Track Trigger Designs for Phase II

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for

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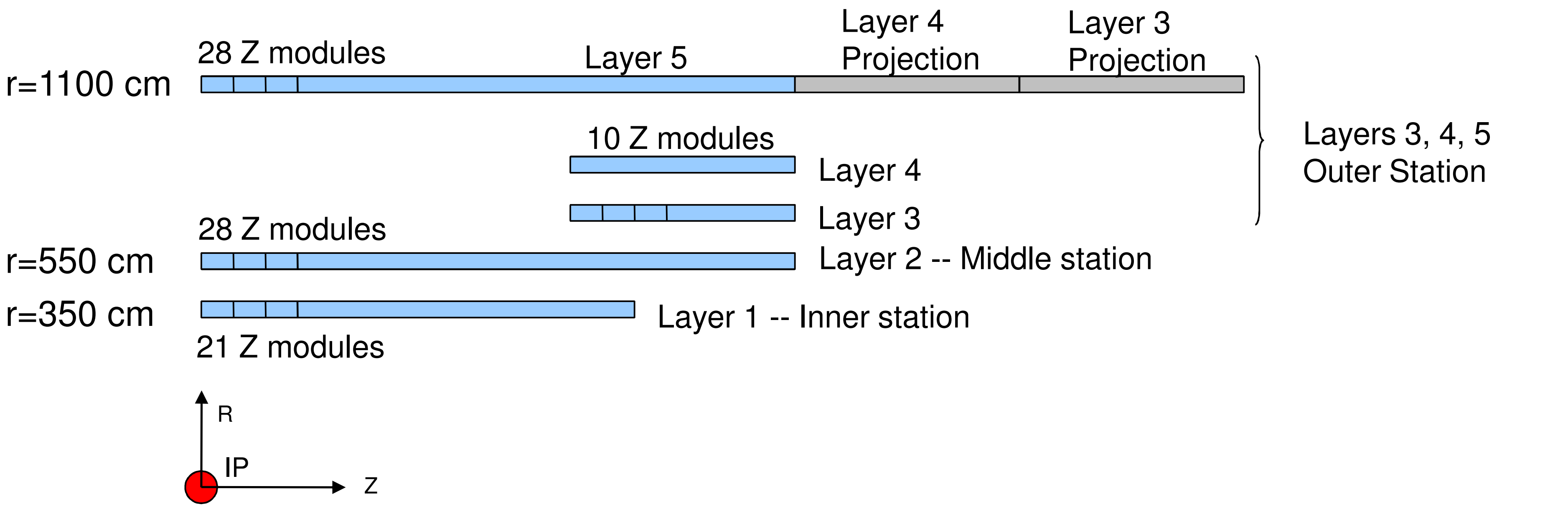
geometry

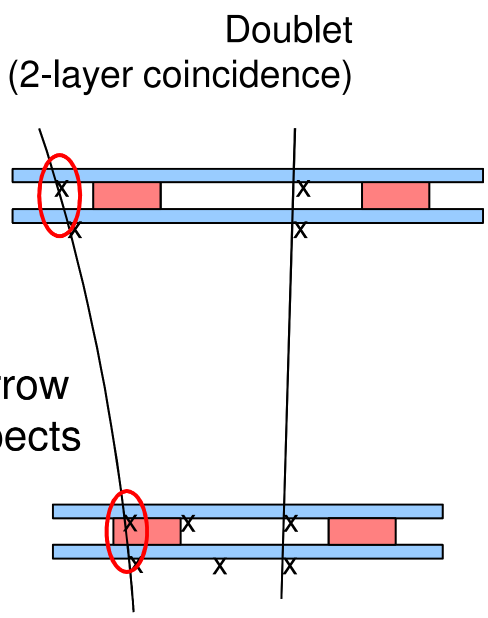
- assume long barrel design for tracker



BUT:
many ideas also apply to geometries with less layers and to different low pT hit rejection schemes (e.g. cluster width)

doublet formation

- reject hits from low p_T tracks on detector
- cluster adjacent pixels with hits
  - reject clusters >2 pixels wide
- require coincidences between clusters in two closely spaced modules in a stack
  - reject single clusters
  - reject doublets from soft tracks

