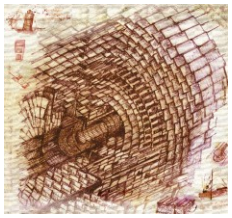
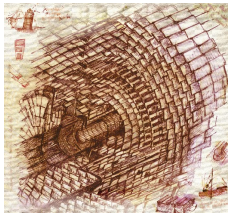
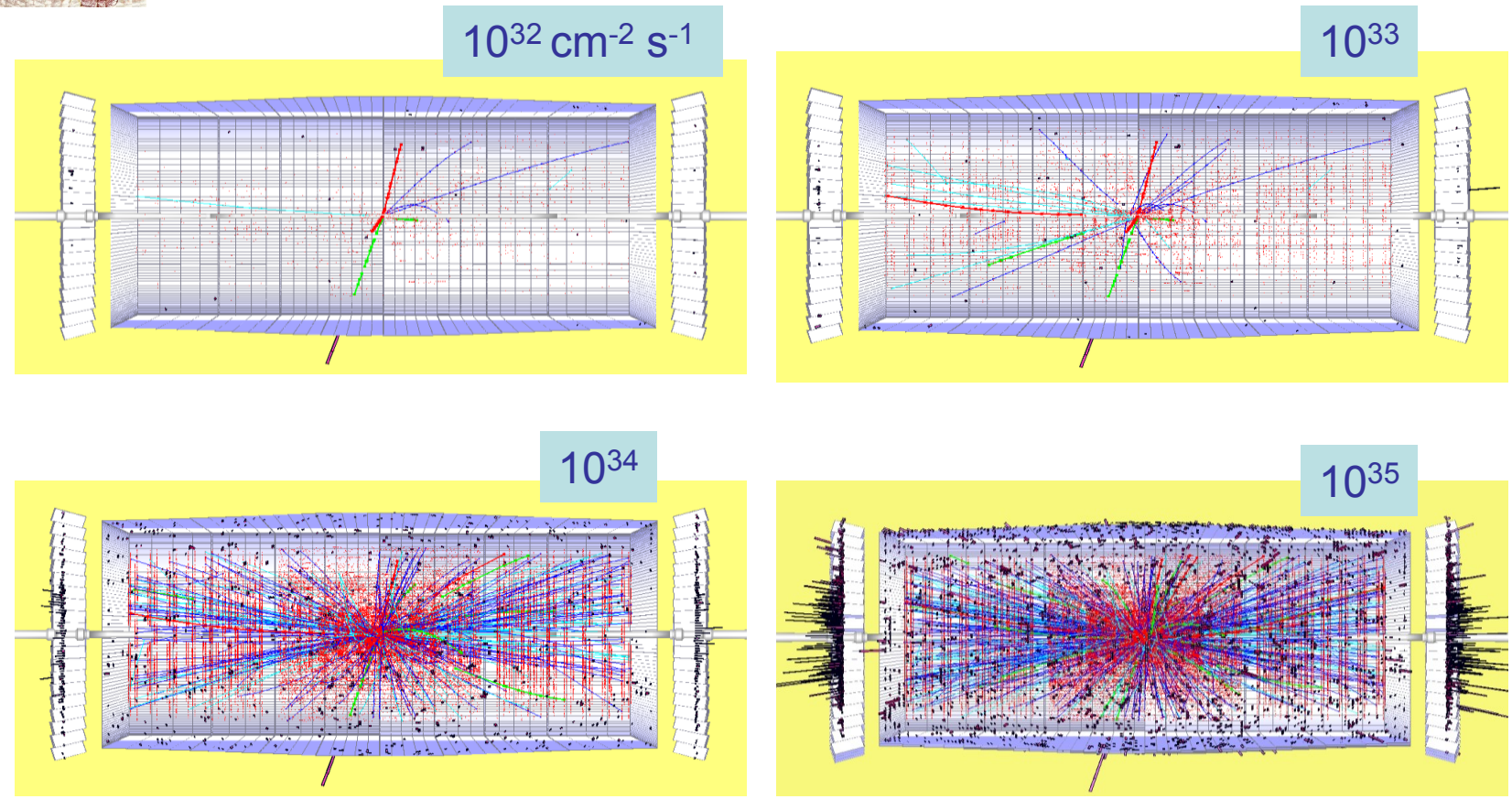


