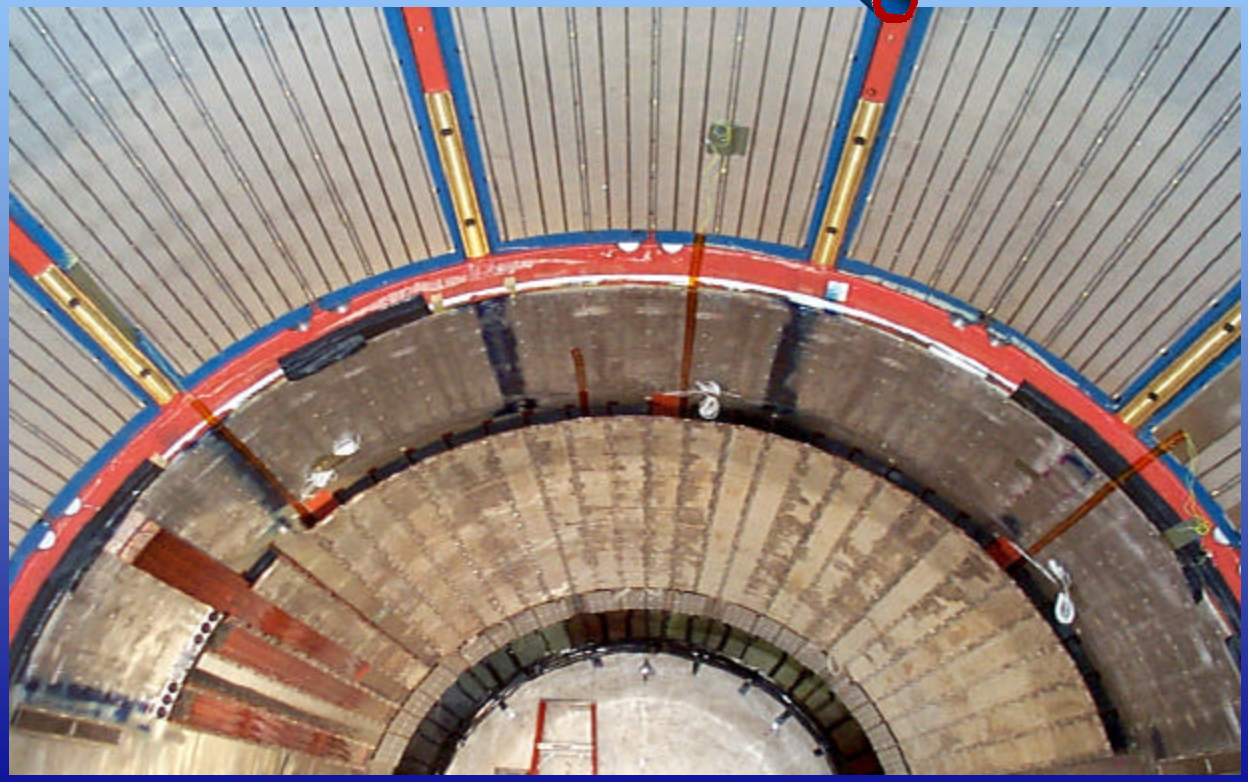
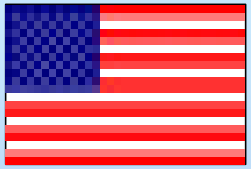
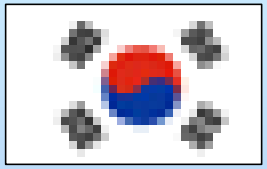
The CDF-II Time of Flight Detector



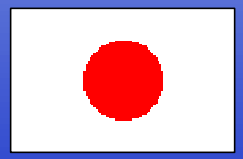
Elena Vataga (INFN Pisa & Moscow State University)

who we are:

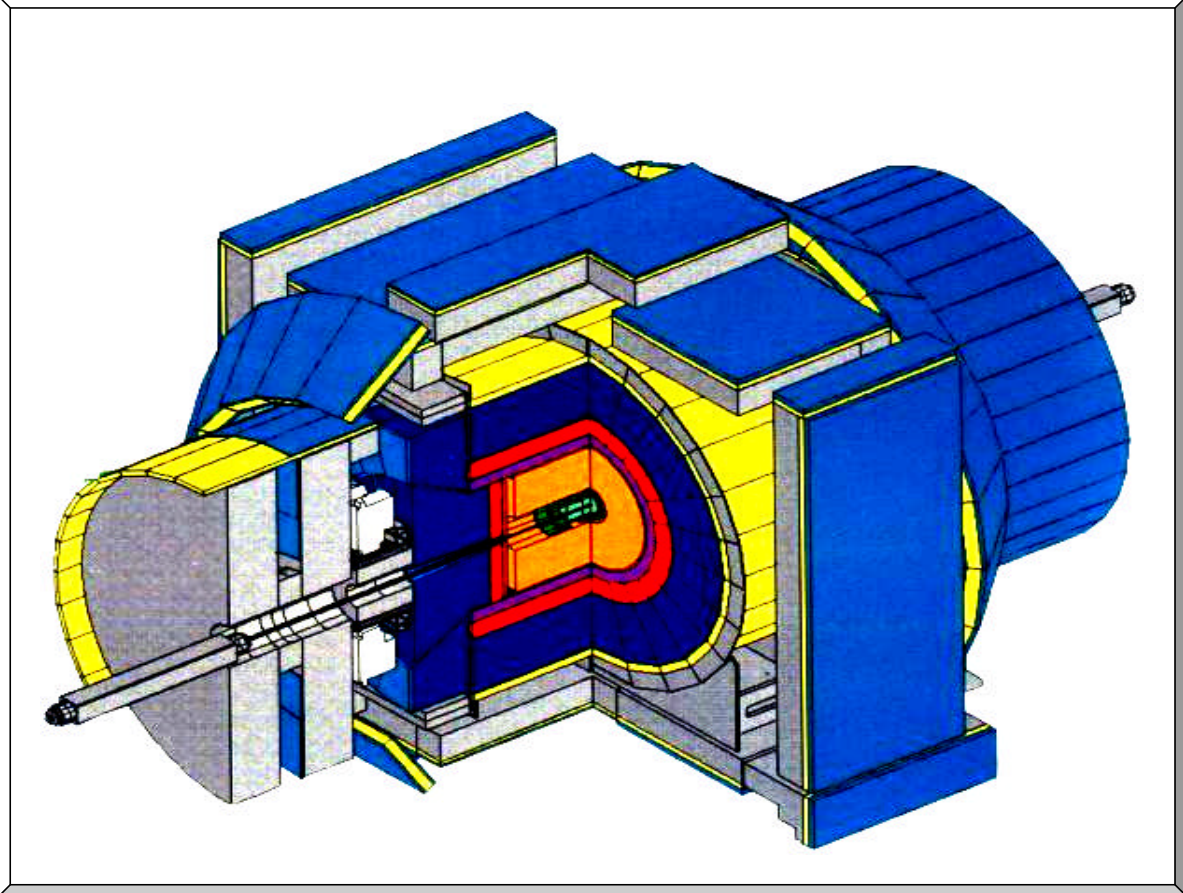




S. Cabrera[a] , J. Fernandez[a] , G. Gomez[a], J. Piedra[a] , T. Rodrigo[a] , A. Ruiz[a] , I. Vila[a] , R. Vilar[a], C. Grozis[b] , R. Kephart[b] , R. Stanek [b], D.H. Kim[c] , M.S. Kim[c] , Y. Oh[c] , Y.K. Kim[d] , G. Veramendi[d] , K. Anikeev[e] , G. Bauer[e] , I.K. Furic[e] , A. Korn[e] , I. Kravchenko[e] , M. Mulhearn[e] , C. Paus[e] , S. Pavlon[e] , K. Sumorok[e] , C. Chen[f] , M. Jones[f], W. Kononenko[f] , J. Krolf[f] , G. M. Mayers[f] , F. M. Newcomer[f] , R. G. C. Oldeman[f] , D. Usynin[f] , R. Van Berg[f] , G. Bellettini[g] , C. Cerri[g] , A. Menzione[g] , F. Spinella[g] , E. Vataga[g] , S. De Cecco[h] , D. De Pedis[h] , C. Dionisi[h] , S. Giagu[h] , A. De Girolamo[h], M. Rescigno[h] , L. Zanello[h] , M. Ahn[i] , B.J. Kim[i] , S.B. Kim[i] , I. Cho[j] , J. Lee[j] , I. Yu[j] , H. Kaneko[k] , A. Kazama[k] , S. Kim[k] , K. Sato[k] , K. Sato[k], F. Ukegawa[k]



CDF - II



Where we are

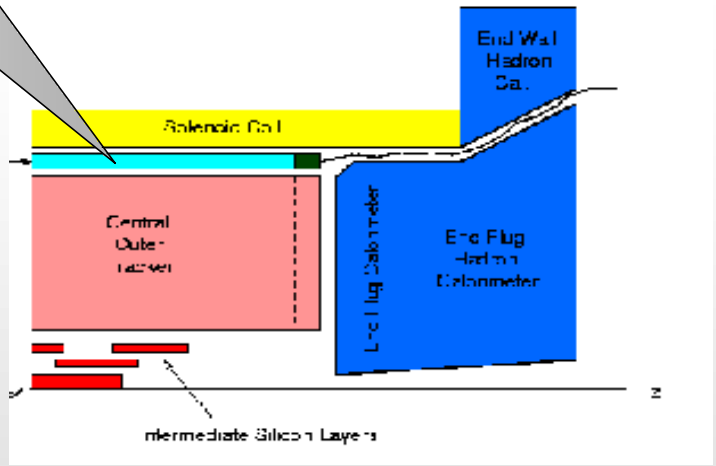
TOF

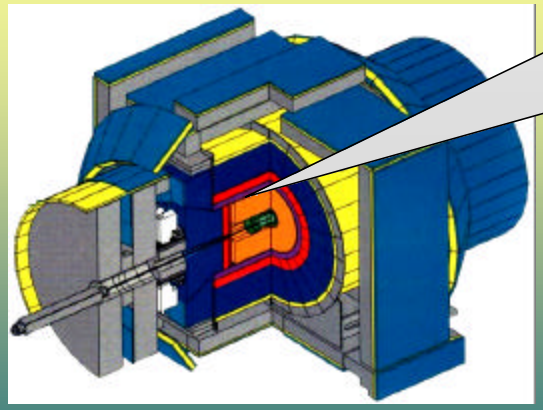
- *Barrel of* 216 scint. counters:

  bars 4*cm*x 4*cm*x 280*cm* - ***long!***

  material : BC-408,

  long L_{atten}~2.5 *m*, *fast* t_{ries}~0.9*ns*

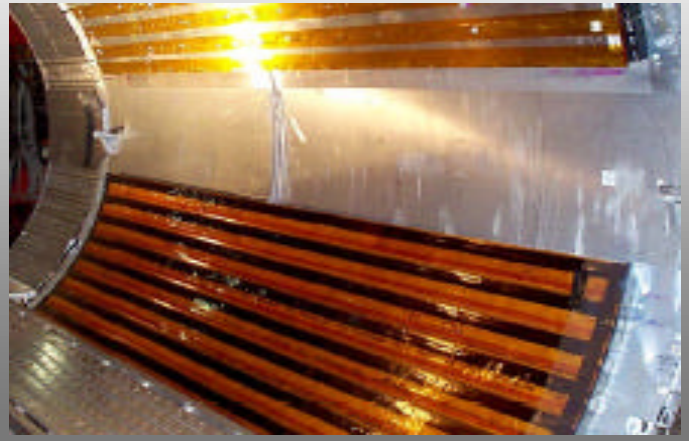




- *Inside solenoid* B=1.4 T
- *Distance from beam-pipe* 1.4 m

  t_{tof} ~5 *ns* *for fastest particles*

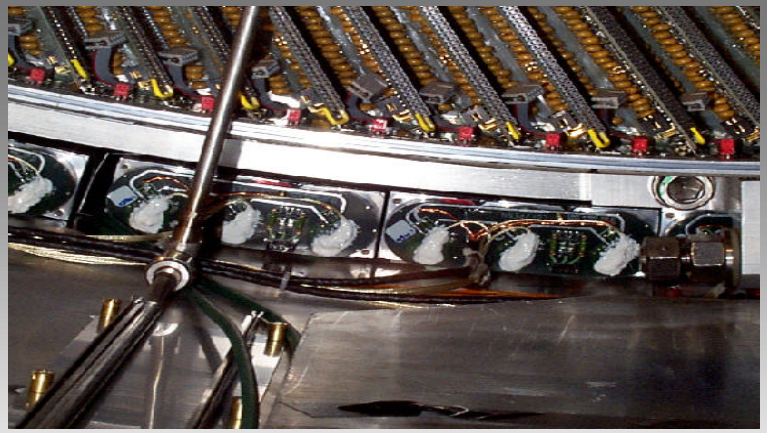
MECHANICS



216 bars in 3-packs – 72 triplets
(Bicron BC-408 4 x 4 x 280 cm)

