrow l^+ \nu D^{*-}$

Δm_d

$B^0 \rightarrow J/\psi K^0_s$



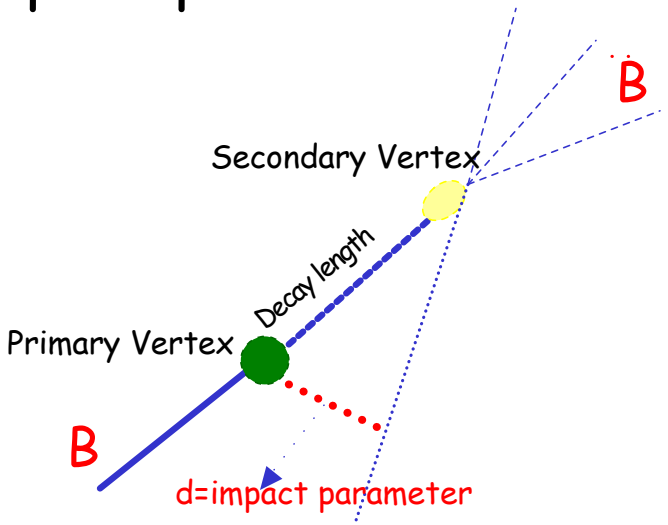
$\sin 2\beta$

The new era: Silicon Vertex Tracker (SVT)

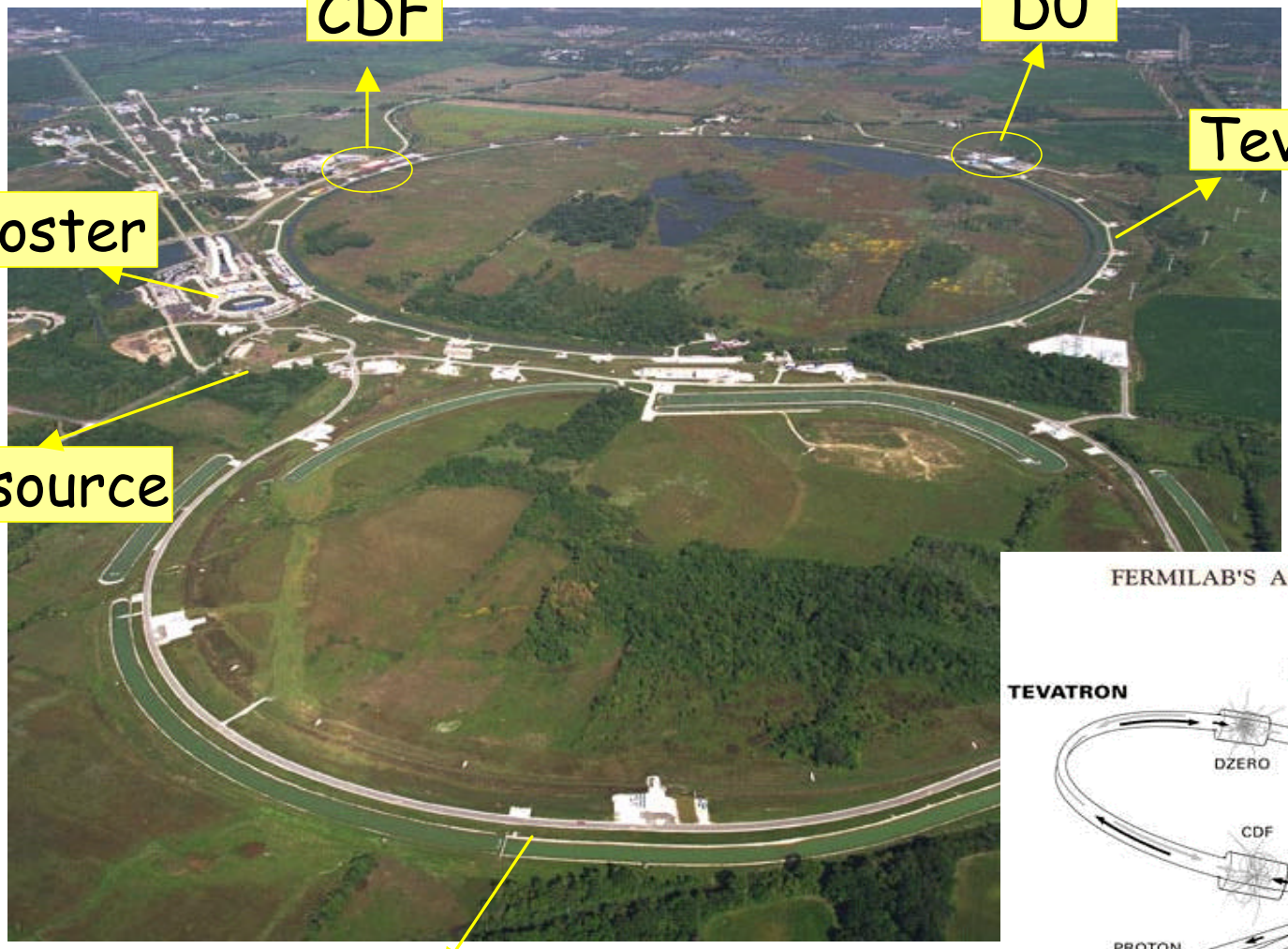
Fully hadronic modes are crucial for B_s mixing and CP violation measurements

