KLM trigger status and plan

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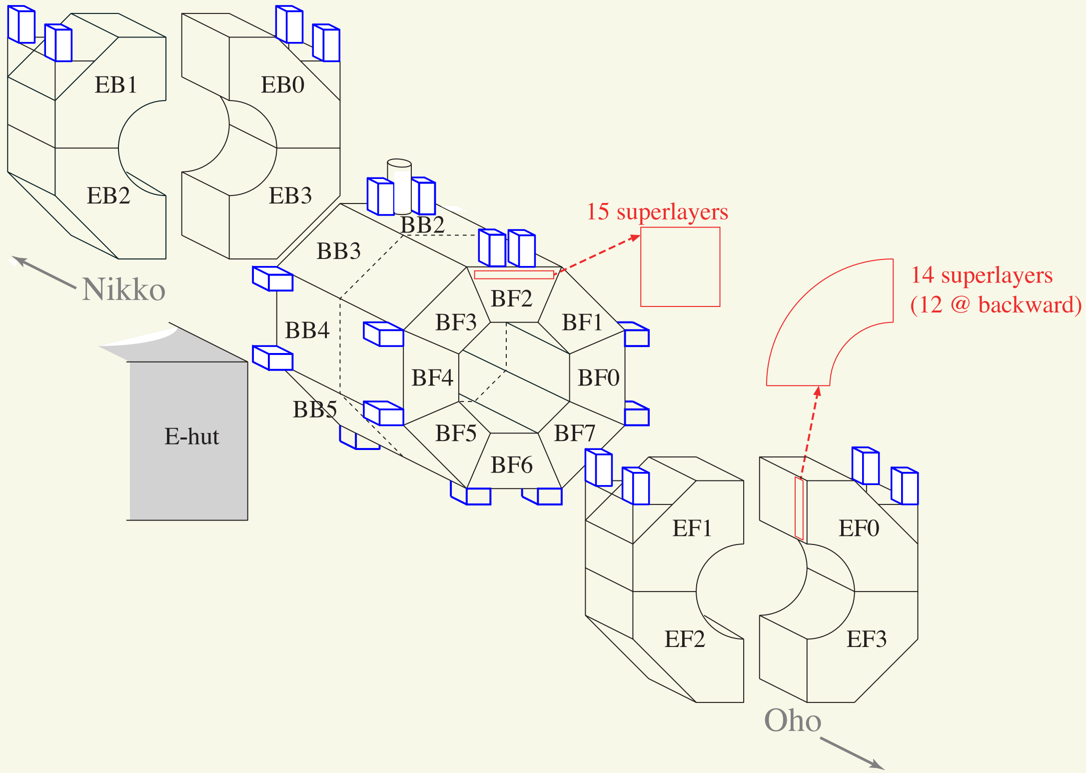
- ✓ KLM structure overview
- ✓ KLM trigger design
- ✓ Trigger status and plan