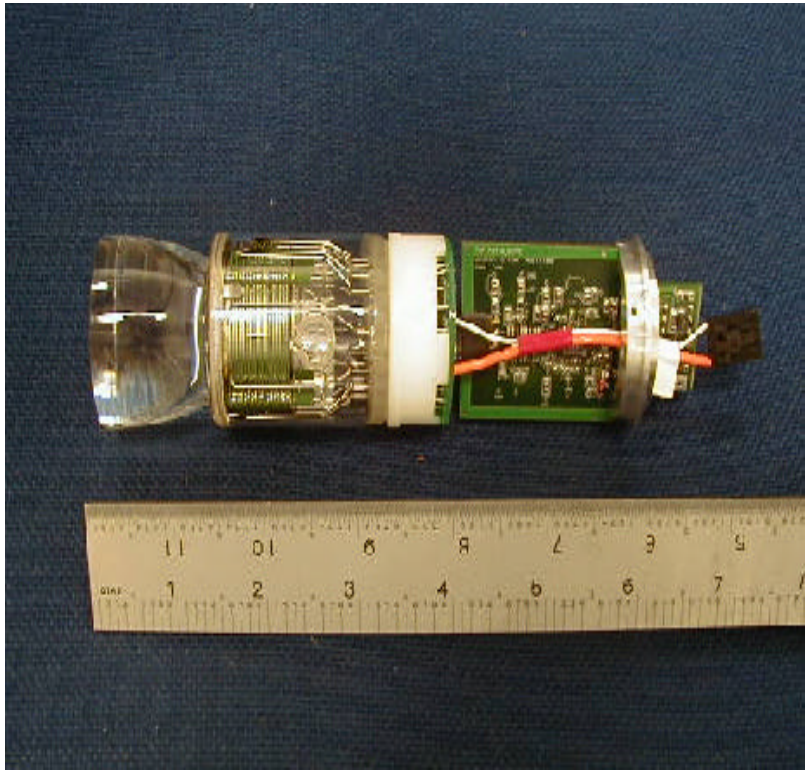
Coverage: |?|< 1

TOF located in 4.7 cm radial space btwn COT & creostat
NOT glued =>
deviation from nominal geometry, corrected for in off-line



Test run (5% "full-scale") in 1995
Fully installed in August, 2000
electronics - August, 2001

PMT – 2 / bar



Hamamatsu R7761 *on both ends*

fine-mesh, 19*-stage PMT* , Ø1.5 *inches*

allow:

- *better tolerate B~1.4 T (gain reduction ~500 times)*
- *TTS small: 250-400 ps*

PMT base *: HV & preamplifier*

Front end electronics

- 216 bars x 2 PMT = 432 channels

for each channel:

- time measure: $t_{stop} - t_{start}$
  - TAC: leading edge discriminator
  - ADC (range 60 ns, least count 17 ps)
  - Common stop (Clock 7.58 MHz, bunch crossing 132 ns , jitter< 25ps)
- ADC measure Q for t_{slew} correction

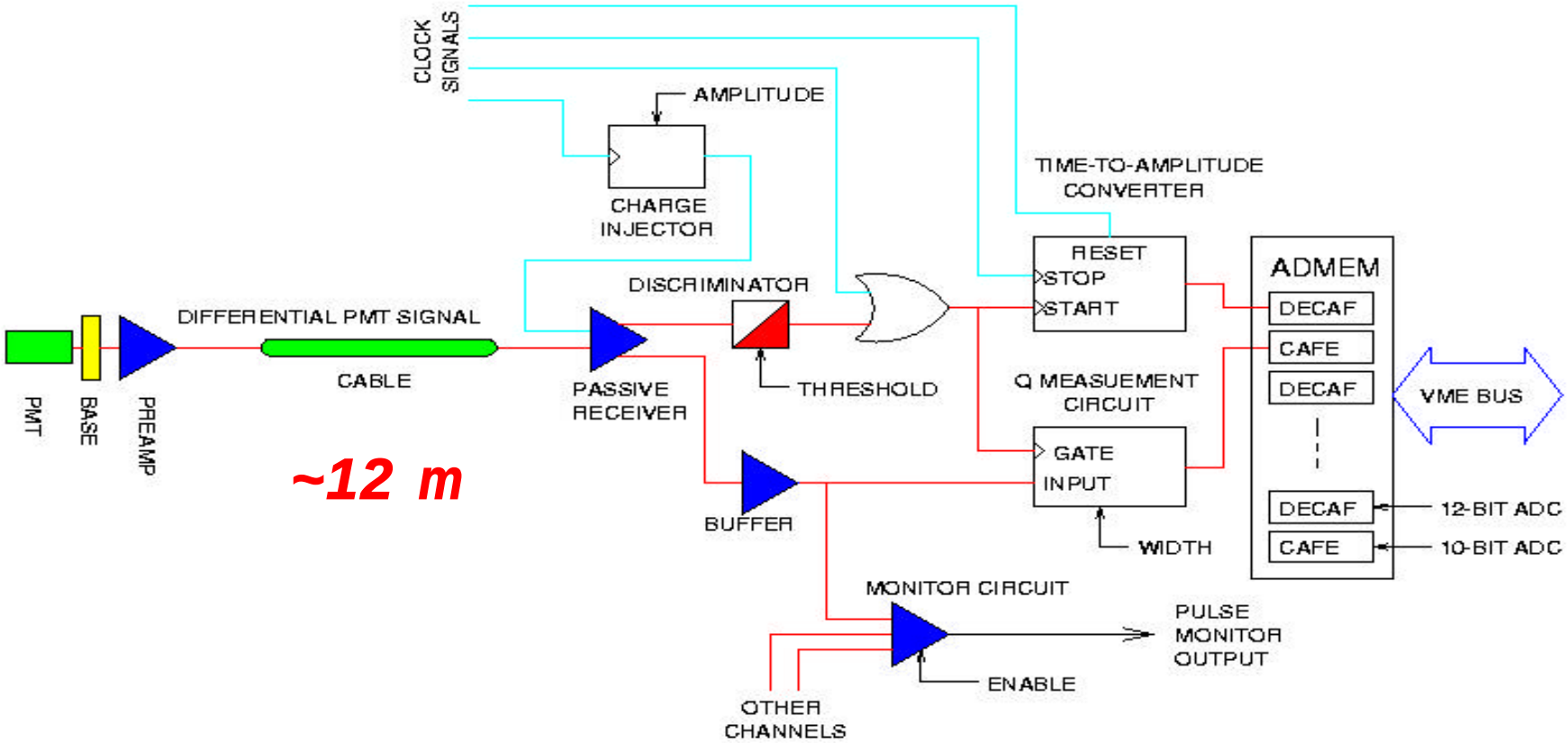
DECAF (12 bit)

CAFE (10 bit)

8 FE crates

- ✓ Readout use Calorimeter analog memory module (ADMEM) : ready VME + trigger interface
- ✓ Front-end electronic also do calibration, monitoring, configuration, testing

Signal path



Timing stability < 25 ps

TDC output

$$T_i = C_i - (t_0 + t_{tof} + t_{scin} + t_{walk} + c_i)$$

C_i – common stop

c_i – some constant term (propagation through cables…)