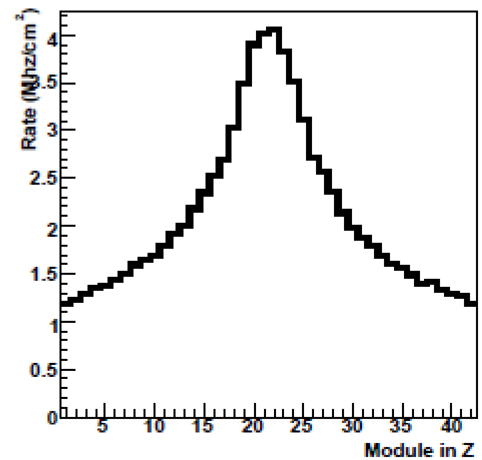


see Ron Lipton's talk at track trigger session tomorrow for details on technical aspects

r-ϕ view of rod structure

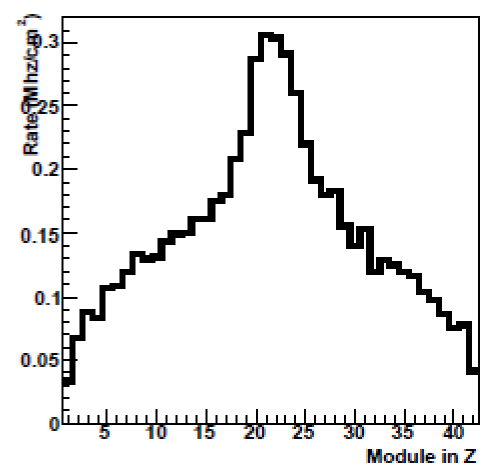
rates

- MC simulation (Laura Fields, Cornell U, track trigger session tomorrow)
  - cluster rate
    - max 2 pixels wide



R = 35 cm	R = 55 cm	R = 110 cm	@ z=0
≈4	≈1.6	≈0.2	MHz/cm^2
≈10	≈4	≈0.5	/xing/module

  - doublet rate
    - 1 mm stack separation
    - 2 GeV threshold



R = 35 cm	R = 55 cm	R = 110 cm	@ z=0
≈0.3	≈0.13	≈0.025	MHz/cm^2
≈0.7	≈0.3	≈0.06	/xing/module

number of fibers

- average rate over length of rod $\approx {}^{1}/_{2}$ max rate @ z=0
- safety factor of ≈10
- ➔1.5 MHz/cm^2 in inner layer
- 42 modules in z
- ➔ 4200 cm^2
- 20 bits/doublet
- ➔ 250 Gb/s per sector per station (2 stacks)
- bandwidth of fiber links = 3.6 Gb/s
- ➔ 70 GBT per sector per station
- ➔ ≈5000 GBT for entire tracker