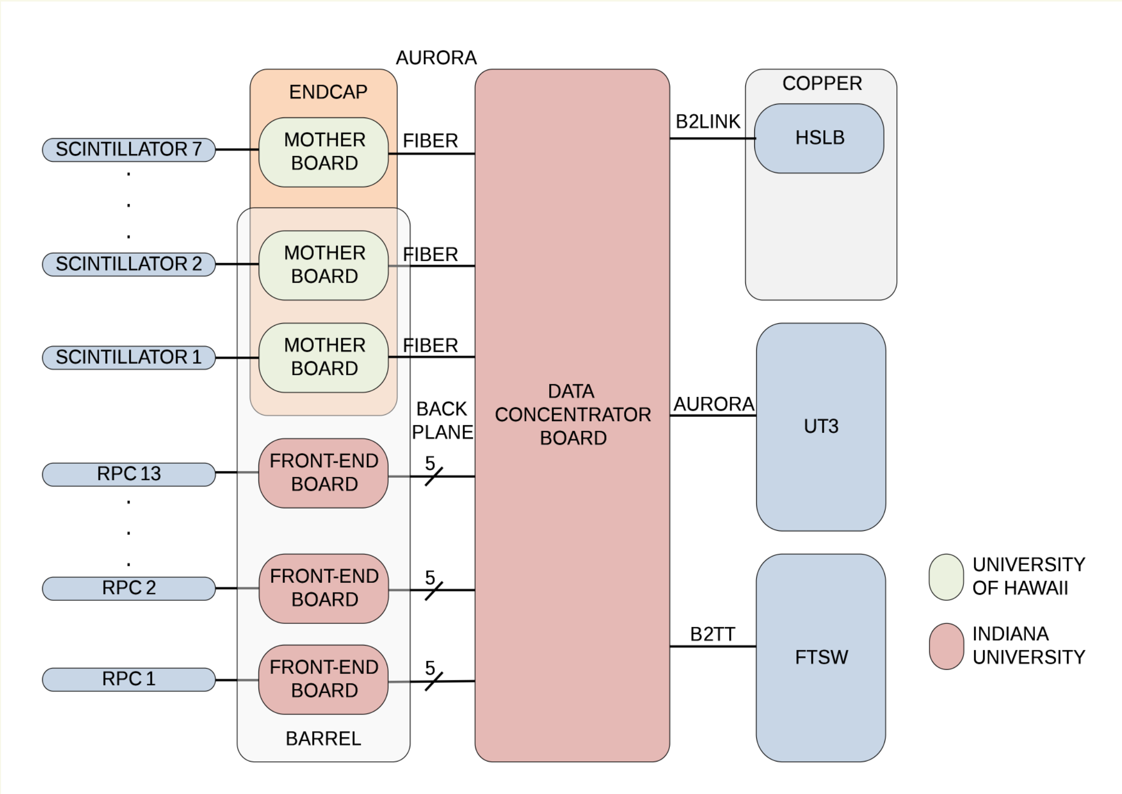
KLM structure

- KLM is divided into a barrel and endcaps;
- The barrel is divided into forward and backward halves,
  - eight sectors (octants) in each half,
  - 15 layers in each sector;
- Endcaps are divided into four sectors (quadrants) each,
  - 14 layers in the forward endcap;
  - 12 layers in the backward endcap;
- Two inner barrel layers and entire endcaps are instrumented with scintillator strips;
- 13 outer barrel layers are instrumented with RPCs.

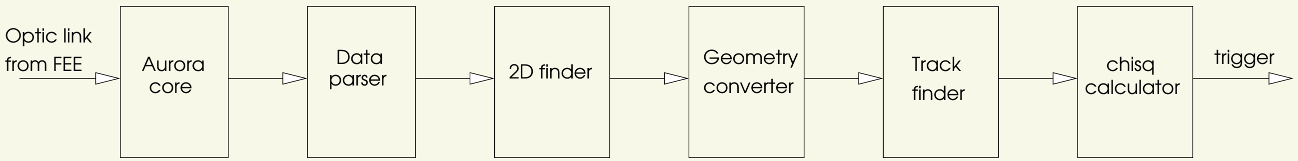


Readout electronics

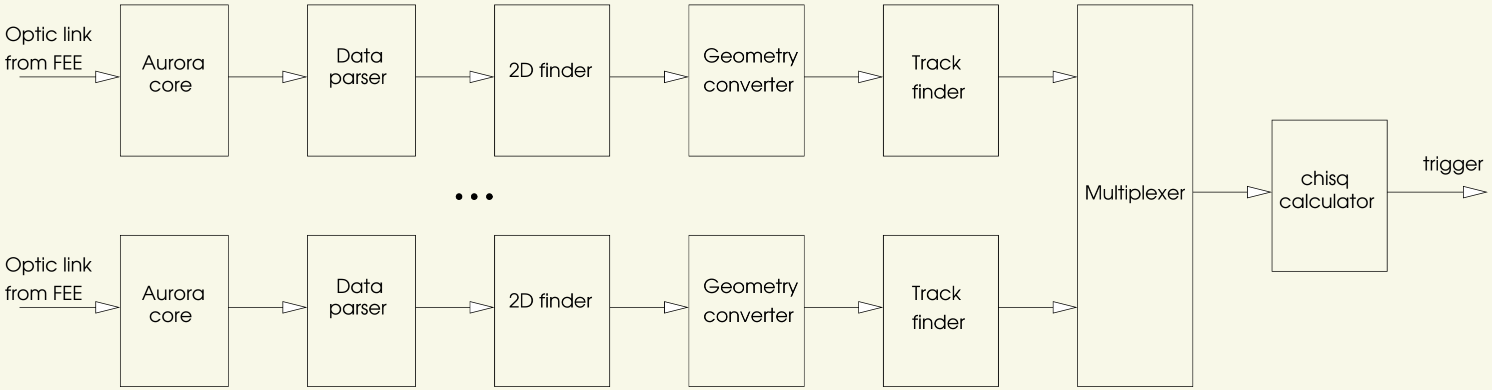
- Each module is connected to a FE board;
- In the barrel all FE boards of the same sector are connected to one data concentrator.
- In the endcaps all FE boards of the same sector are connected to two data concentrators.
- Data concentrators talk to FTSWs, UT3, COPPERs.