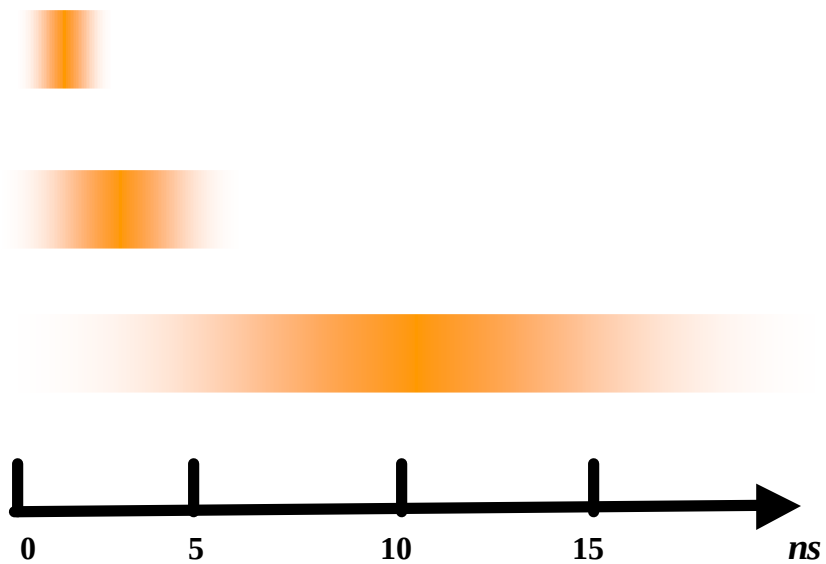
collision time t_0

time of flight t_{tof}
(K, p ~ 0.5 GeV/c)

Scint. Light prop. t_{scin}

$(L/2 \pm z)/v$

$t_{walk} \sim a_i \log (Q/Q_0)$



Challenge – Calibration !

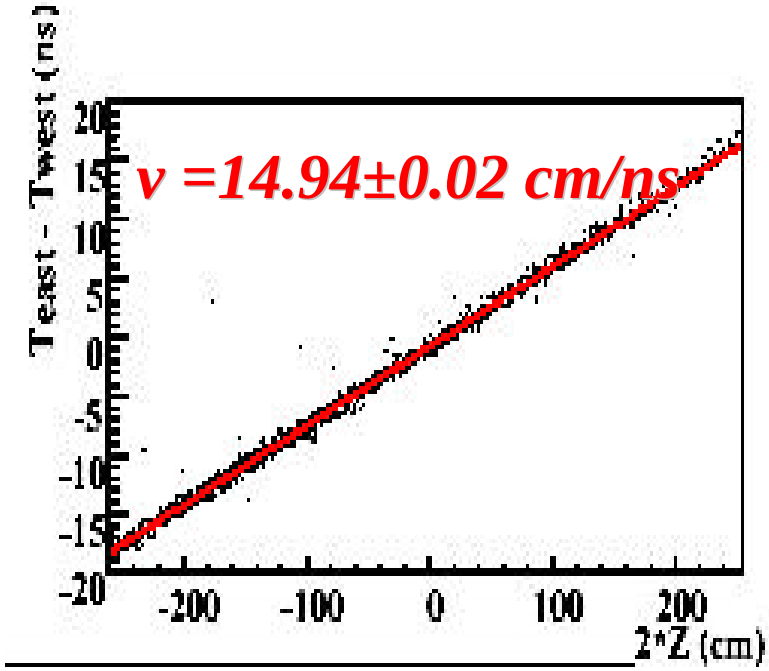
Without calibrating s_{TOF} ~ few ns

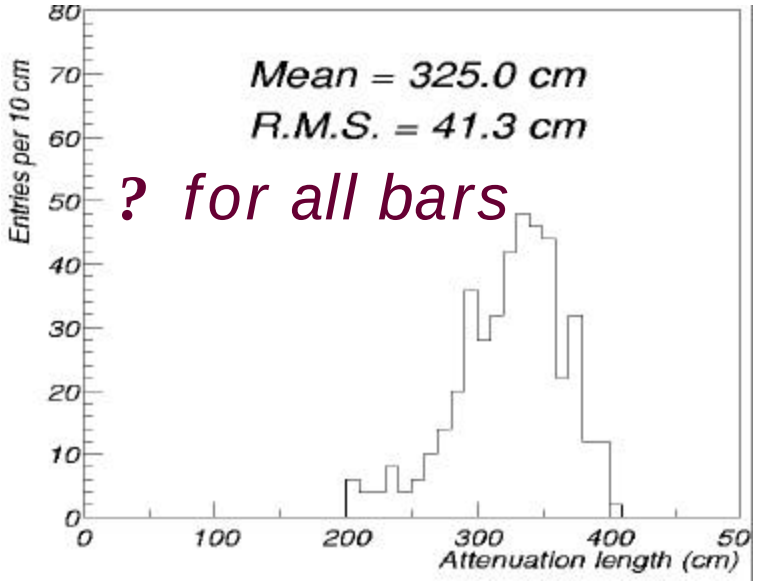
our GOAL - 100 ps!

1. Speed of Light
2. Attenuation Length
3. Walk Correction
4. Channel-to-channel t_0 offset

Speed of light & attenuation length

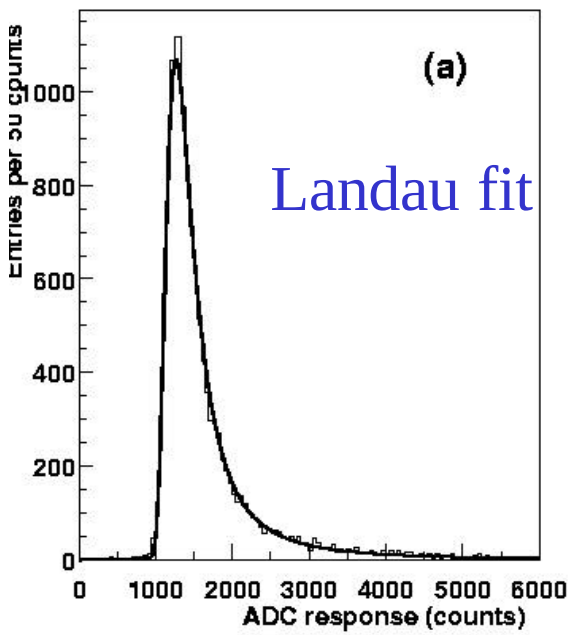
$$? t = t_e - t_w = 2 z / v + t_{offset}$$