basic idea

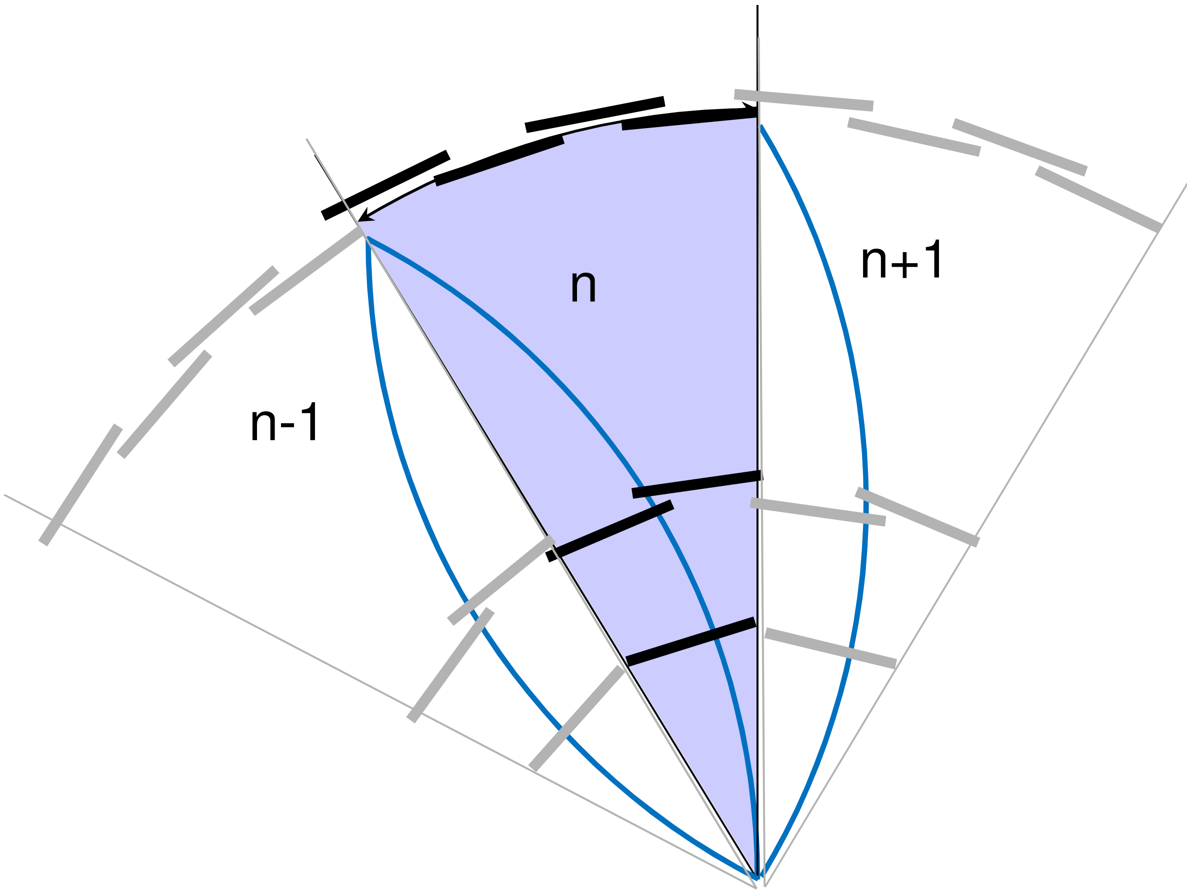
- represent every possible hit combination by a logic "equation":

  $$S_{1i} \cap S_{1o} \cap S_{2i} \cap S_{2o} \cap S_{3i} \cap S_{3o}$$

  - create a table of all possible equations in FPGAs
  - feed all hits for an event into the FPGAs
  - evaluate all equations simultaneously.
  - the equations which are satisfied correspond to the reconstructed tracks
  - timing dominated by time needed to load hits into FPGAs
- problem
  - too many equations
  - too many inputs
  - need to factor problem

sector structure

- trigger logic handles inputs from sectors n-1, n, n+1
- active area of module ≈ 95 mm (ϕ) x 100 mm (z)
- sector size determines min p_T for full acceptance



minimum p_T

- what is the minimum p_T we need to trigger on?

min p_T	sector opening angle	
2 GeV	18°	← requires more/wider modules
2.5 GeV	15°	← lots of inputs but geometry easier
5 GeV	7.5°	← less inputs – makes trigger easier

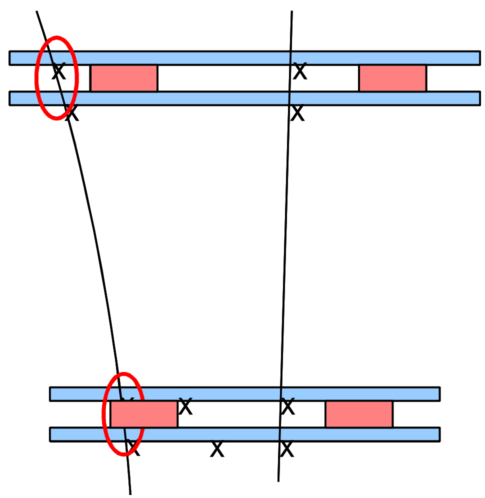
- built into the hardware design
- need to decide soon

