Timing and Pile-up Considerations

Pile-up in **trigger** and pile-up **off-line** (HLT) very different issues.
Here I consider only **off-line** pile-up rejection.

1) Kinematics (e.g. JJ ... more in WW/ZZ):

$MM(pp) >\approx M(\text{Central}); E_T(J1) \approx E_T(J2); \Delta\phi(JJ) \approx 180^0$

2) Vertexing in space (z) using pp time ... we know this but:

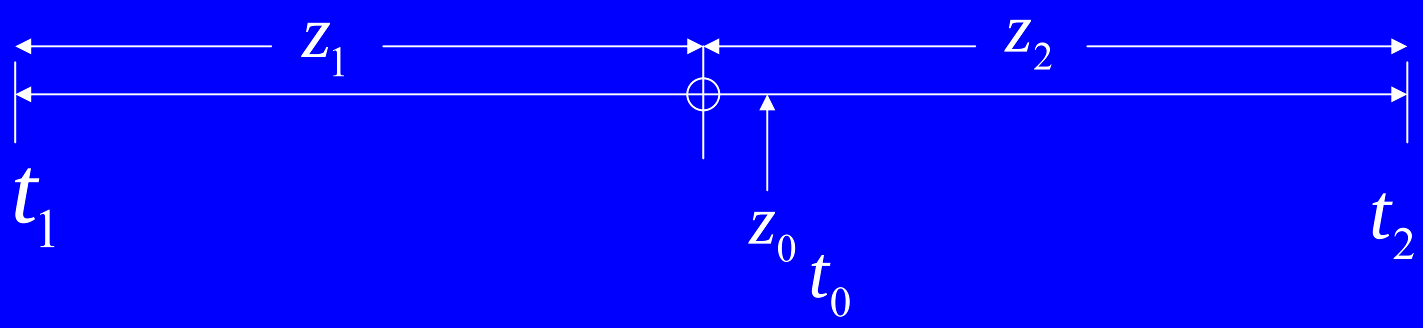
Reference time (jitter-free clock) essential.

3) Rejecting vertices in space with forward tracks (track-rap-gap)

4) Vertexing in time (space-time!)

Apologies if I am CMS-specific. ATLAS people should consider similar possibilities.

Reference Timing for FP420



$$t_1 - t_0 = \frac{c}{|z_1| + z_0}\,; \quad t_2 - t_0 = \frac{c}{|z_2| - z_0}$$

($|z_i|$ are distances but z_0 is signed)

Stating the obvious, but → $z_0 = \left(\frac{c}{2}\right) \times \left(\frac{1}{t_1 - t_0} - \frac{1}{t_2 - t_0}\right)$

if $z_1 = z_2$

The reference time, given by a local (to FP420) "clock" must

(a) have no differential jitter (at few ps level) between L and R stations

(b) be calibrate-able → fix $z_0 = 0$ and $\left(\frac{dz_0}{d - TDC}\right)$

→ We must have a good reference signal free of jitter between E and W stations. This is as important as the detectors themselves. Temperature control? Return path control?