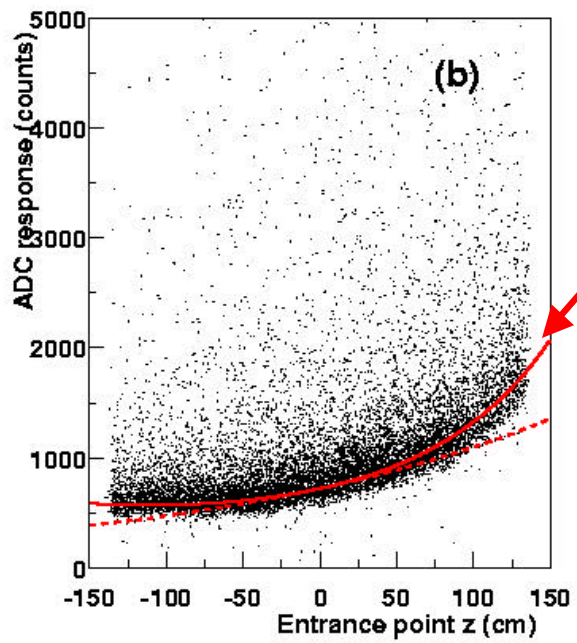




ADC response

$$Q(z) = Q_0\, e^{-(L/2 \pm z)/? + a\, z^2}$$



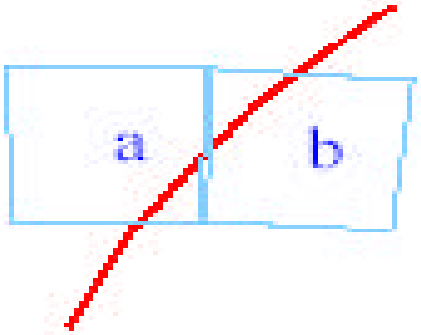


Reflection off the end of bars

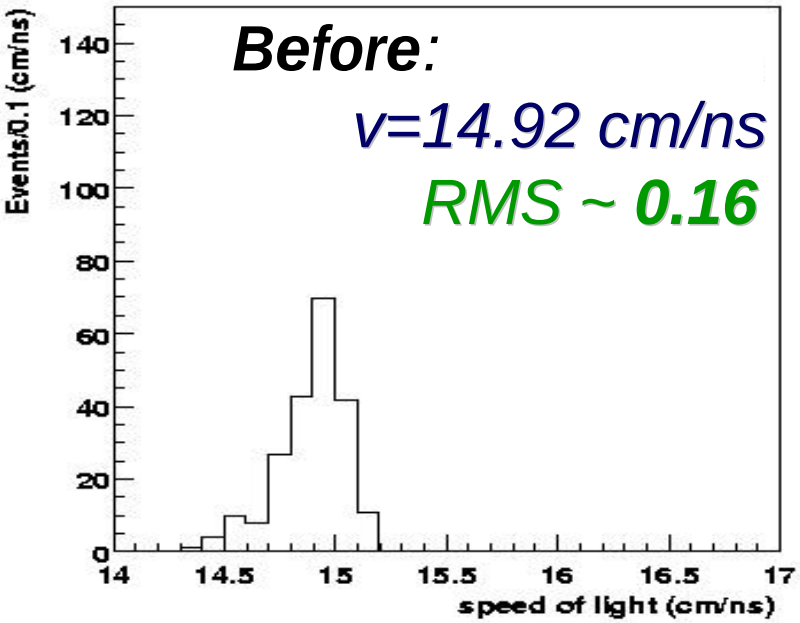
Walk correction

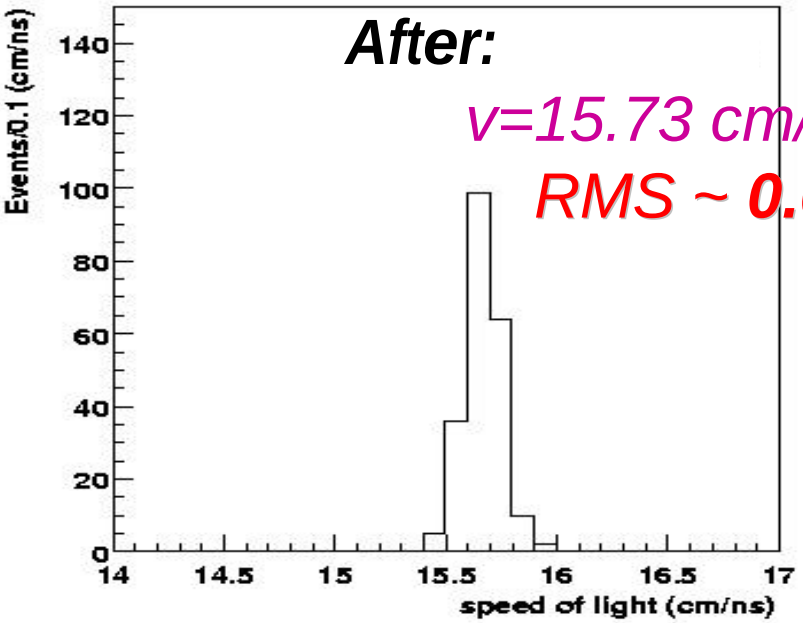
- 2 ns over ADC range
- sample of track that intersected 2 bars:

$t_a \gg t_b$

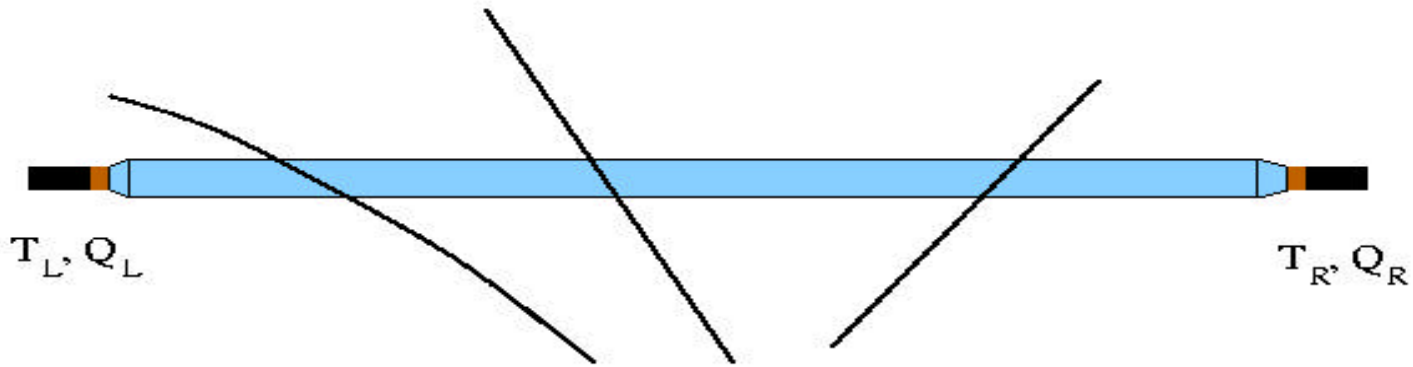


$t_{walk} \sim a_i \log (Q/Q_0)$





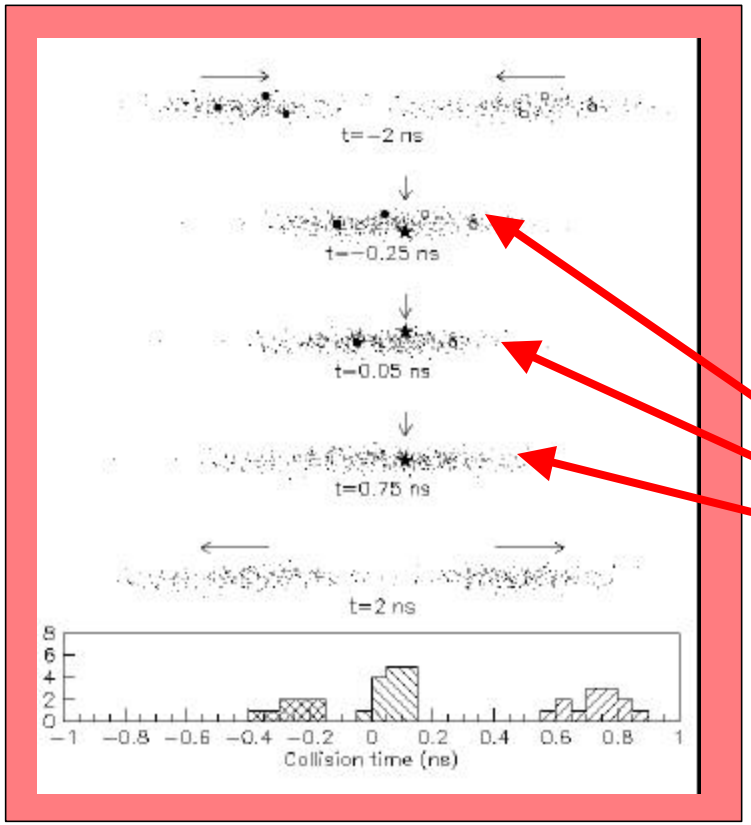
Event Reconstruction



1. Associate track to PMT hits
2. Apply correction to get best possible timing resolution
3. Tof calculation for all matched track
4. Determine t0 – primary interaction time
   (for B^0 ® J/? K^0_S <n> ~ 10 tracks, s ~ 30 ps)

How TOF measures t0

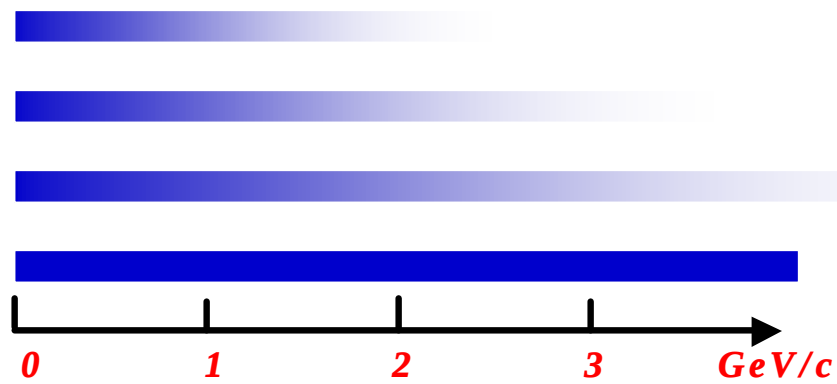
$$s \sim \frac{1}{\sqrt{N_{tracks}}}$$



3 interactions:
same z –
different t_0

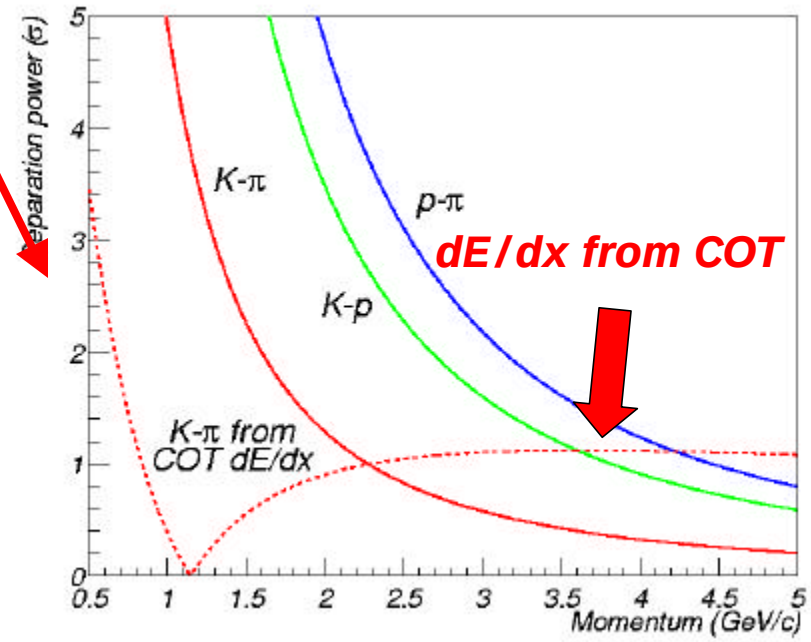
Particle separation

2 s K/p
2 s K/p
2 s p/p
1.2 s K/p over all p



$$Dt_{ij} = \frac{L}{pc}\left(\sqrt{m_i^2 + p^2} - \sqrt{m_j^2 + p^2}\right)$$

COT maintains
dE/dx Run I perfomance
TOF enhance
PID capability for low p



Why we need all this

2 method of tagging

OKT:

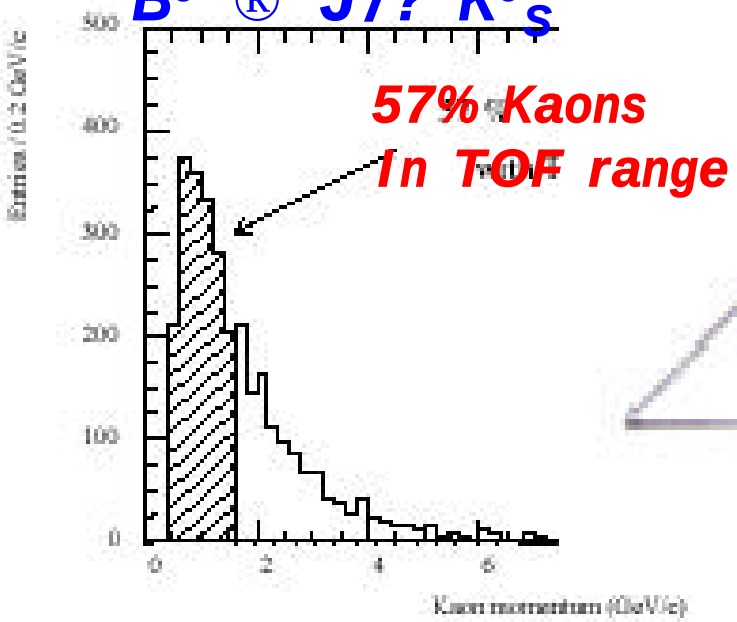
`b ® K^+

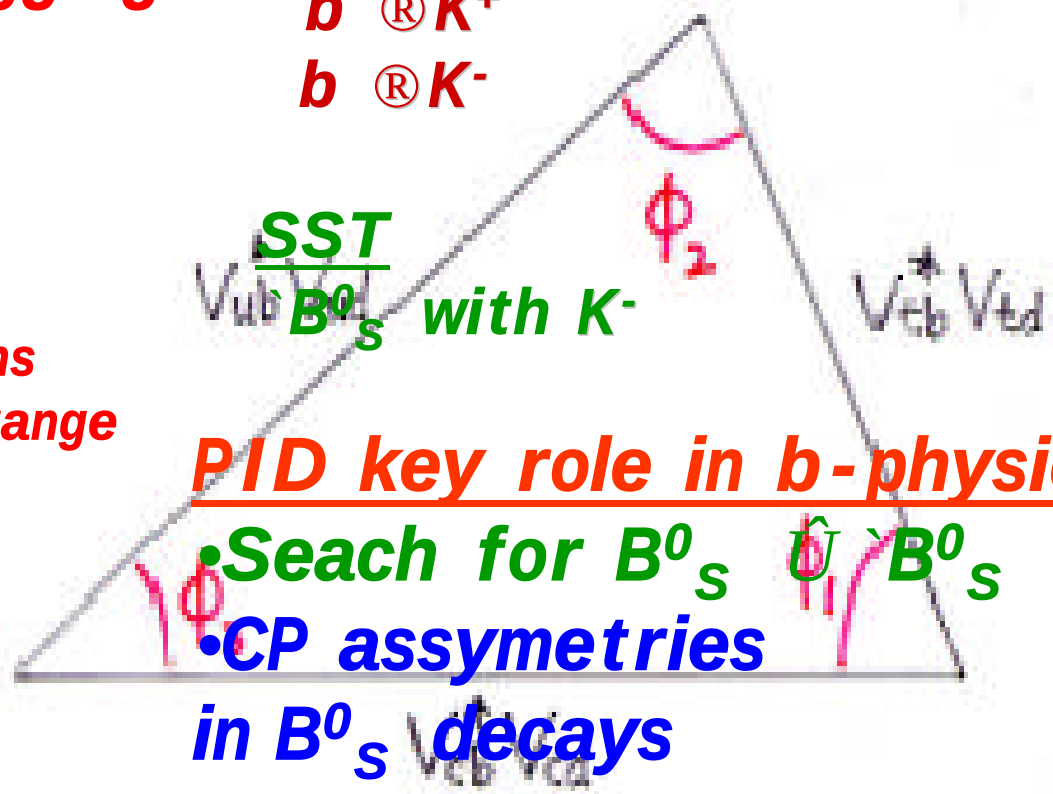
b ® K^-

SST

`B^0_s with K^-

`B^0 ® J/? K^0_s

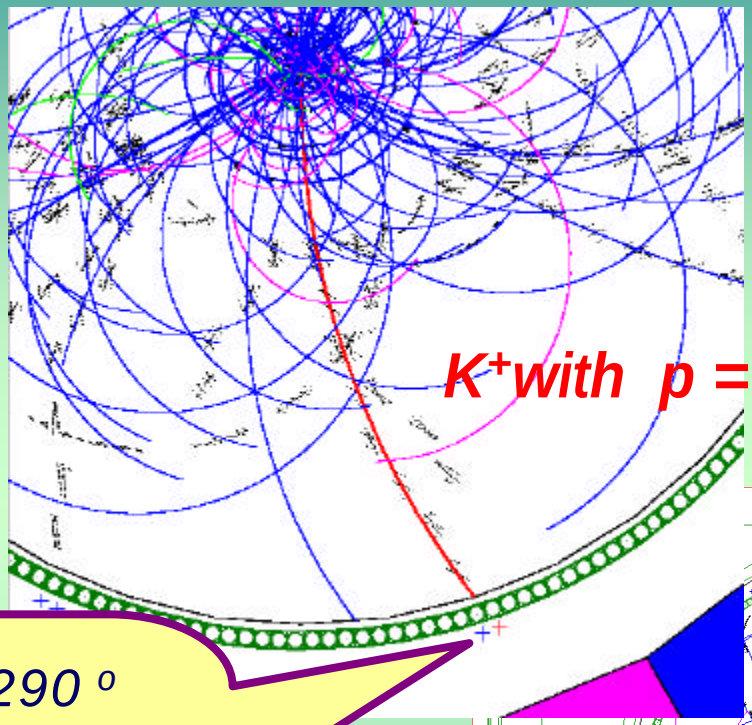




PID key role in b-physics

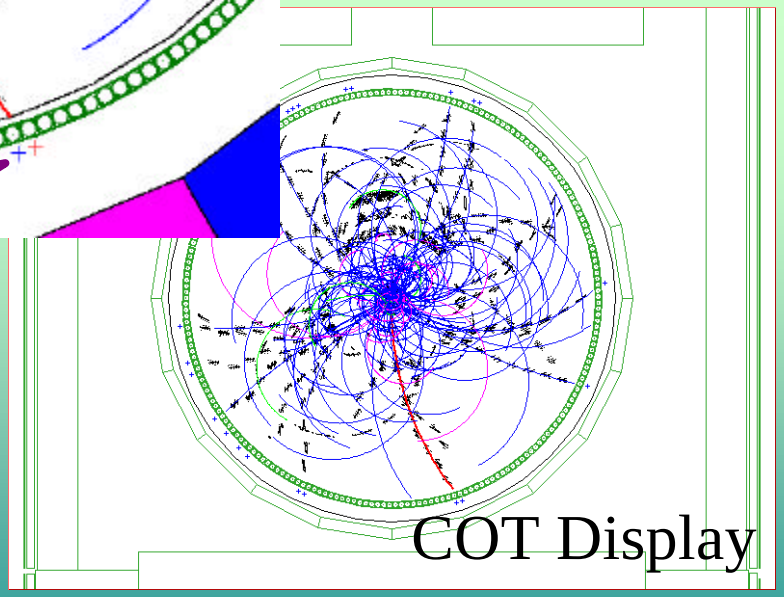
- Seach for B^0_s Ù `B^0_s
- CP assymetries in B^0_s decays