Q. Is it possible to disentangle $B \rightarrow$ hadrons signal from background ?

A. SVT ⟹ we can trigger on $B \rightarrow$ hadrons decays by exploiting the impact parameter

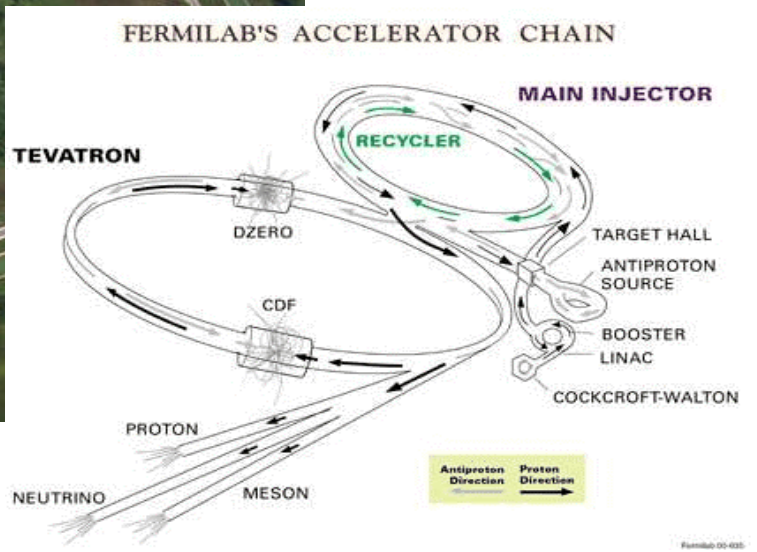


The New Machine

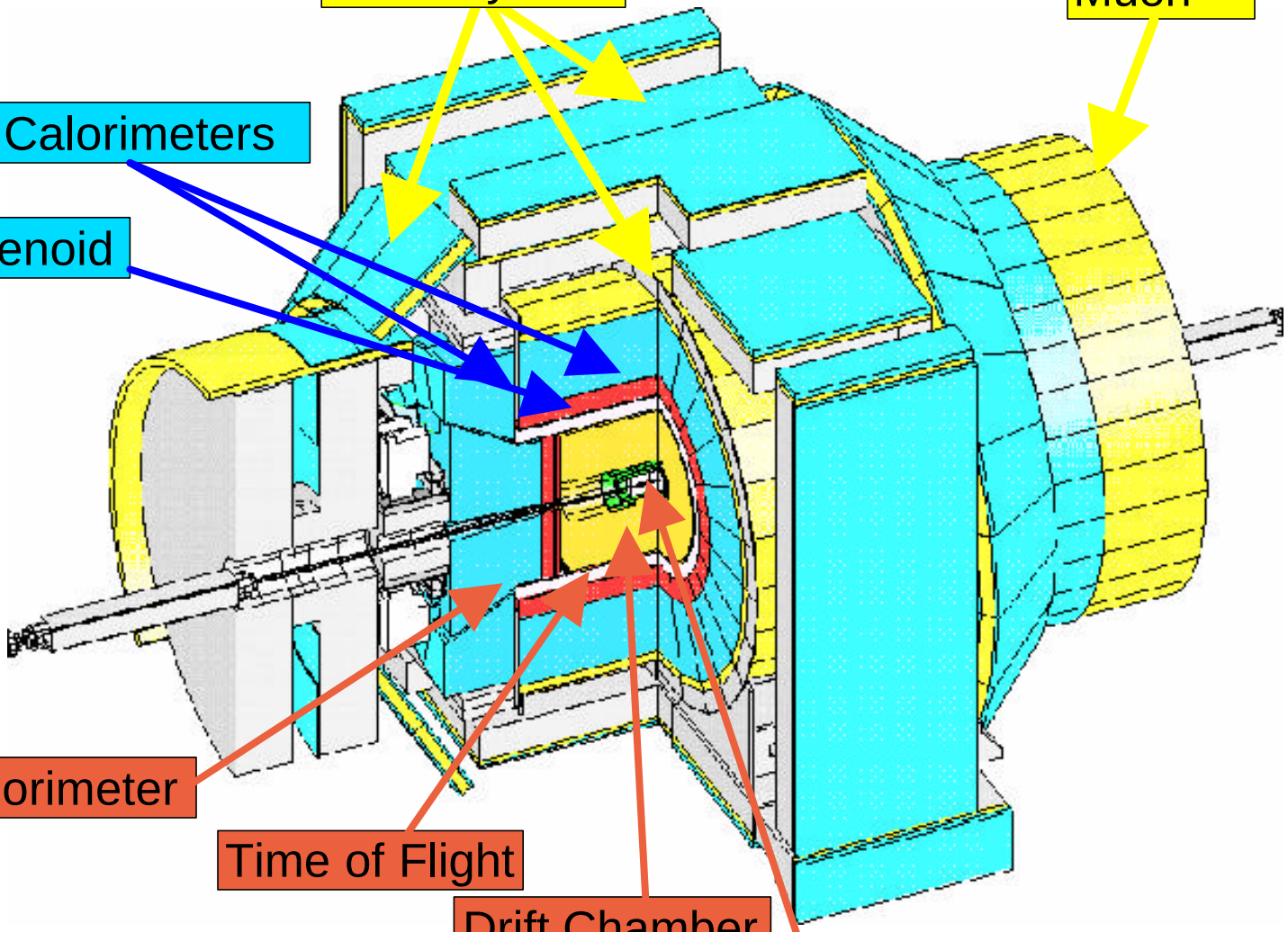


L_{peak}: ~$1 \times 10^{32} s^{-1} cm^{-2}$

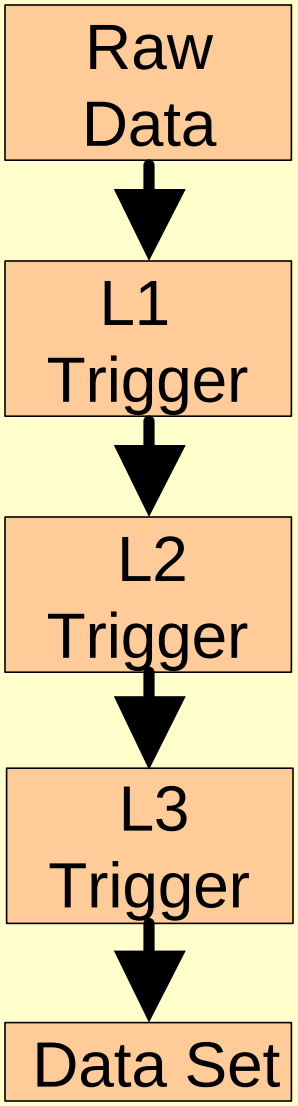
Bunch spacing: 396 ns



The Detector



Trigger Overview



Crossing rate:1.7 MHz
Inelastic Cross Section: 56mb

Acc. Rate 40 KHz (400 mb)
Latency 5.5 μs
Pipeline: 42 clock cycles

Acc. Rate 300 Hz (3 mb)
Latency 20 μs
Buffer: 4 events

L3 Acceptance Rate
75 Hz (750 nb)

Average size
60 Kbytes/event

Level 1 synchronous streams:

- Calorimeter
- eXtremely Fast Tracker
- Muons

Level 2 asynchronous systems:

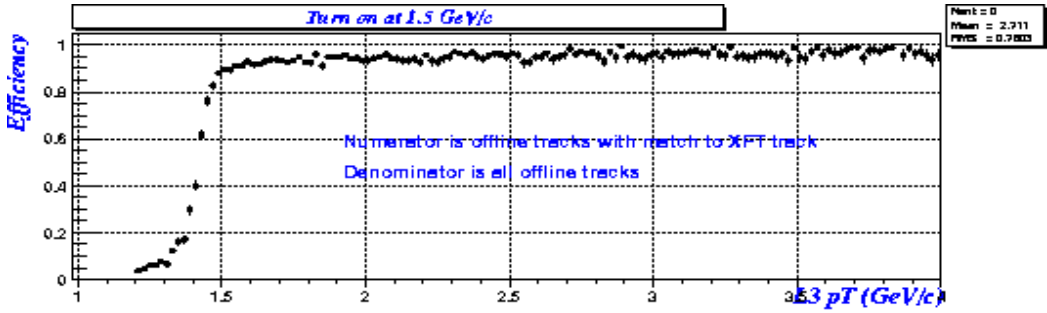
- Calorimeter Clustering
- Silicon Vertex Tracker
- Shower Maximum