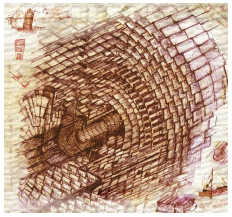
Overview of CMS Tracking Trigger



CMS from LHC to SLHC
Motivation for L1 Tracking Trigger



At SLHC CMS faces new challenges, in particular for both Tracking and Triggering



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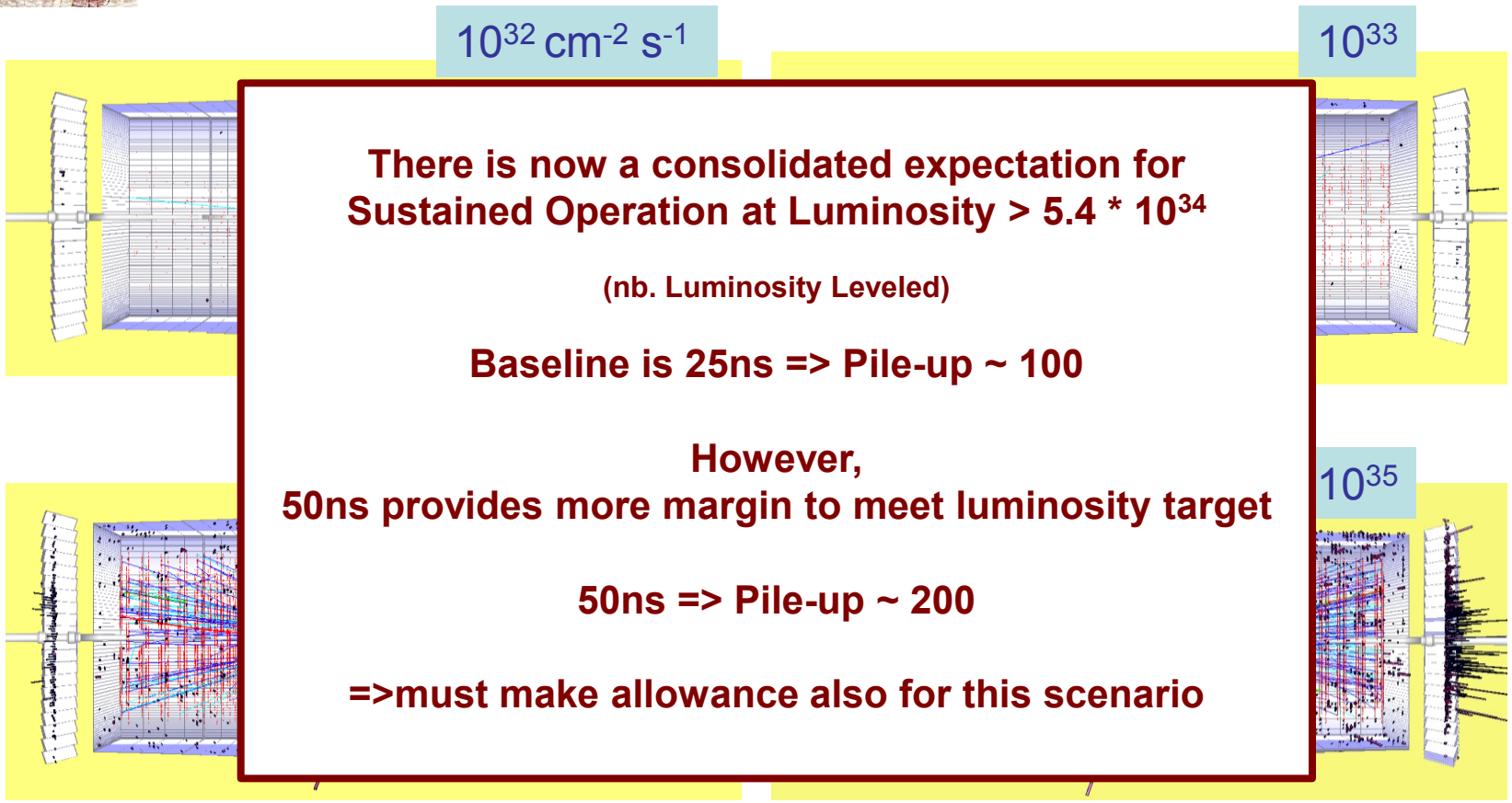


There is now a consolidated expectation for Sustained Operation at Luminosity > 5.4 * 10^{34}

(nb. Luminosity Leveled)