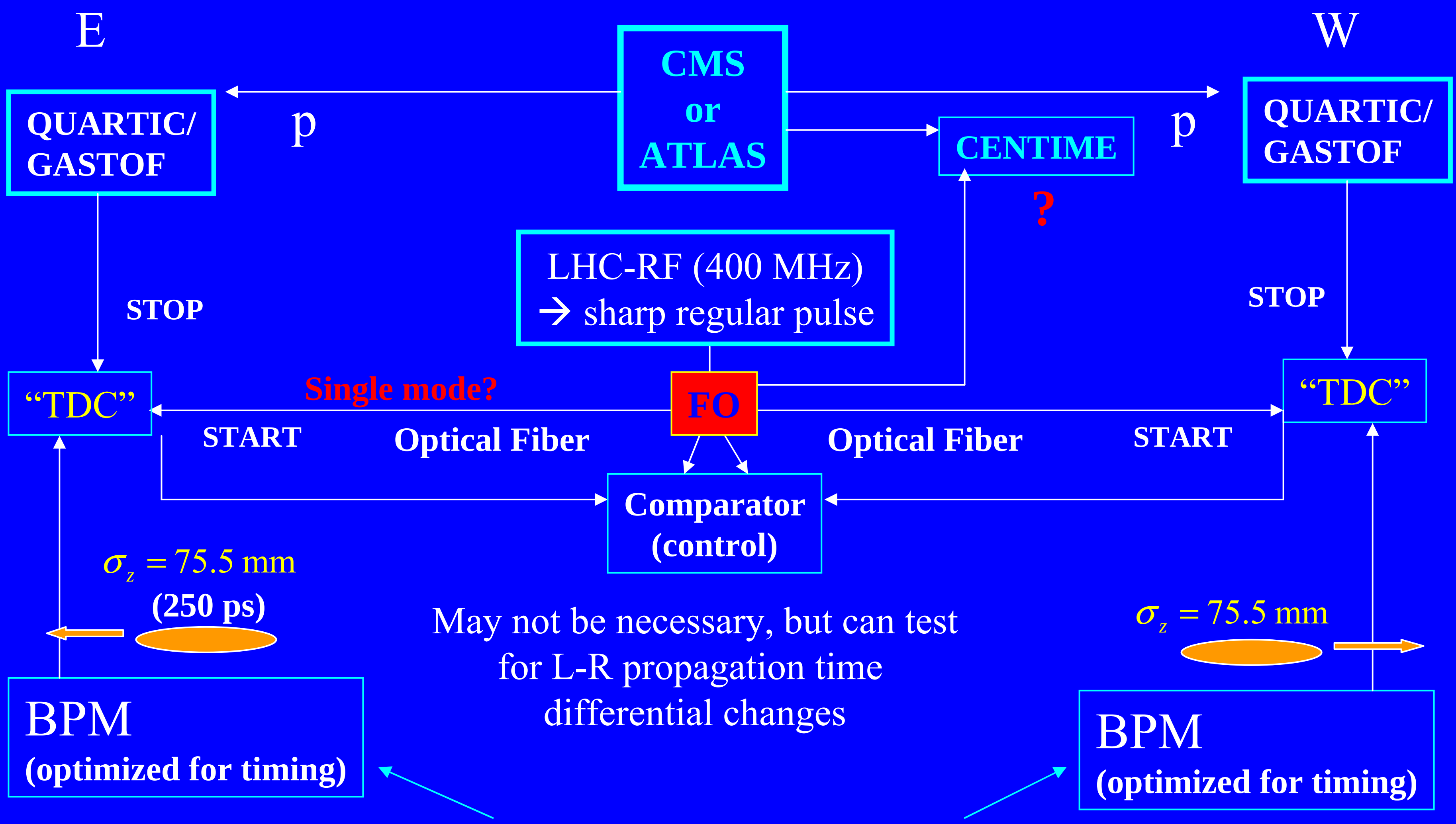
→To use 220m stations together with 420m, these need timing too.

→ Position of interaction in bunch: tight (?) correlation with position in time of p wrt bunch center at 420, because no RF cavities intervene.

→Need to discuss with LHC RF/clock experts.

→ Upgrade for very high Lum (or earlier?) CENTIME ?