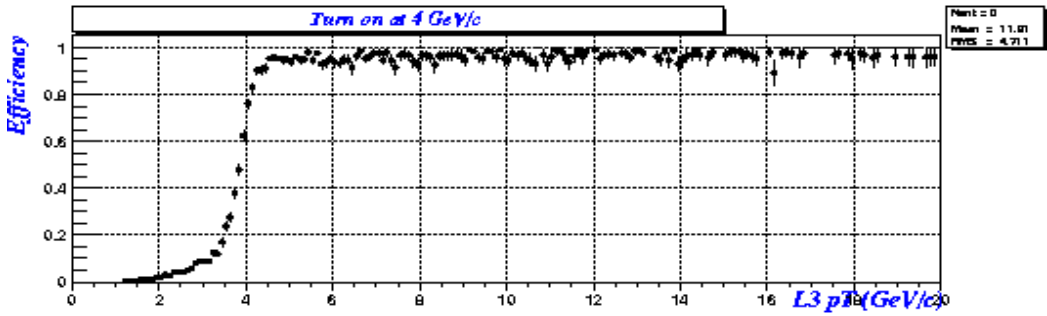
Level 3:

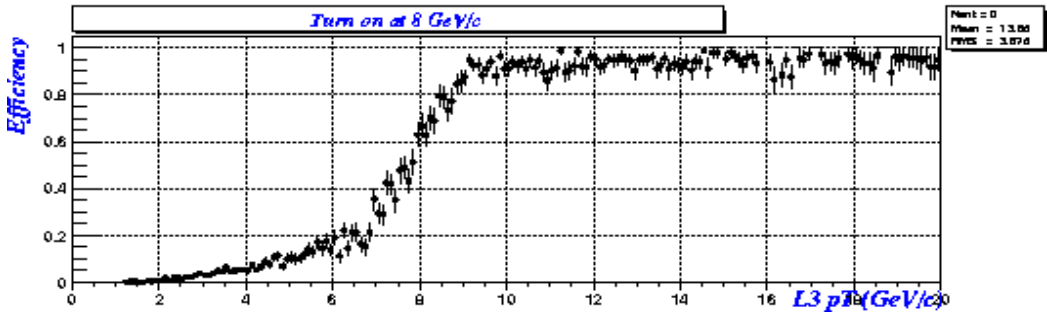
- Offline-like

L1 Track Trigger: XFT

Uses Central Outer Tracking chamber axial hits (4 Super Layers)
Finder: looks for segment in each SL
Linker: matches 4 segments



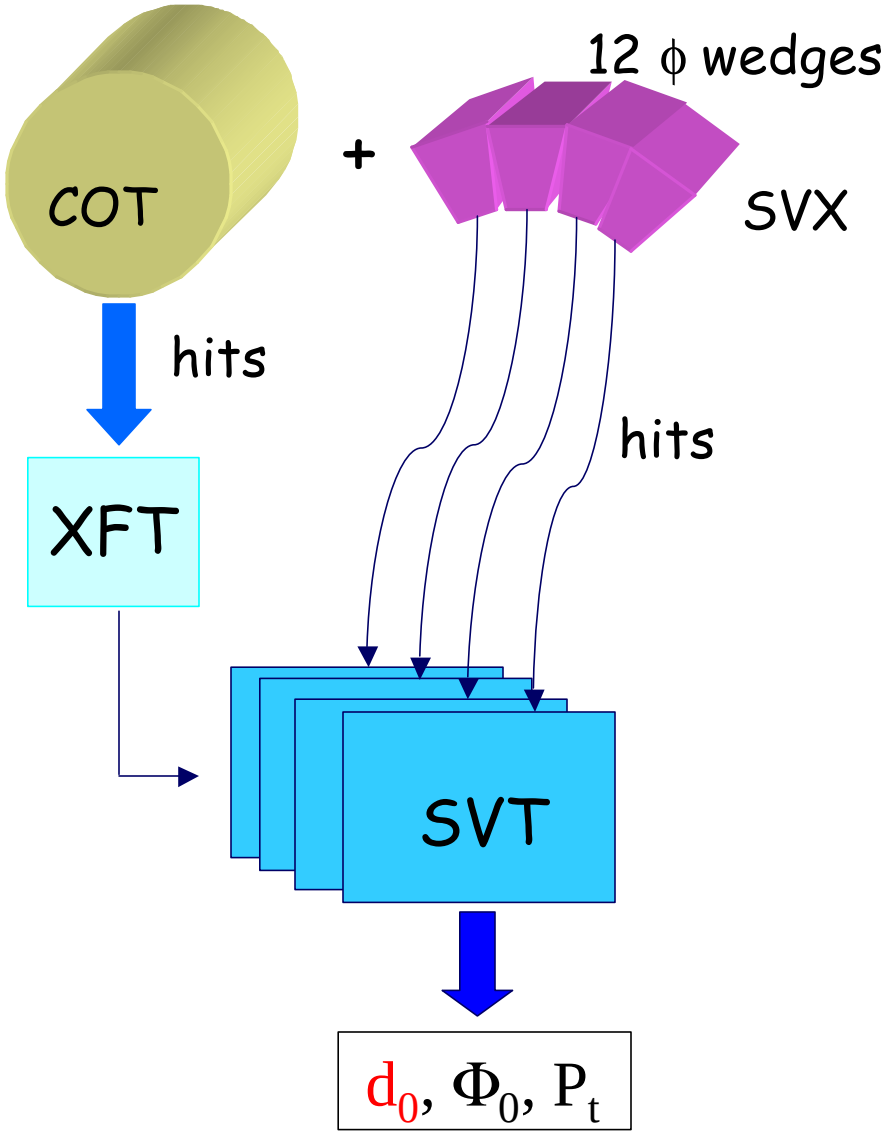




Performances:

- $dP_t/P_t^2 = 1.65\%\ (GeV)^{-1}$
  design: $2\%\ (GeV)^{-1}$
- $\Delta\Phi = 5.1$ mrad
  design: 8 mrad