How `bb event looks in CDF

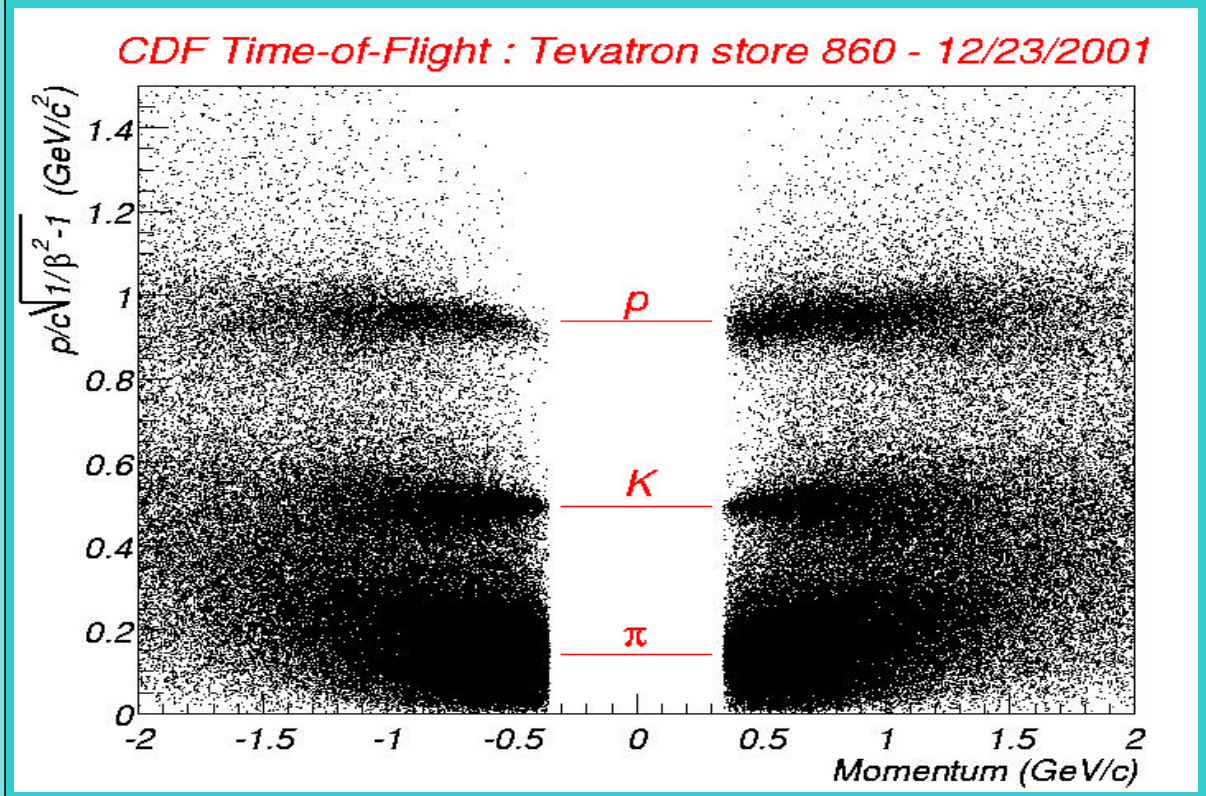


K^+ with $p = 0.854$ GeV/c

- Bar # 173 Phi = 290 ^{o}
- East TDC count 2901
- East ADC count 1941
- West TDC count 2303
- West ADC count 1319

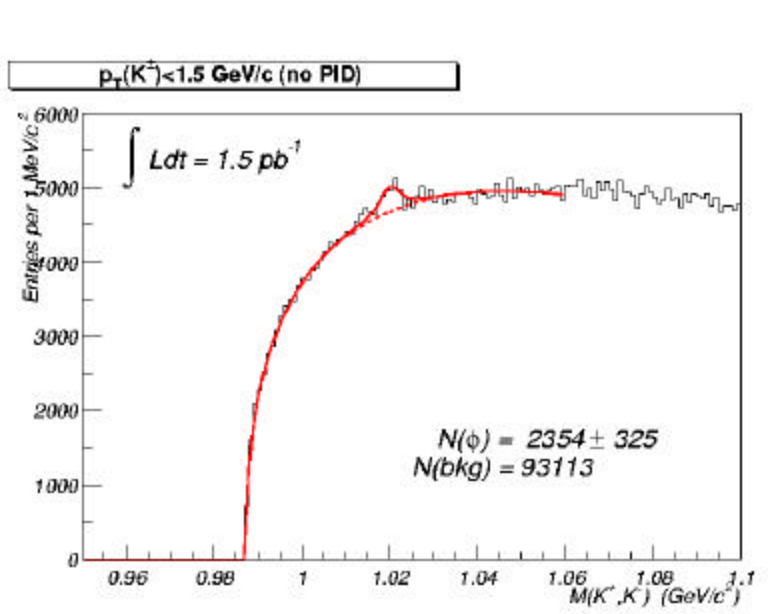


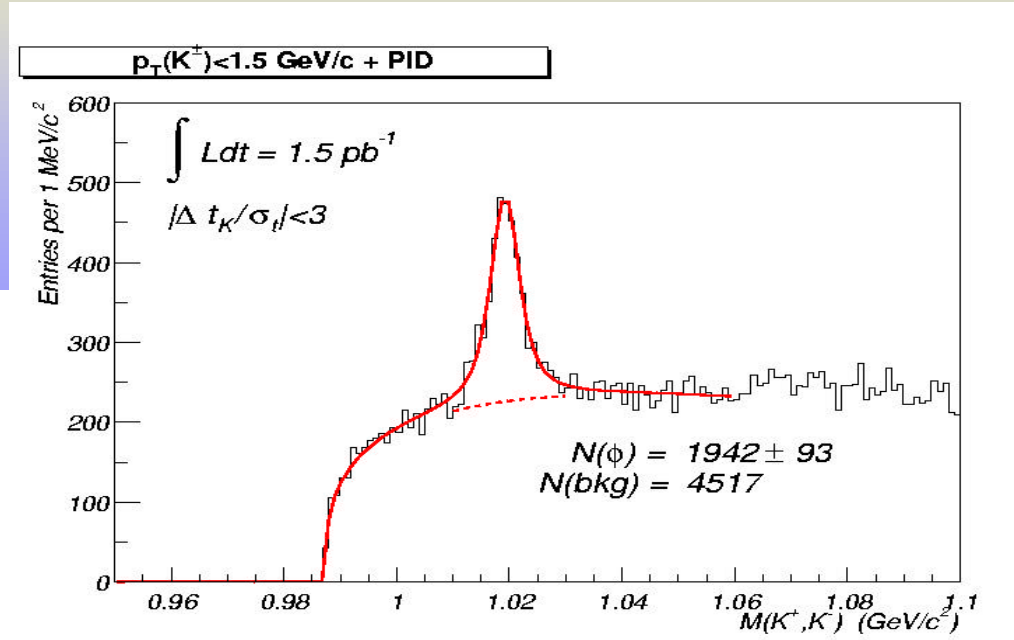
Performance



PID perfomance

$f(1020) \to K^+K^-$





- $p_\wedge(K^\pm) < 1.5$ GeV/c
- $w_K = Dt_K / s_t < 3\ s_t$

Conclusion

- ✓ full TOF in operation for 9 months
  100 ps looks reachable
- ✓ first iteration of calibration
  is available
- ✓ still expect few % improvements
  for individual channels
- ✓ first results are on the way