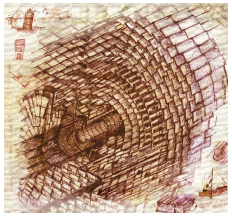
Baseline is 25ns => Pile-up ~ 100

However,
50ns provides more margin to meet luminosity target

50ns => Pile-up ~ 200

=>must make allowance also for this scenario

At SLHC CMS faces new challenges, in particular for both Tracking and Triggering



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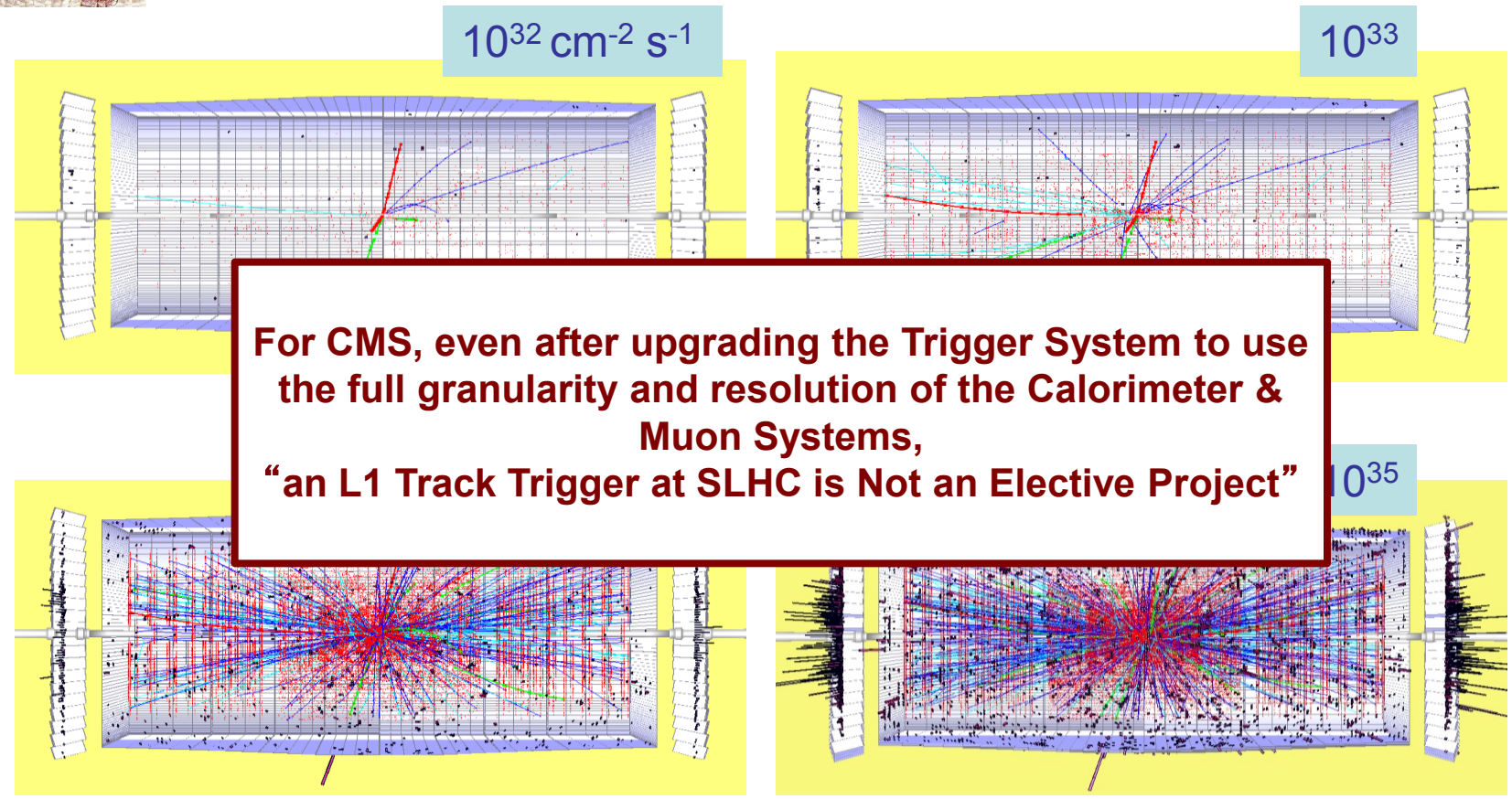
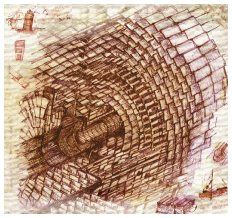