Baseline (implemented):



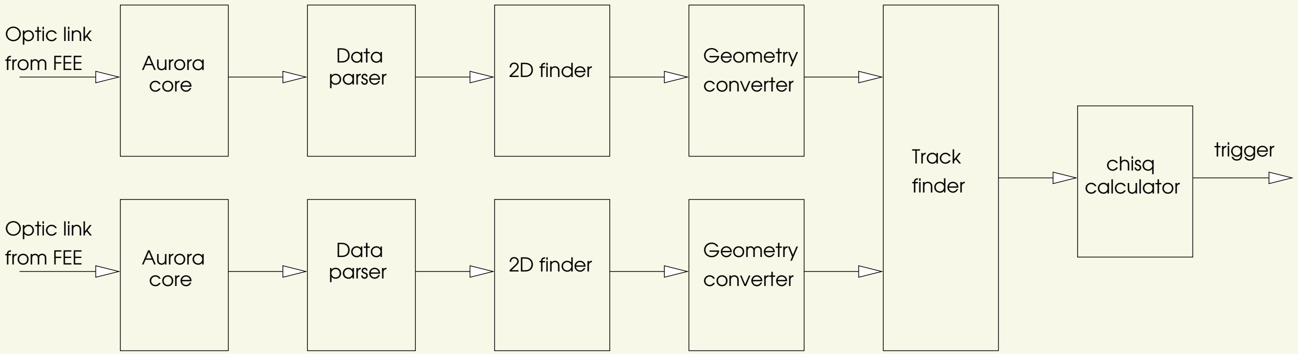
Alternative:



- ✓ One optic link per sector (16 sectors at all);
- ✓ Sectors are processed independently in parallel; tracks are assumed to be confined in a single sector.
- ✓ Individual sectors trigger outputs are ORed;
- ✓ Mathematics in FPGA are very resource demanding. Decreasing number of χ^2 calculators we can save resources.