L2 Track Trigger: SVT Overview

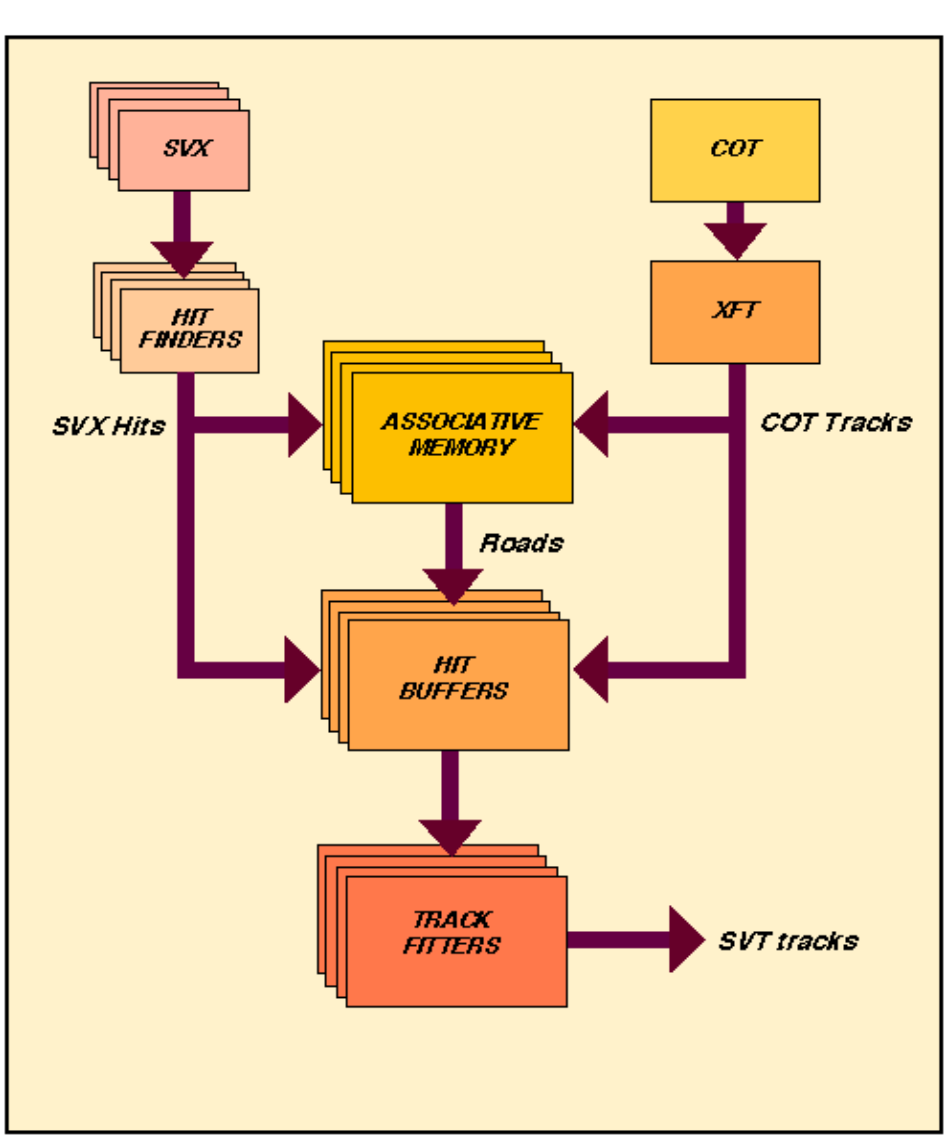


Requirements:

- Impact parameter resolution as good as offline (~ 35 μm)
- Fast (~ 10 μs)
- No dead time

- Drop stereo info: 2D tracking
  Beam parallel to SVX
- Parallel processing (12 ϕ sectors, each 30°)
- Data driven pipeline

SVT: System architecture



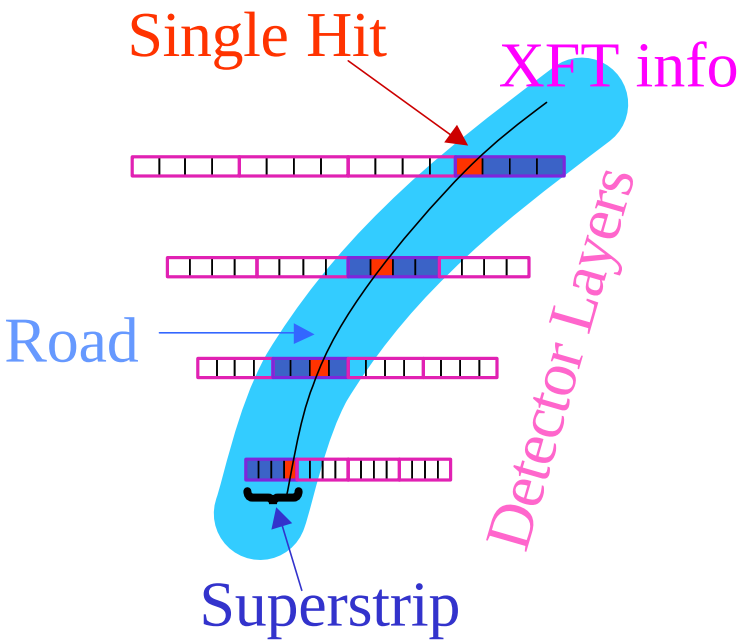
Hit finder: computes and outputs the centroid of each SVX cluster

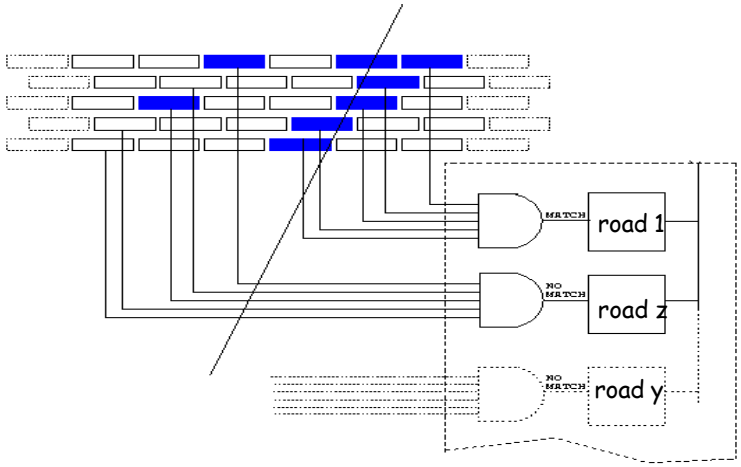
Associative memory: pattern recognition

Hit buffer: retrieves the original full resolution silicon hit coordinates and XFT track associated with each road

Track fitter: fits XFT track and SVX hits

SVT: Pattern Recognition (AM)





Full custom VLSI chip

0.7μm technology

35mm^2,

180000 transistors

Working up to 40MHz

The AM chip is the physical realization of the template matching pattern recognition algorithm: each AM Chip can compare each hit with all the patterns in memory in parallel, providing the high speed necessary for trigger applications.

With the AM, pattern recognition is complete as soon as the last hit of an event is read!