For CMS, even after upgrading the Trigger System to use the full granularity and resolution of the Calorimeter & Muon Systems,
"an L1 Track Trigger at SLHC is Not an Elective Project"

At SLHC CMS faces new challenges, in particular for both Tracking and Triggering



CMS from LHC to SLHC
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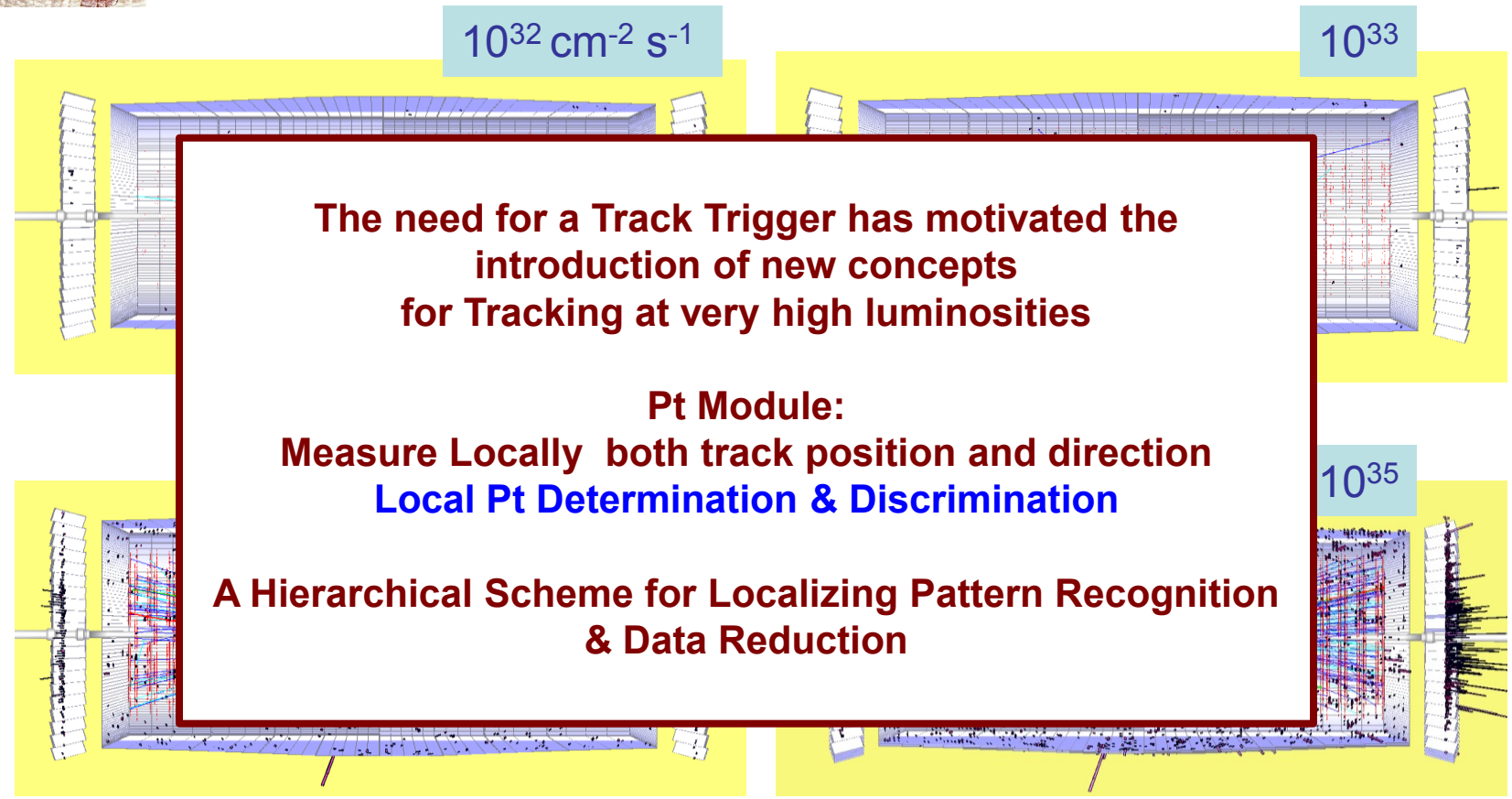
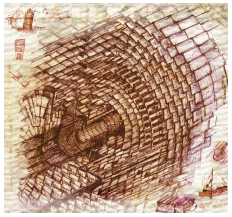


The need for a Track Trigger has motivated the introduction of new concepts for Tracking at very high luminosities