- ➔ here assume 15° sectors

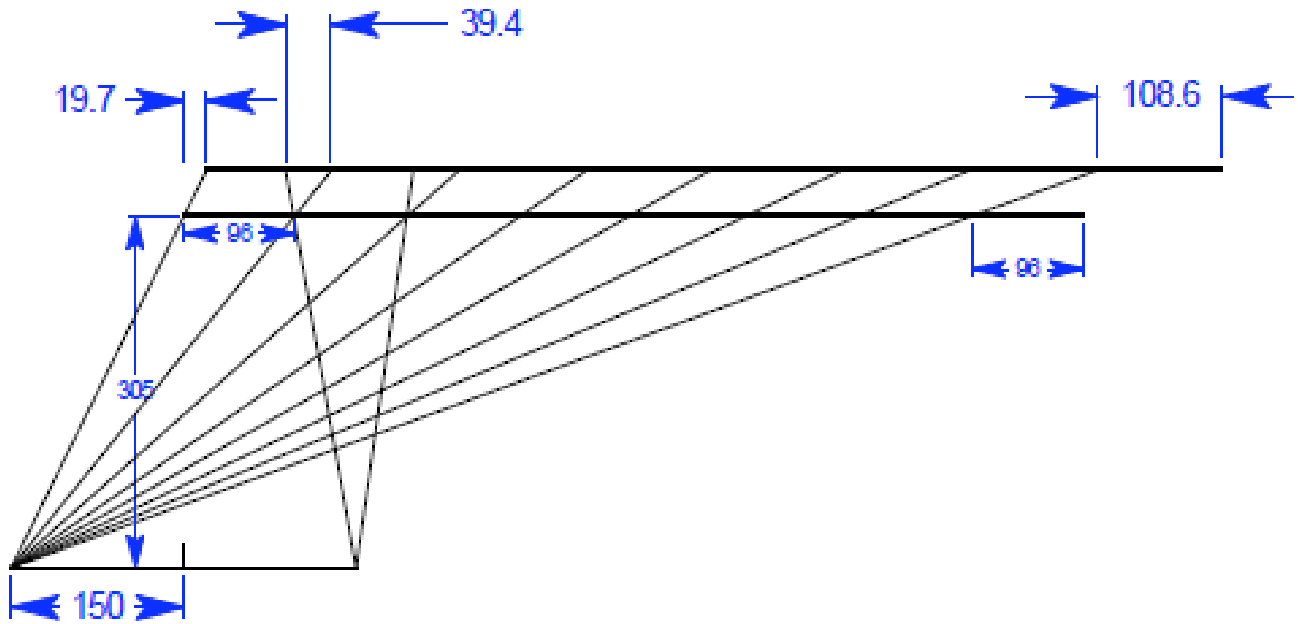
tracklet formation

- combine doublets from the two stacks in each station to form tracklets
  - drop in rate by about factor 4 (but need ≈40 bits/tracklet)
  - for each stack in inner layer need to process data from two adjacent stacks in z in outer layer

Doublet
(2-layer coincidence)