Coarser resolution
250 μm superstrips
95% coverage
each 30° slice:
2AM boardx128chipsx128roads~32.000 roads

SVT: Track fitting

6 coordinates: x_1, x_2, x_3, x_4, x_5 (P_T), x_6 (ϕ)

3 parameters to fit: P_T , ϕ , d

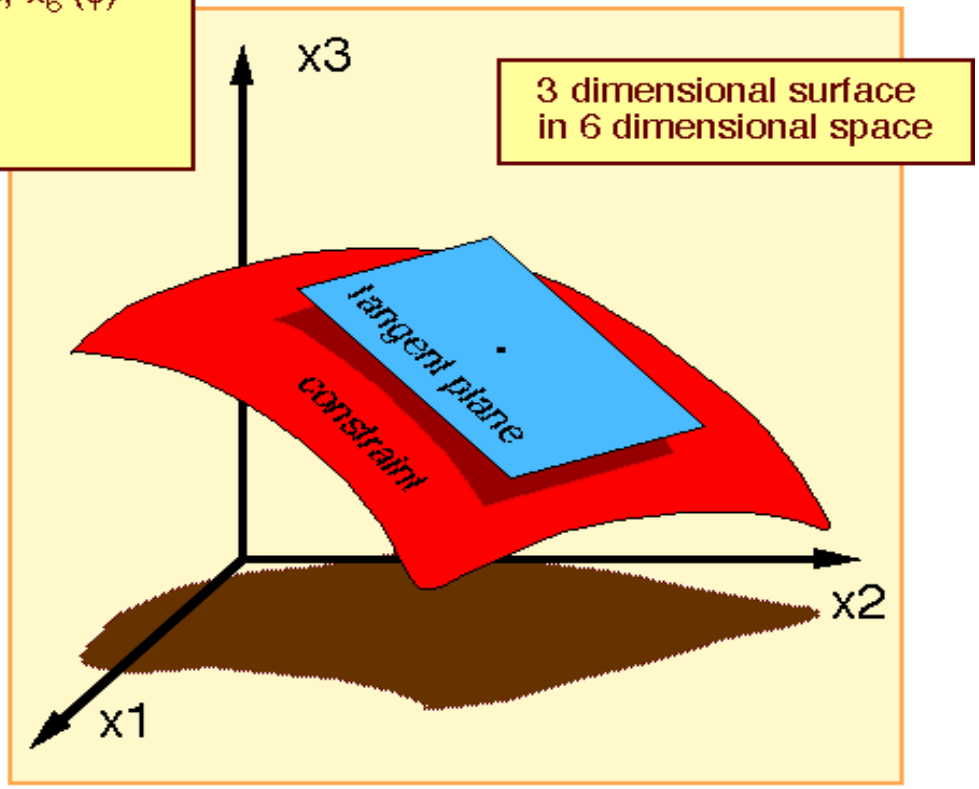
3 constraints

tangent plane:

$$\sum_1^6 a_i x_i = b$$

track parameters:

$$d \approx c_0 + \sum_1^6 c_i x_i$$



Linear approximation is so good that a single set of constants is sufficient for a whole detector wedge (30° in ϕ)

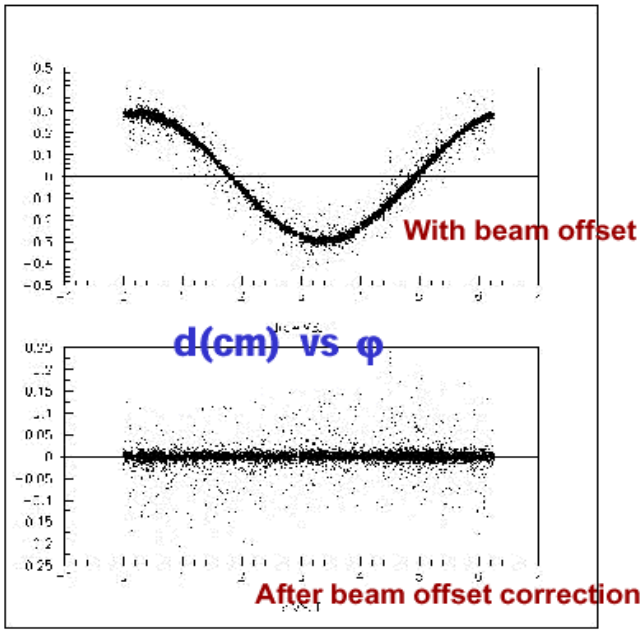
Expected resolutions:

σ_d~35 μm (@2 GeV/c)

σ_ϕ~1mrad σ_{P_t}~0.3%P_t^2 (GeV)

SVT: The real object!

Is SVT working?



- Large beam offset

  ⇓

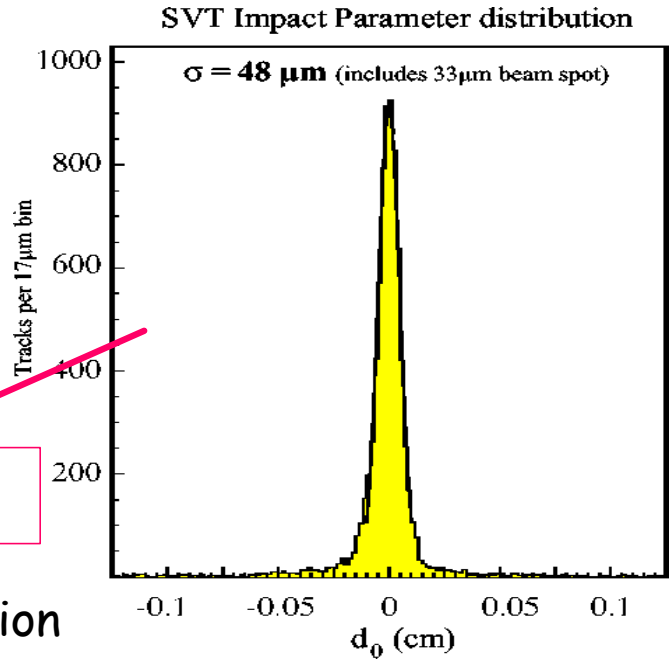
  large d, non linearity in the fit
- Beam slope should be < 100 μrad

Solution:

Beam position computed in real time and subtracted online

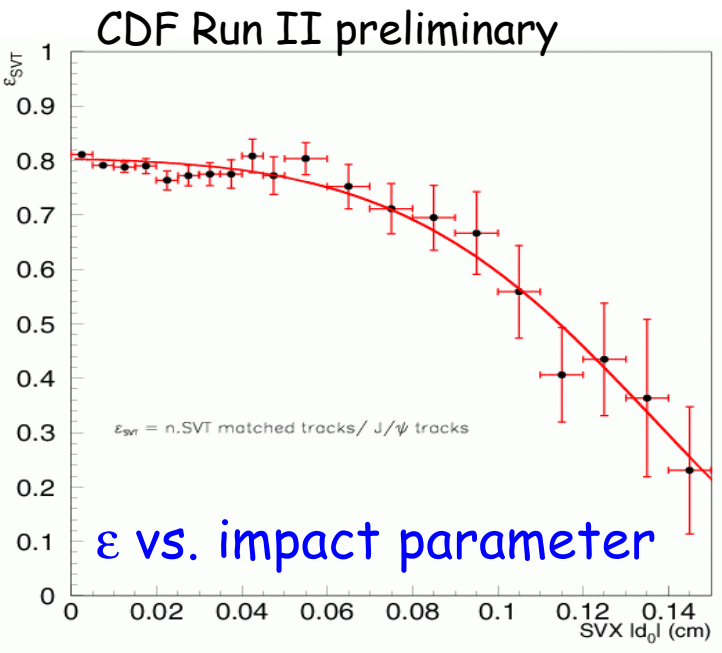
$$\sigma = 48\ \mu m = 33\ \mu m \oplus 35\ \mu m$$

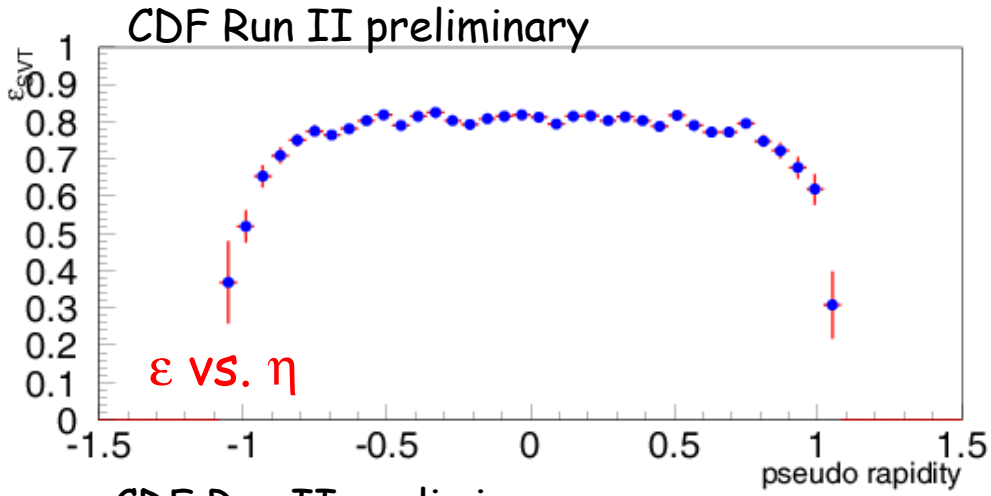
Beam spot — SVT resolution

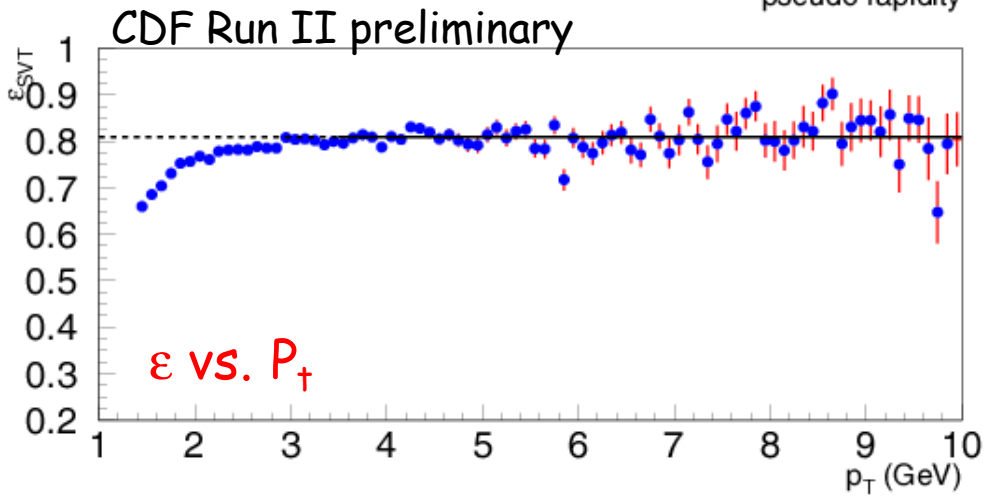


SVT performances

Efficiency evaluated on a sample of $J/\psi \rightarrow \mu\mu$







Two Track Trigger: Current Settings

L1 Requirements:
2 XFT Tracks
P_t>2 GeV/c
opposite charge
$\Delta\Phi$<135°
$P_t^1+P_t^2$>5.5 GeV

L2 Requirements:
2 SVT Tracks
P_t>2 GeV/c
100 μm <|d|< 1 mm
χ^2_{SVT} < 25

L3 Requirements:
Match of 2 SVT Tracks with reconstructed tracks in the central chamber

Confirm cuts:
- 100 μm <|d|< 1 mm
- P_t>2 GeV/c

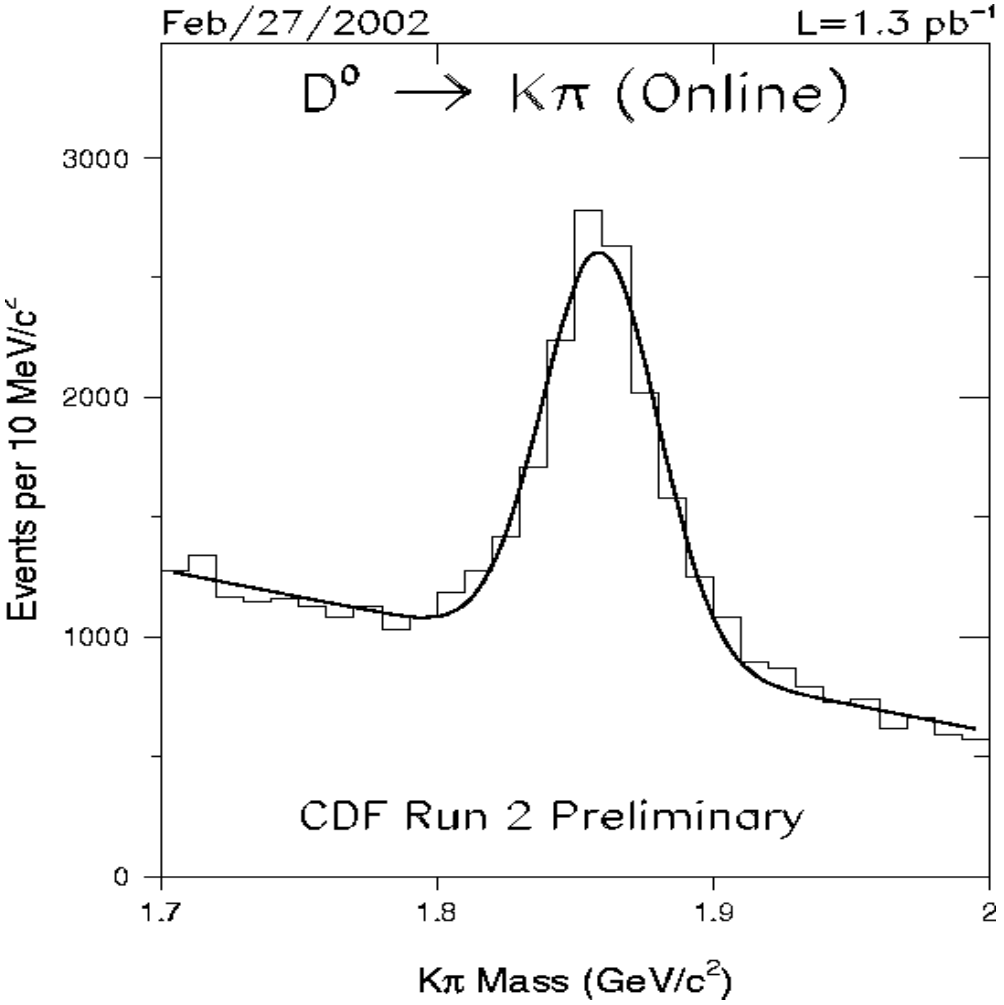
New Cuts:
- 2° < $\Delta\Phi$ < 90°
- Projected decay length >200 μm