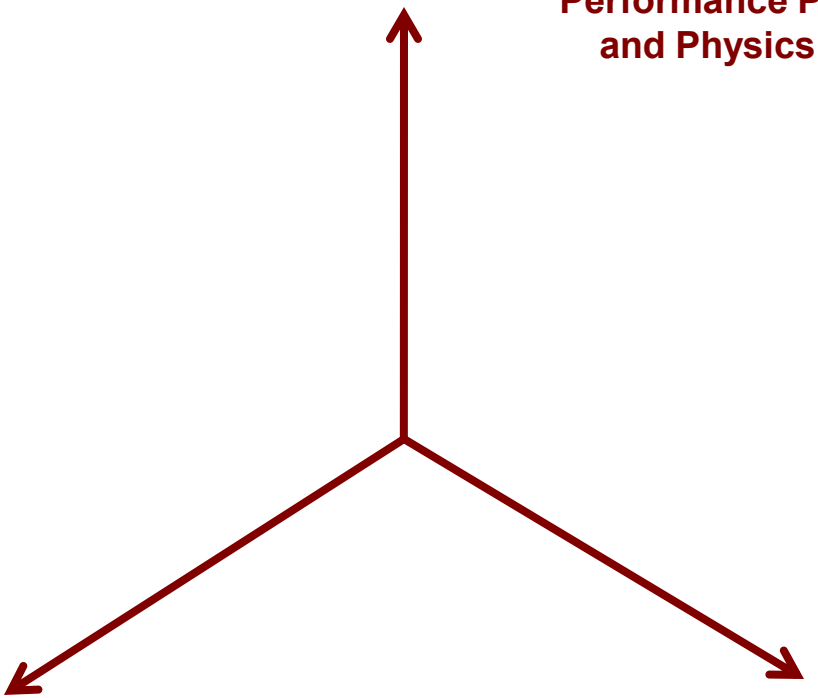
Pt Module:
Measure Locally both track position and direction
Local Pt Determination & Discrimination

A Hierarchical Scheme for Localizing Pattern Recognition & Data Reduction

At SLHC CMS faces new challenges, in particular for both Tracking and Triggering



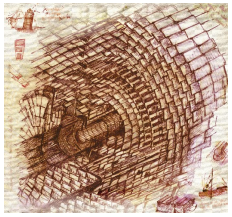
Tracking Trigger Studies: a Three-Pronged Approach



Performance Potential and Physics Case

Enabling Technologies

Architecture and System Design



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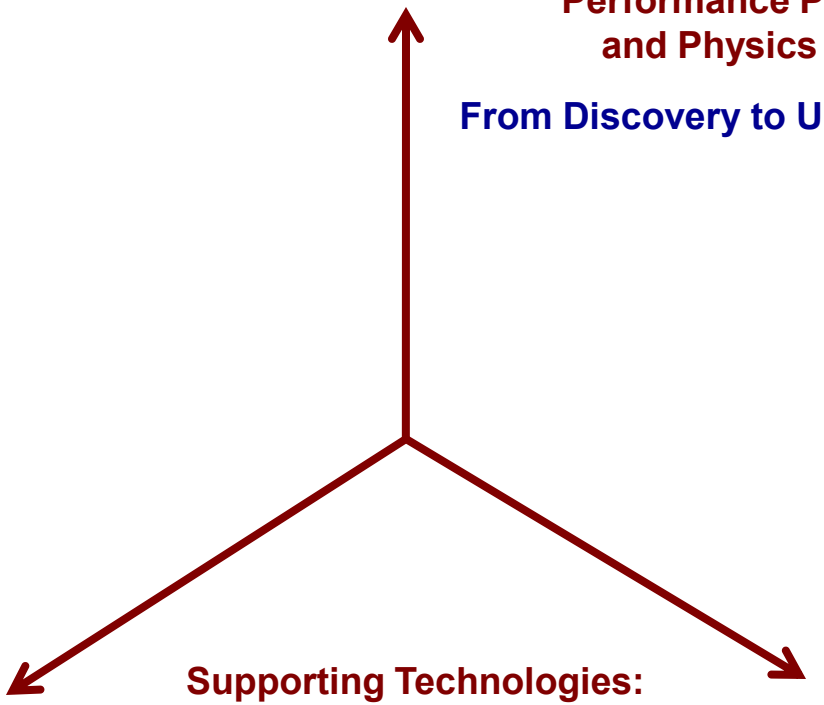