A possible scheme:



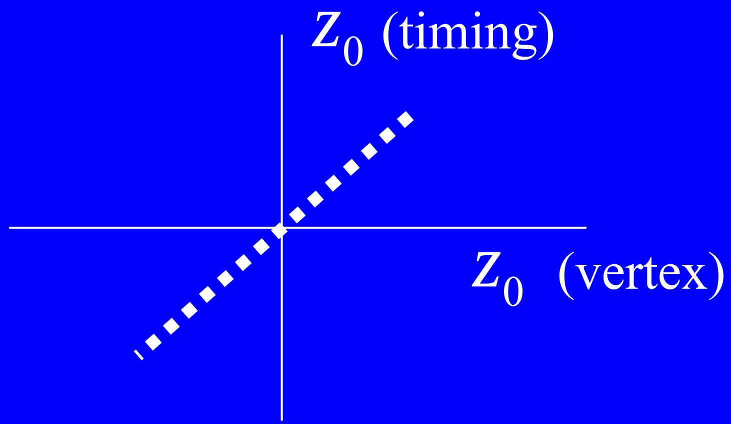
Tell where p is w.r.t. bunch centroid. (few mm/70mm)
Fine correction on p_incident. Compare with sum time from $t_E + t_W$

Assuming jitter problem solved,
Calibrate with real DPE events.

Want low-ish Lum, enough single interactions $L \leq\sim 5\times10^{32}\,cm^{-2}s^{-1}$
(maybe want a special low-L bunch crossing later)

Trigger on two forward rap gaps - needs better coverage $6.5 < |\eta| < 9.5$
plus central state (could be dijets, or just ΣE_T)

"Know" central vertex and z_0



Ambiguities give much background if do not select single interactions. Could require (e.g.):

$$\xi_1\xi_2 > \left(\frac{M_{JJ}^2}{\sqrt{s}}\right)$$

This is Calibration!

Pile-up rejection by Forward Tracking

Say exclusive H → $b\bar{b}$ has ~ 0 tracks for $|\eta| > 2.0\ (15.4^0)$

Any (?) vertex with tracks **both** sides $-3 < \eta < -2\ \ \&\ \ 2 < \eta < 3$

is background. Would prefer $3 < |\eta| < 4$ but no pixel coverage.

SIMULATION NEEDED

CMS Pixel Detector

1) 3 barrel layers,
   2 at startup (low lumi.).

2) 2 endcap disks,
   maybe 1 at startup,
   upgrade to 3 disks.

3) 720 barrel modules,
   16 ROCs each.

4) 672 endcap modules,
   2−10 ROCs each.

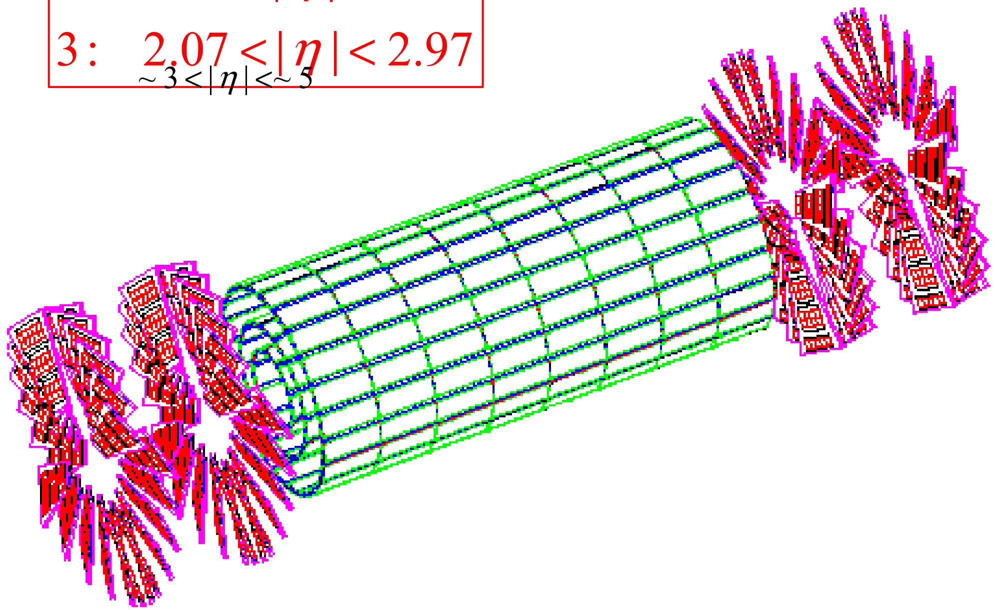
5) Pixel size 100μm*150μm,
   (baseline 150μm*150μm).