KLM trigger scheme: endcap

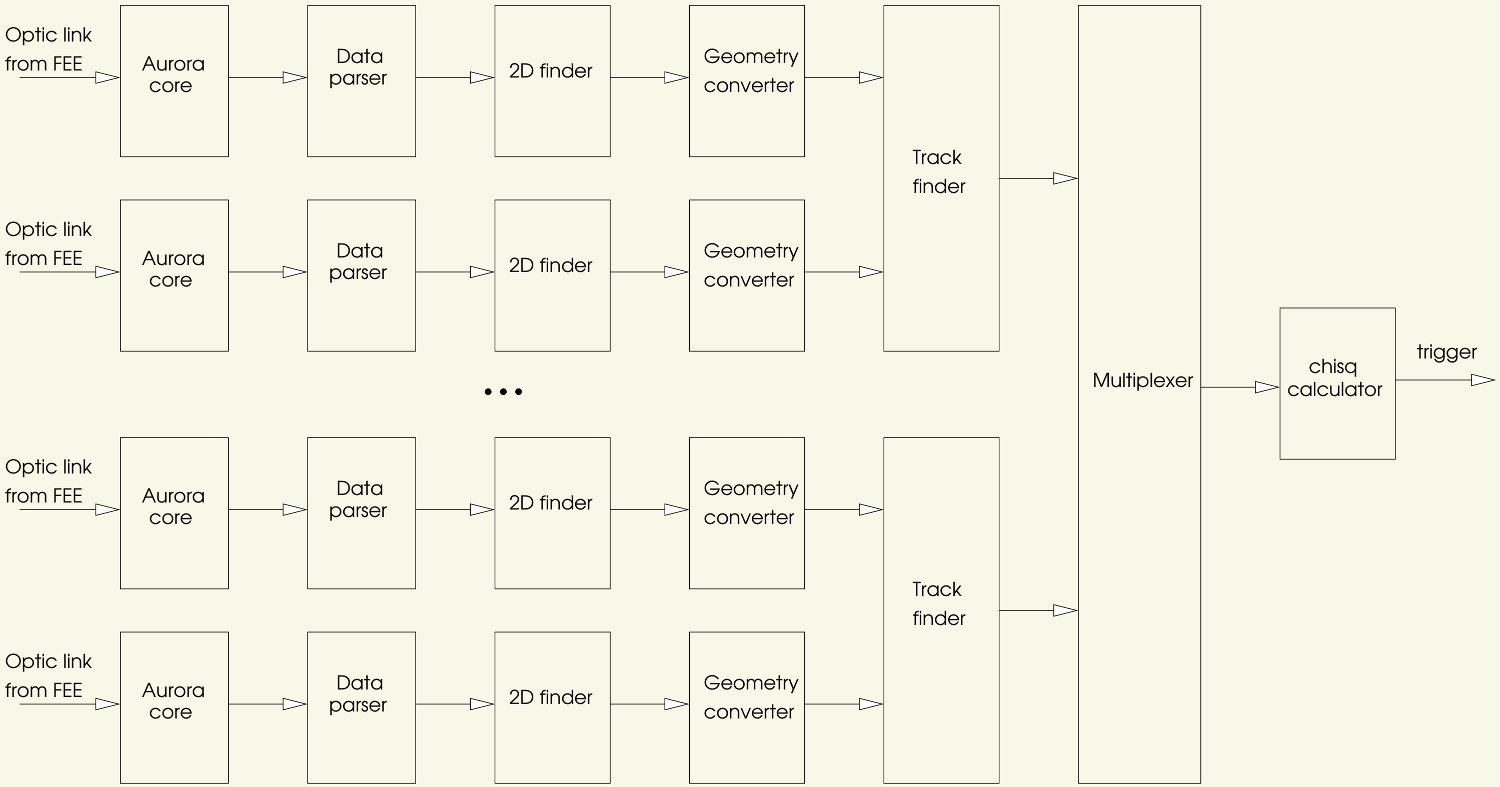
Baseline:



- ✓ Two optic links per sector (8 sectors at all);
- ✓ Sectors are processed independently in parallel; tracks are assumed to be confined in a single sector.
- ✓ Individual sectors trigger outputs are ORed.

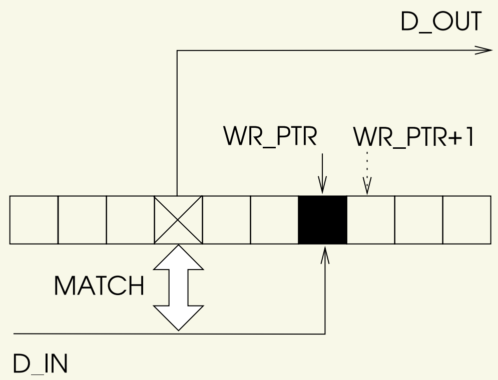
KLM trigger scheme: endcap (2)

Alternative:



- ✓ Two optic links per sector (8 sectors at all);
- ✓ Mathematics in FPGA are very resource demanding. Decreasing number of χ^2 calculators we can save resources.