Performance Potential and Physics Case

From Discovery to Understanding

Enabling Technologies

Pt Modules, Data Links

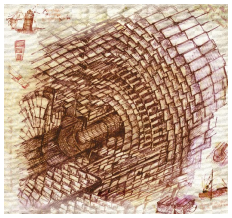
Supporting Technologies:

Power
Cooling
Mechanics

EMC
Material Reduction

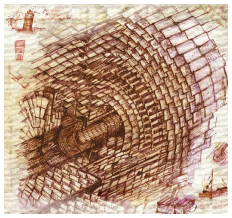
Architecture and System Design

Aim for 40(20)MHz System
Pre-trigger a possible fall-back



Tracking Trigger Studies a Three-Pronged Approach

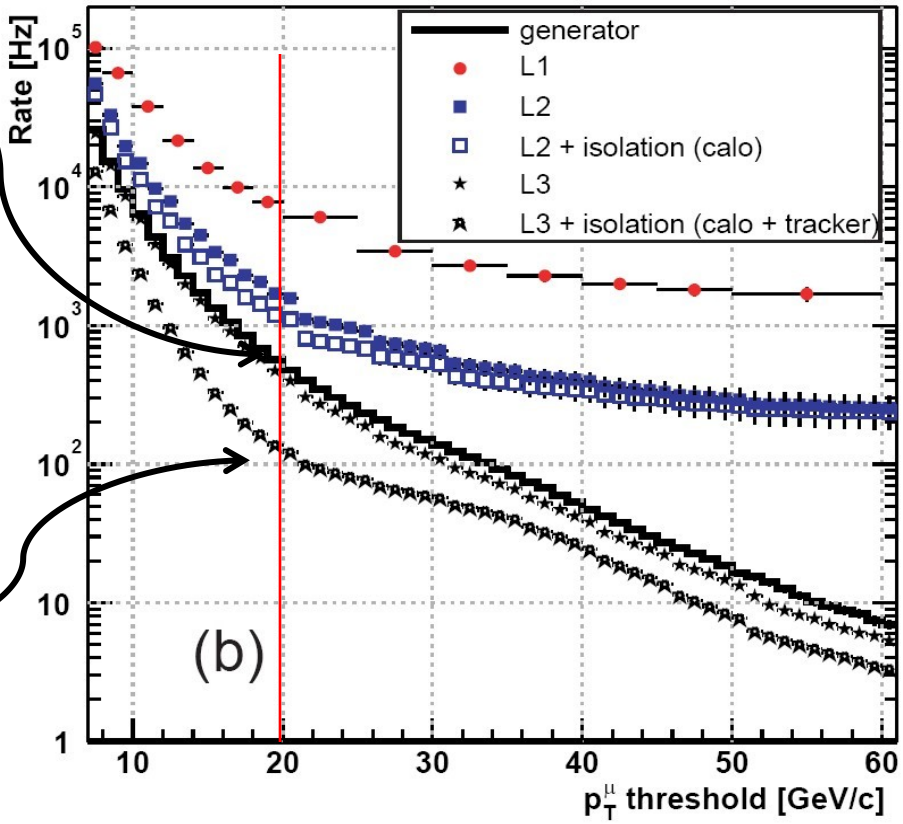
- **Performance Potential and Physics Case**
  - **Ability to adapt to evolving Physics Areas of Interest: from first discovery to detailed study and in depth understanding**
    - High Luminosity => study increasingly rare process in challenging environment !
    - Precision Higgs physics (SM or not ?)
    - Precision SUSY ? Exotica ?
    - Extend range of discovery ?
  - **High quality Tracking is certain to play an increasingly crucial role**
  - **High quality Tracking Trigger Discriminants a potentially key asset**
    - Assess Impact of different Architecture, Layout & Technology options



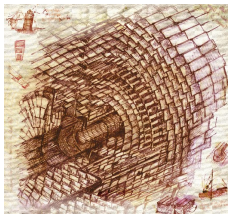
Required Functionality
L1 Trigger: Muons

- **Confirmation of High Pt Muon Candidates**
  - **now done in HLT**
- **Accurate measurement of Tracks with Pt > 15 ~ 20 GeV**
  - **Fast, Efficient high Pt Tracking**
  - **Excellent Pt resolution**
    - 1 ~ 2% Pt resolution for $\eta < 2$
- **Isolation can be useful**

Pile-up effects at > $5*10^{34}$ not included in L1 μ Pt threshold curve !