$1:\ \ 1.57 < |\eta| < 2.45$

$2:\ \ 1.85 < |\eta| < 2.74$

$3:\ \ 2.07 < |\eta| < 2.97$

$\sim 3 < |\eta| < \sim 5$

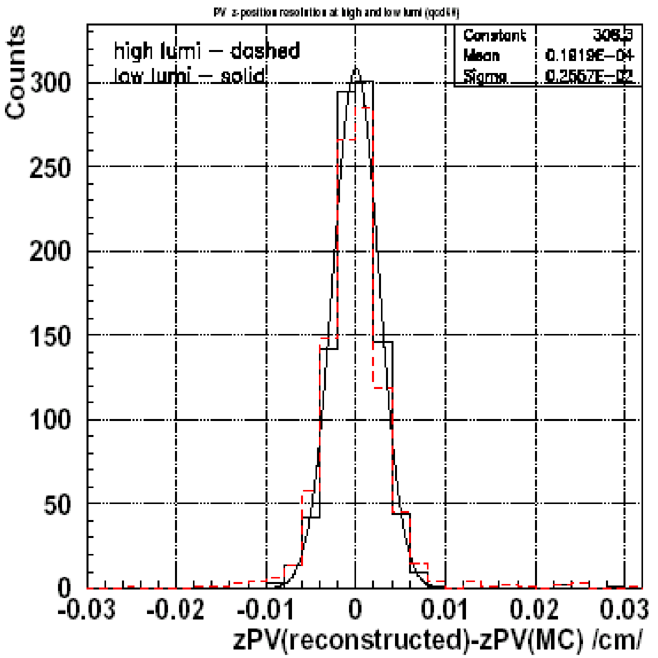


Can separate two vertices within ~ 150 um in z $\sigma_z = 26\ \mu m$

This is for **central barrel.**

For Endcap pixels? To study, but $\sigma_z \approx 300 - 400\ \mu m$

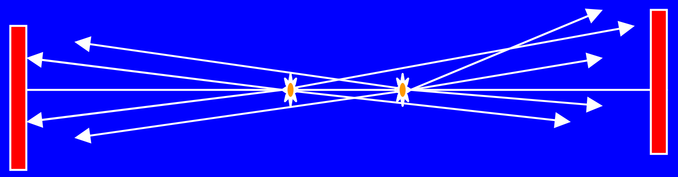
Very good primary vertex reconstruction



In this case 26μm.
Very close to the best resolution with tracks!

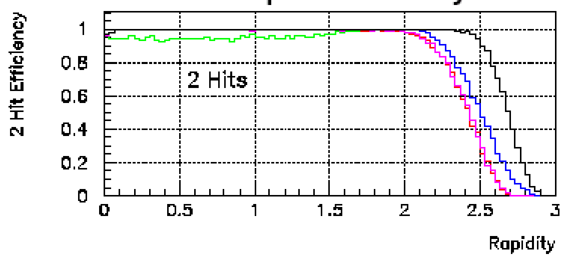
For all channels studied the signal primary vertex position resolution is < 50μm.

Pile–up primary vertices can be also found if they have at least 2 charged tracks above 1GeV.