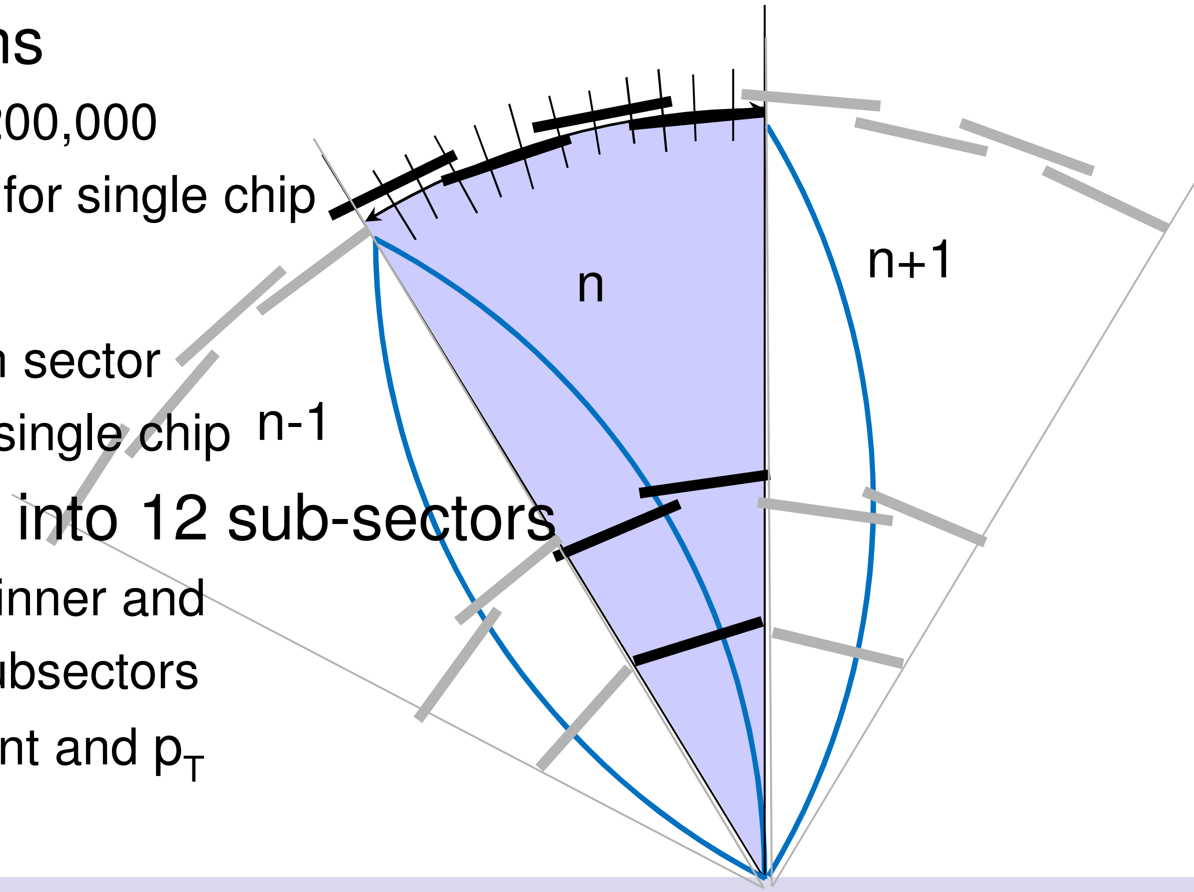


Tracklet
(4-layer coincidence
with P_T validation)