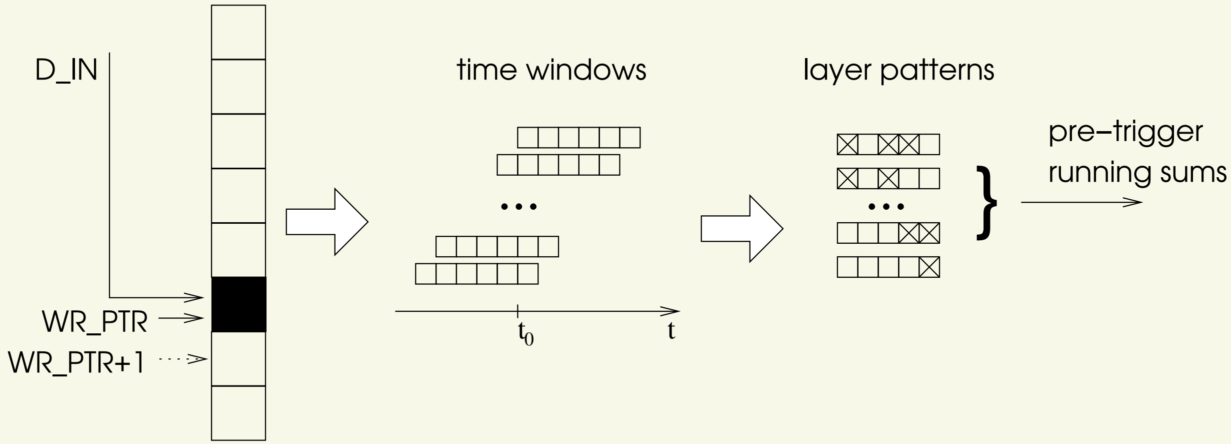
- ▷ Data parser – deserializer (three words $\times$ two bytes $\Rightarrow$ 41 bits). Three clock cycles per hit.
- ▷ 2D finder – searches for matches of 1D hits in coincidence window of six cycles of 127MHz clock ($\sim$ 47ns).
  1D hit storage is divided into small parts for different layers and detector strip orientation (axis). Match only against proper 1D hits (layer, axis).
  $1 + N(2D)$ clock cycles.



- ▷ Geometry converter – maps layer and channel numbers to coordinates (x, y, z).
  LUT and some arithmetic.
  One clock cycle.

Components functionality (2)

- Track finder – checks 2D hits in coincidence window of six cycles of 127MHz clock ($\sim$ 47ns) searching for a track. If found, generates a pre-trigger and running sums needed for χ^2 calculator. Two clock cycles.



- χ^2 calculator – assumes that track is a straight line; using running sums provided by the track finder calculates track parameters, impact parameter and $\chi^2 \times$ ndf of the track.
  31 clock cycles (23 for a division).

χ^2 calculation

A straight line $y = a \cdot x + b$ fitting to n points (x_i, y_i) is given by

$$a = \frac{n \cdot s_{xy} - s_x \cdot s_y}{D}, \quad b = \frac{s_y \cdot s_{xx} - s_x \cdot s_{xy}}{D}, \quad \text{where} \quad D = n \cdot s_{xx} - (s_x)^2,$$

and

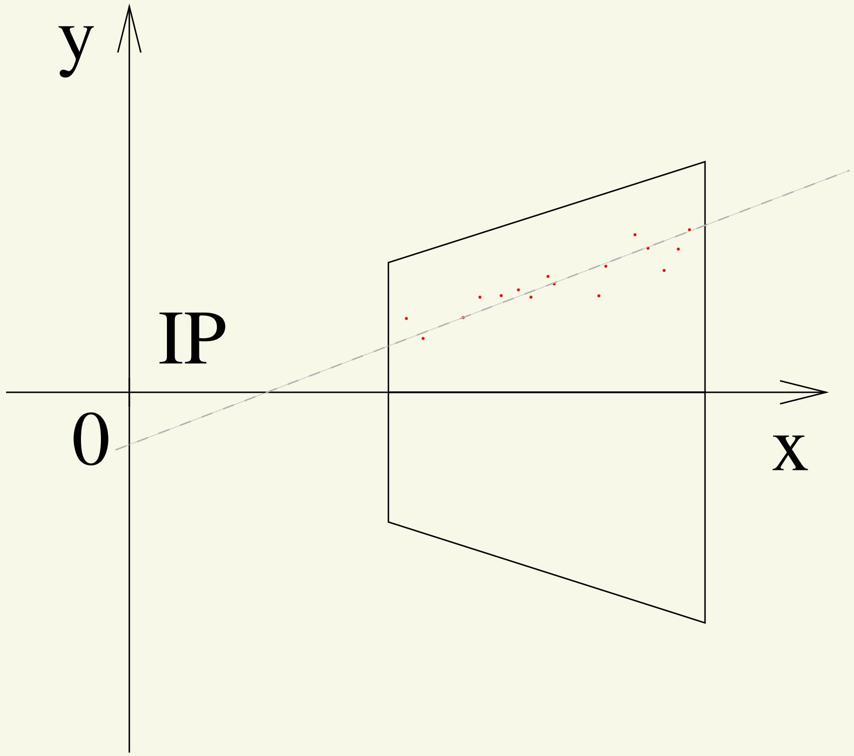
$$s_x = \sum x_i, \quad s_{xx} = \sum x_i^2,$$