The Online Monitor

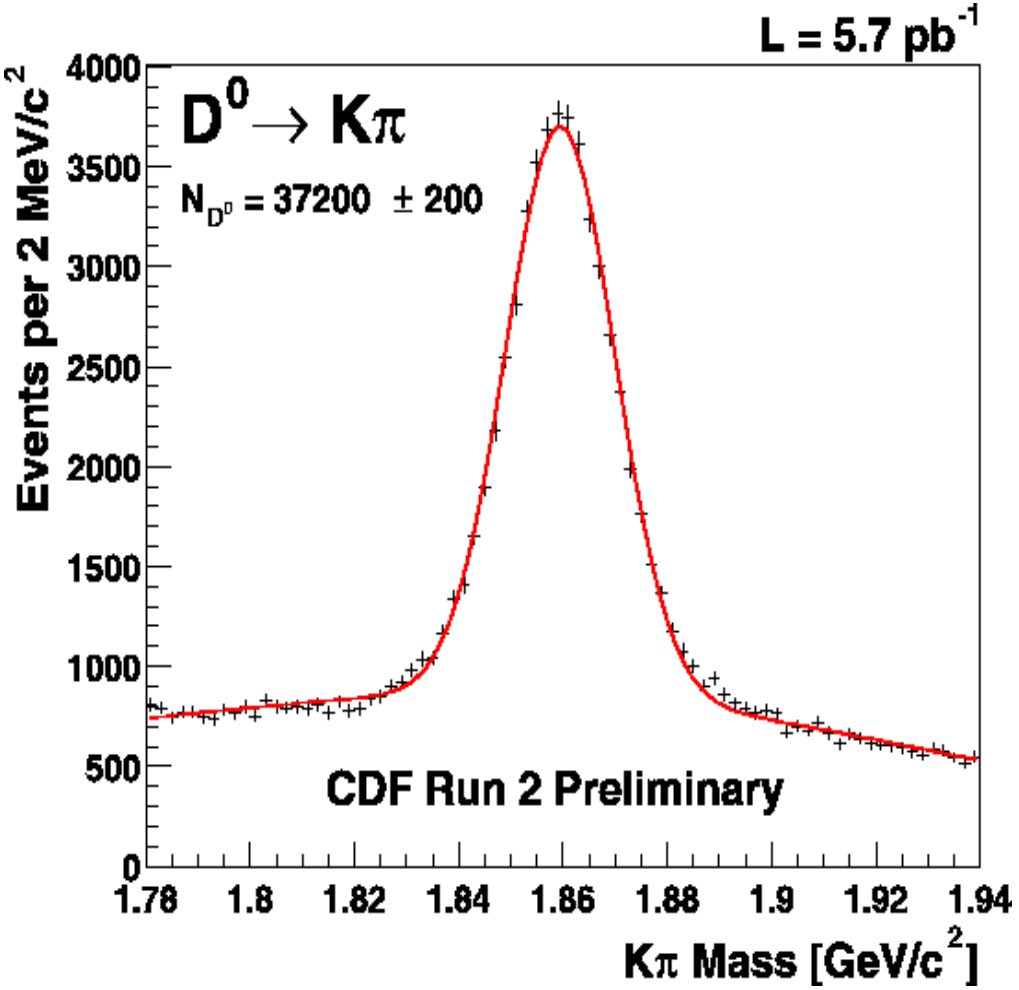
Using tracks found at L3 calculate $K\pi$ invariant mass

The number of D^0 per store has to remain constant if detector and trigger are performing well.

It was a dream in Run I!



First physics data: Two bodies decays



D^0 reconstruction cuts:

- Offline confirmation of trigger cuts
- COT hits:20(ax.) & 20(st.)
- SVX hits: 3 (only axial)
- $|\Delta z^0|<5$ cm
- $L_{xy}>500$ μm
- $d^0_k \bullet d^0_\pi < 0$
- $P_t(D)>5.5$ GeV/c