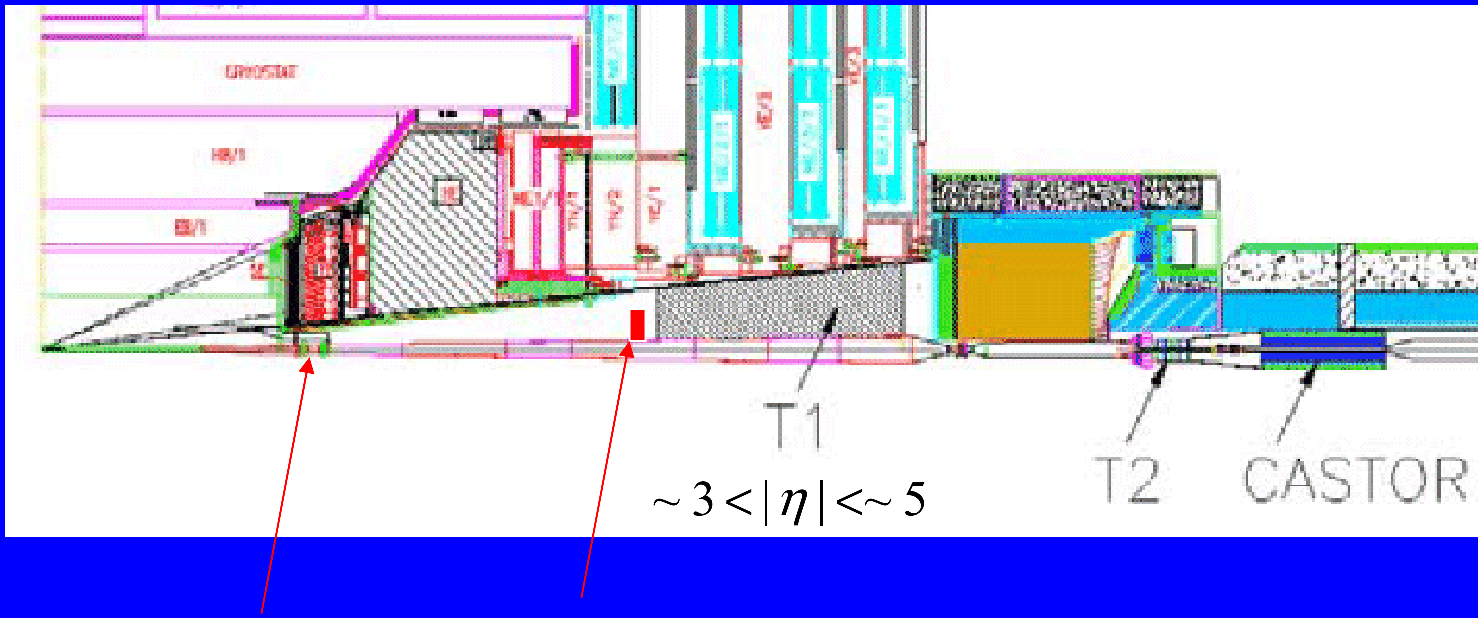
Find vertices and reject (track-rap-gap)

Need to swim tracks through Mag Field (small angle)



- 2 barrels + 1 disk at startup
  –> 2 hit coverage
- 3 barrels + 2 disks
  –> 3 hit coverage
- 3 barrels + 3 disks upgrade
  –> 2&3 hit coverage

What is efficiency for $H \rightarrow b\bar{b}$ if veto 2 – 3?
Would prefer further forward, but tracking (T1) not nearly good enough.

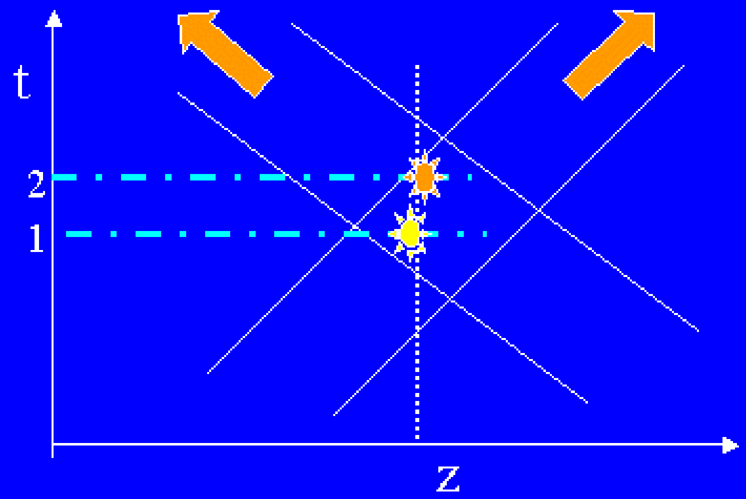


FORWARD PIXELS

FAST TIMING LAYER

Vertexing in Spacetime

Matching z(from pp timing) with z(from central di-jet/WW/ZZ) is 1-dimensional. Interactions are spread also in time.