$$s_y = \sum y_i, \quad s_{xy} = \sum x_i \cdot y_i.$$

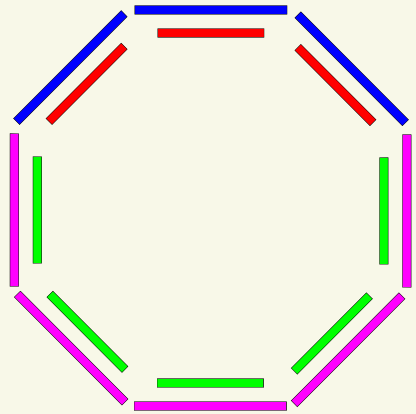
Then impact parameter d_{ip} and χ^2 are given by

$$d_{\text{ip}}^2 = \frac{b^2}{1 + a^2} \simeq b^2(1 - a^2) \quad (a \sim 0.5),$$

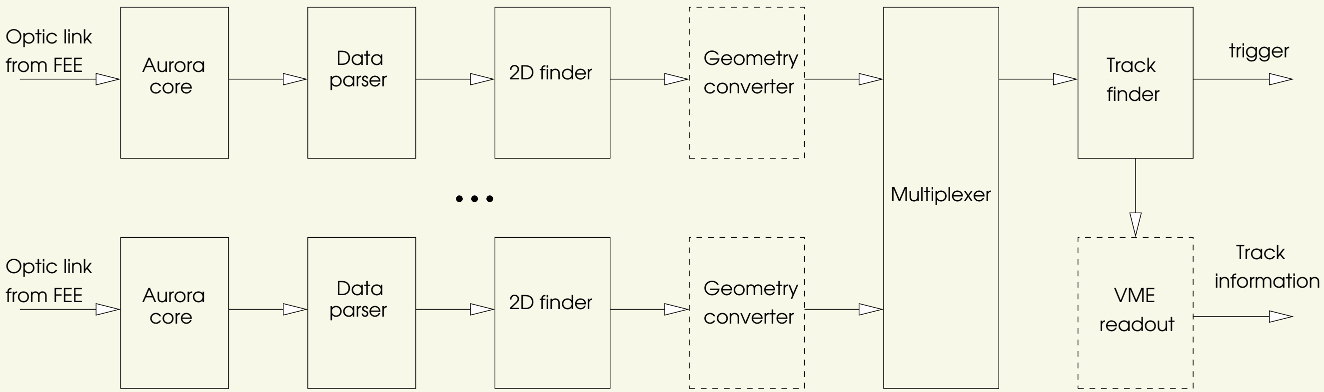
$$\chi^2 \cdot n = \sum (a \cdot x_i + b - y_i)^2.$$



KLM trigger for TOP



- Barrel KLM may be used to generate a trigger for TOP.
- Only scintillator KLM layers are used (no FEE for RPCs yet).
- Scintillator modules are combined into four groups (shown by different colors).
- Trigger is generated when we have simultaneous 2D hits in all four groups.
- Firmware is written based on the general KLM trigger firmware.



KLM trigger status and plan

- ✓ All components of the KLM trigger are written. Some are tested, some need testing.
- ✓ KLM trigger for TOP written but not used yet due to FEE unavailability. Hardware (boards, fibers, cables) is ready; Isar (UH) is coming to KEK in the middle of September to connect and test it.
- ✓ After extensive optimization and streamlining the full KLM trigger for TOP firmware meets timing and resource requirements.
- ✓ KLM trigger stream recorder is used for the analysis of the data stream from data concentrators to verify changes made by Isar and Brandon (IU) to FE and DC firmware.

- ➢ Update tsim to the present state of the FW.
- ➢ Properly test all components with simulation.
- ➢ Test the FW with random data and real data with tsim and UT3 using VME readout.
- ➢ Provide a KLM trigger for TOP.
- ➢ Further optimize FW to increase memory depth.