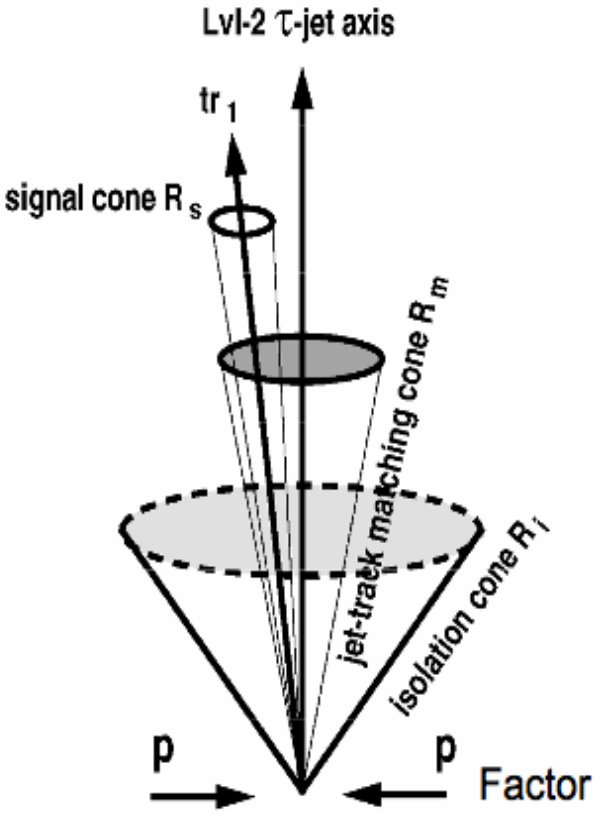


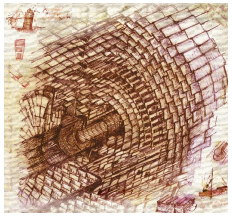
Factor ~ 100 rate reduction for same Pt threshold



SLHC L1 Tracking Trigger: An Illustration of the case for Tau Lepons

- **Confirmation of High Pt Narrow Jet Candidates**
  - Tracks with Pt above ~ 10 GeV
  - Fast, Efficient high Pt Tracking
  - Good Pt resolution
- **Isolation**
  - Tracks with Pt above ~ 2 GeV
  - Fast, Efficient and Clean Tracking down to Pt ~ 2GeV
- **Longitudinal Primary Vertex association**
  - Required to maintain efficiency at high pile up
  - Tracks with Pt above ~ 2 GeV
  - Good Z Vertex resolution