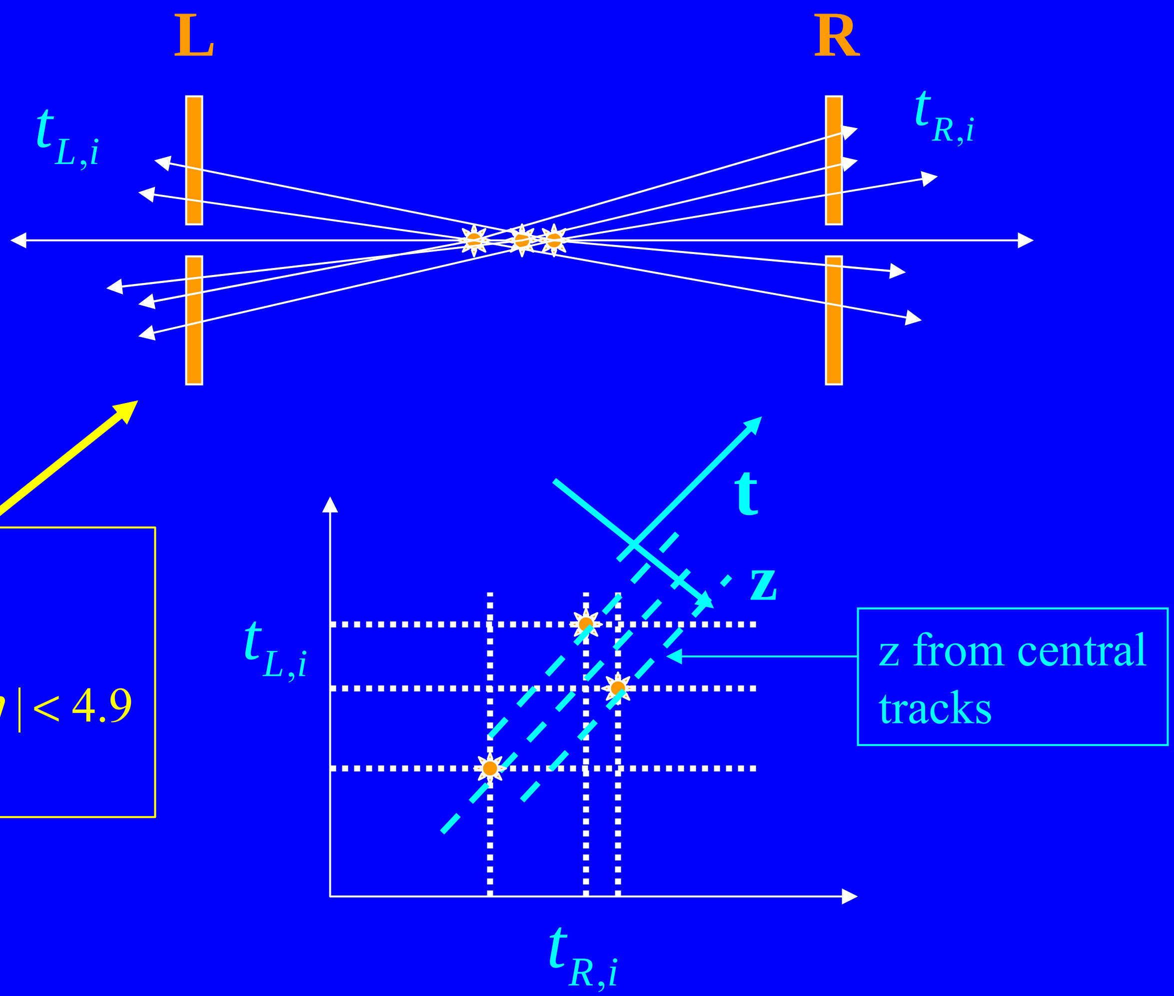


$\sigma_t \approx 170$ ps

Can use this extra dimension if we know time of interaction.
High precision (~ 10 ps) counters around central beam pipe not on unless one can invent a fast detector < few % Xo !

But can go forward and time the non-central exclusive B/G events!

This may be dreaming, maybe not for Day 1, but P/U worse in 2010!



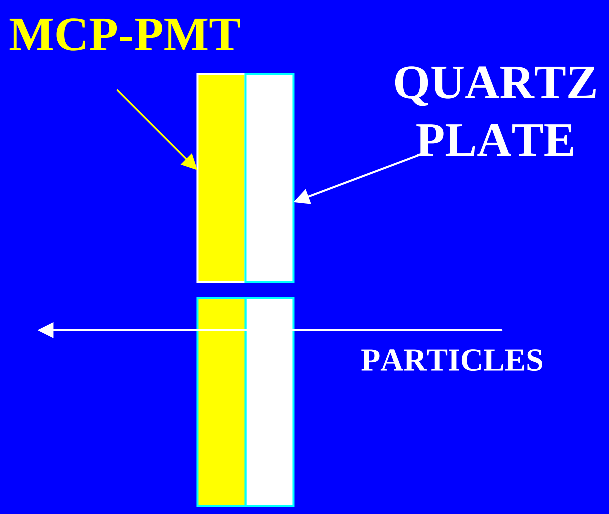
Pads $\approx 1\text{cm} \times 1\text{cm}$
with $\sigma_t \approx 10-20$ ps
covering (e.g) $3.9 < |\eta| < 4.9$
at $z = (5.0?)7.5$m

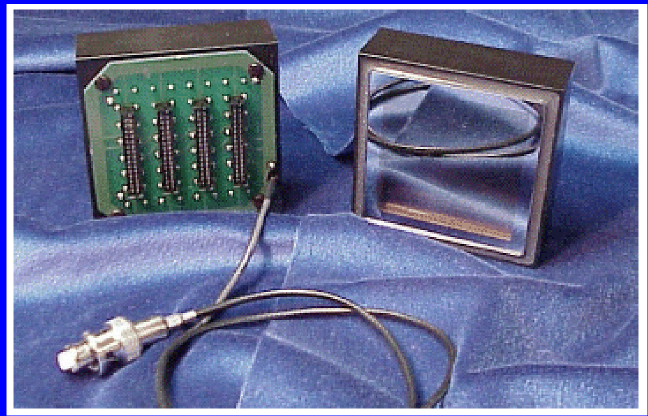
This can identify (in principle) interactions that have particles in both L and R detectors. ***All are background for CEX!***

Fast Timing Layer Detectors

~ Existence proof:
Burle 48mm x 48mm MCP PMT (Micro-channel plate PMT) as for QUARTIC
Developing 10 micron channels, approaching 10 ps.

Tile the plane with these





Approximate numbers:
~ 250 each side, perhaps 1000 1cm x 1cm pads
Expensive solution (~1M$?) but cost could drop.

Questions: Simulation, acceptance, background crap and especially <u>RADIATION HARDNESS</u>. Another solution?

Summary

Assuming we can trigger at high luminosity, <n> large, pile-up in data-on-tape probably very high, but for Central Exclusive Production (unlike HSD) we have many handles:

1) **kinematics,**
2) **FP timing,**
3) **Track-rap-gap vertexing**
4) **Forward timing layers ?**

3 & 4 are just ideas and may be shot down in flames.
All need serious simulation.