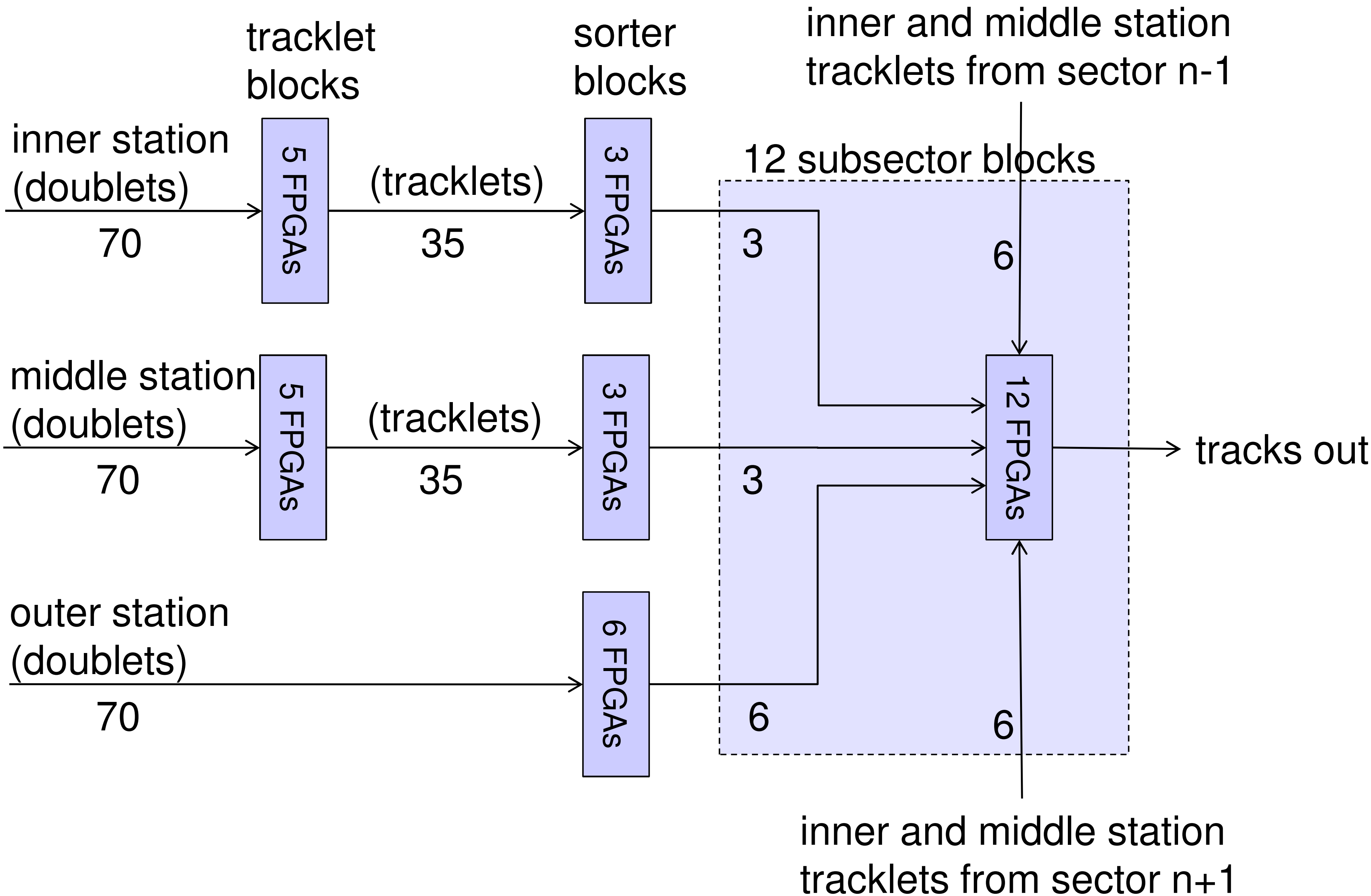


equation count

- assume azimuthal position resolution ≈ 0.1 mm
- number of ϕ positions per sector:
  - ≈ 2900 in outer station
  - ≈ 1450 in middle station (for each outer station position)
- number of equations
  - ≈ 2900 * 1450 = 4,200,000
  - too many equations for single chip
- number of fibers
  - 210 fibers from each sector
  - too many inputs for single chip
- divide outer station into 12 sub-sectors
  - route tracklets from inner and middle stations to subsectors using interaction point and p_T



sector processor



sector processor

- outer station
  - no pT information required for sorting
  - no need to form tracklets in outer station
  - robust against inefficient sensors
  - number of equations in each sector
    - $\approx$ 4,200,000/12 $\approx$ 350,000
- middle and inner stations
  - loose entire station if there is an inefficient sensor
- solution
  - in parallel sort into 12 subsectors anchored in middle layer and into 12 subsectors anchored in inner layer
  - robust against inefficient sensors in any layer

sector processor

- for each trigger specify number of tracklets and doublets
  - accept tracks with
    - 3 tracklets
    - 2 tracklets and 0 or 1 doublets
    - 1 tracklet and 0 or 1 doublets
- do r-ϕ tracks satisfy track equations in z?
- remove duplicate tracks

summary

- 3 trigger stations provide full coverage for tracks with p_T>2.5 GeV in 15^o sectors
- hits collected in real time, sent off-detector on ≈5000 optical fibers at 3 Gb/s
- all possible track equations for each sector evaluated in parallel using FPGAs in USC to produce inputs for L1
- total of ≈2000 large FPGAs needed to build this using current technology

next steps

☺ robust against hardware failures

☺ very powerful pattern recognition

☹ large channel count, power, mass

- need MC simulations implementing specific algorithms
- verify rate estimates with LHC data

➔ do we really need 6 trigger layers?

➔ what is the smallest number of trigger layers needed?