Mass resolution:~10 MeV

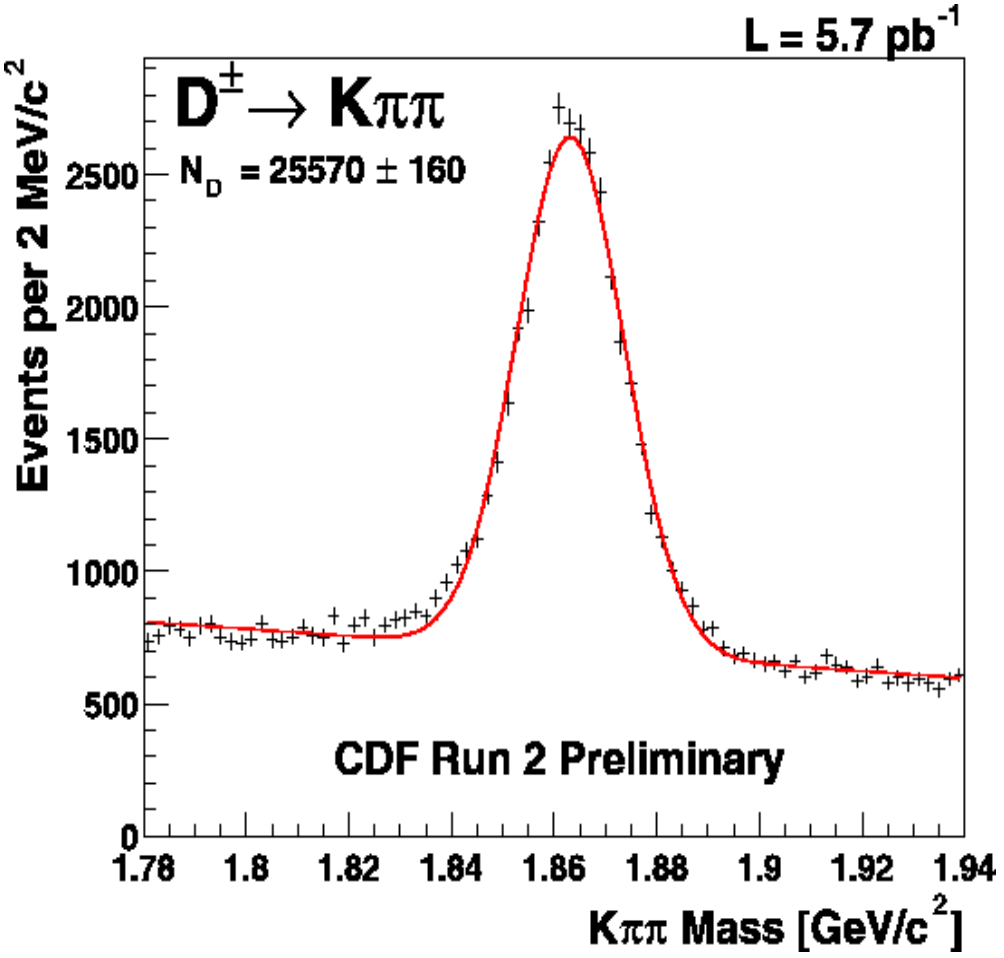
Again Charm: Three prongs

$D^{\pm}$ reconstruction cuts:

- Offline confirmation of trigger cuts (at least one of the two oppositely charged)
- COT hits:20(ax.) & 20(st.)
- SVX hits: 3 (only axial)

Candidate:

- L_{xy}>800 μm
- $\chi^2(r,\phi)$< 30
- $P_t(D)$>6 GeV/c



Towards B_s: $D_s \rightarrow \varphi\pi$ decay

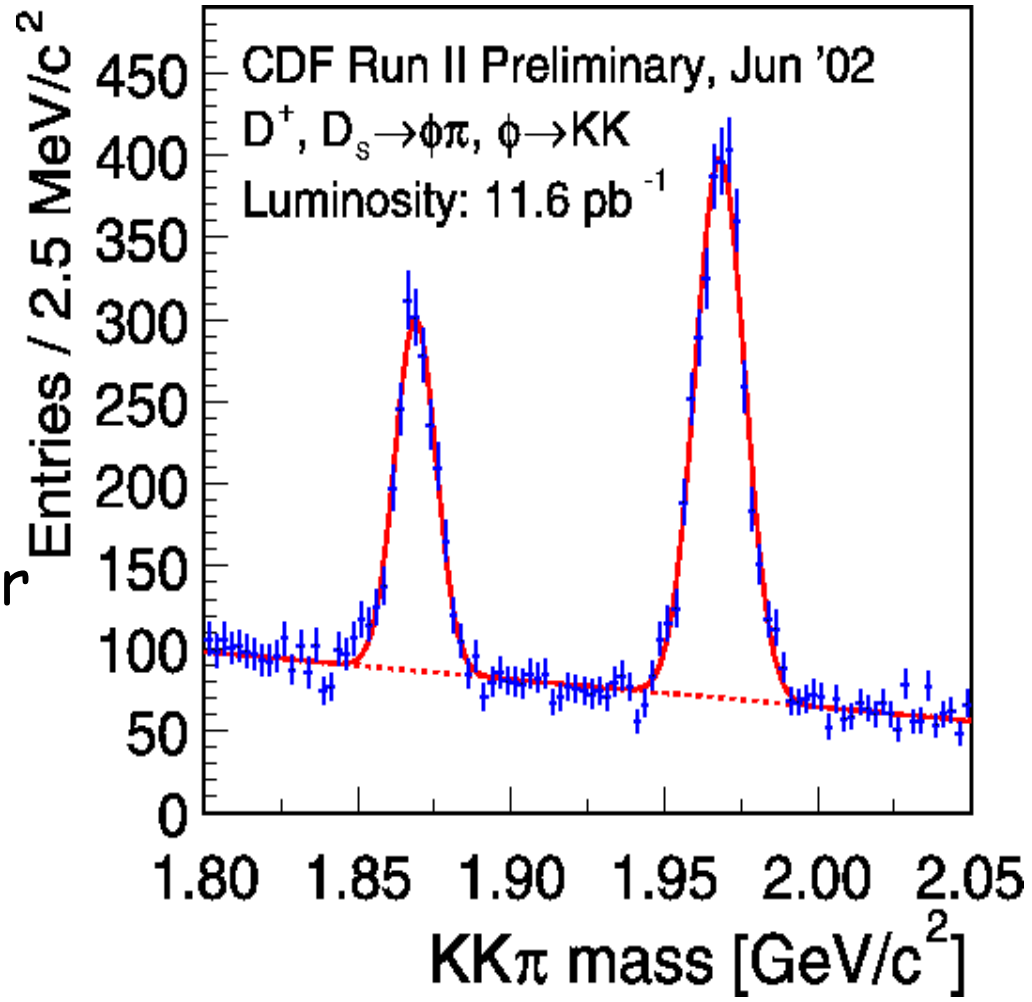
D_s reconstruction cuts:

For each track:

- 20 axial & stereo hits
- SVX hits: 3 (only axial)
- Pt>0.4 GeV/c

Candidate:

- two tracks confirm trigger
- $\Delta z(K^+,K^-)<4$ cm
- $1010 < m(\varphi) < 1035$ MeV/c^2
- $\Delta z(K^+,K^-)<4$ cm
- $\chi^2(r,\phi)< 7$
- $L_{xy}>500$ μm
- $|\cos(\theta^{\phi}_{hel})|>0.4$



Summary

- ✓ CDF has build the first impact parameter trigger in hadron colliders, SVT.
- ✓ It works properly! (not obvious a priori)
- ✓ Physics signal, D^0 peak, is used as online monitor !
- ✓ Many charm decays are reconstructed in the data set collected with the SVT trigger
- ✓ Physics measurements underway

Attend to Manfred Paulini Talk for more details

- ✓ B decays are under reconstruction

.....so

The new adventure with SVT just started…