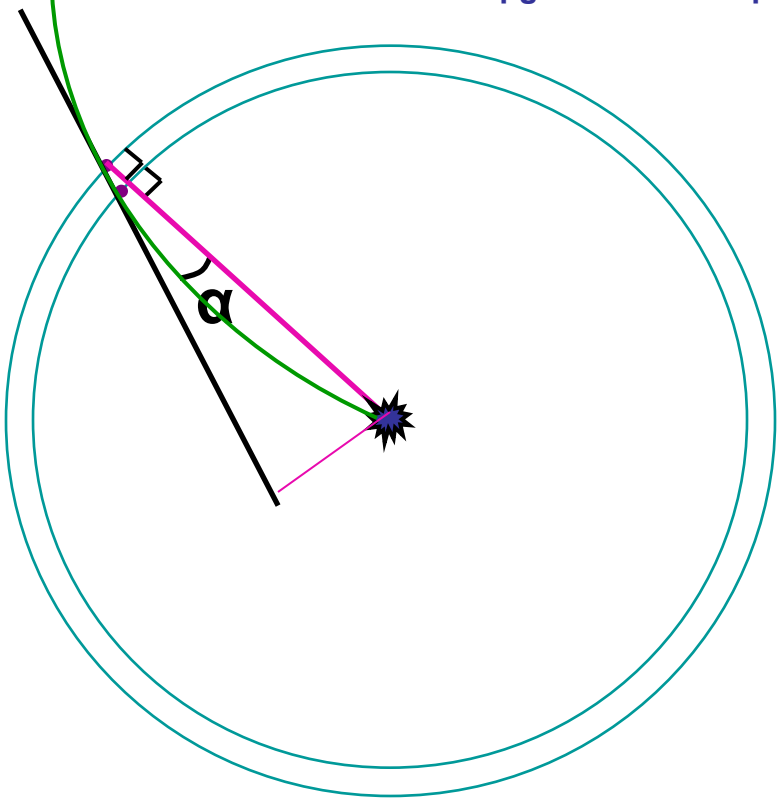




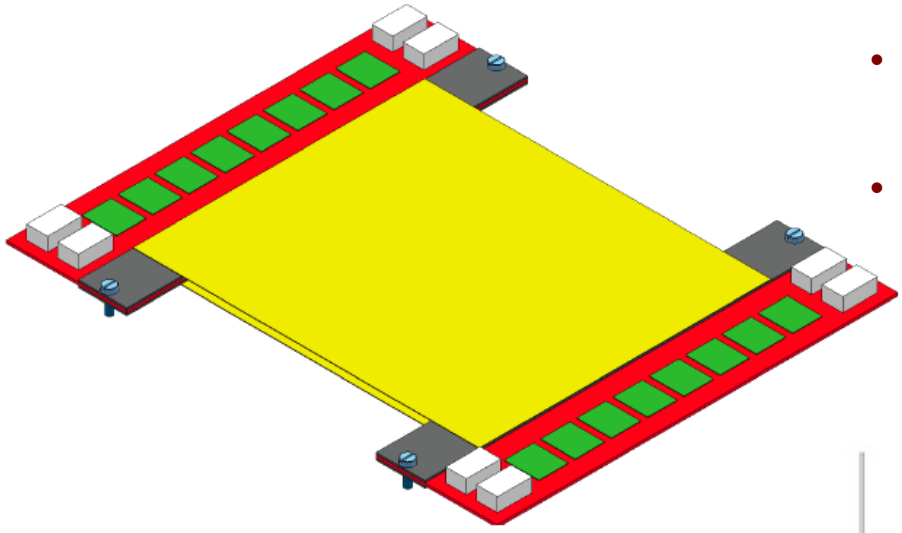
Local Occupancy Reduction with Local Track Vectors

- **Pairs of Sensor Planes, for local Pt measurement**
- **High Pt tracks point towards the origin, low Pt tracks point away from the origin**
- **Use a Pair of Sensor Planes, at ~ mm distance**
  - **Pairs of Hits provide Vector, that measure angle of track with respect to the origin**
  - **Note: angle proportional to hit pair radius**
- **Keep only Vectors corresponding to high Pt Tracks**

J. Jones, A. Rose, K. Fountas (~2005)
CMS Tracker SLHC Upgrade Workshops



A range of Concepts for Pt Modules
The Strip Pt Module



Pros:

- **Based on existing Technologies and well-established know how**
- **Naturally brings together signals from top & bottom sensors for Local Stub Lo**

(See later talks A. Messineo & M. Raymond)

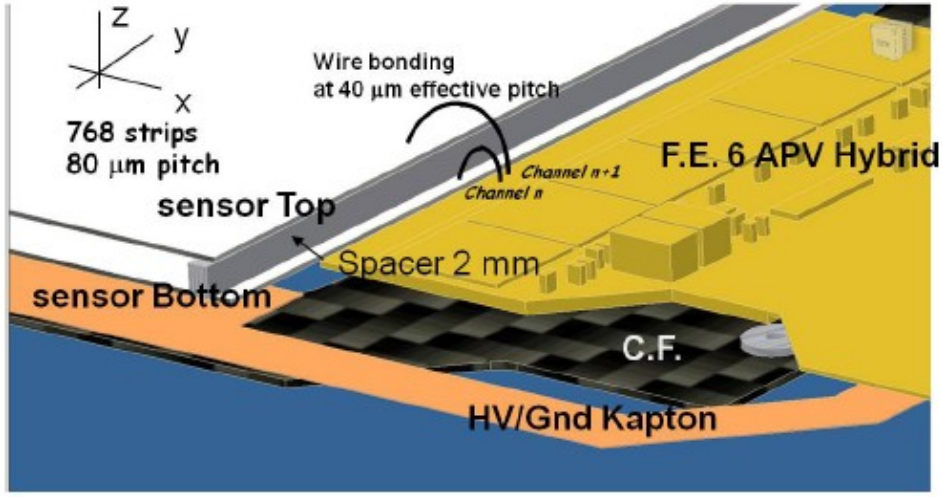
Cons:

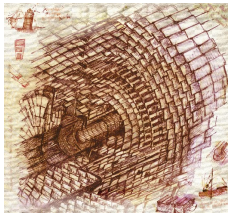
- **~ 5cm strips**

=> limited to large radii

- **Lack of Z information**

=> Difficult for isolation?



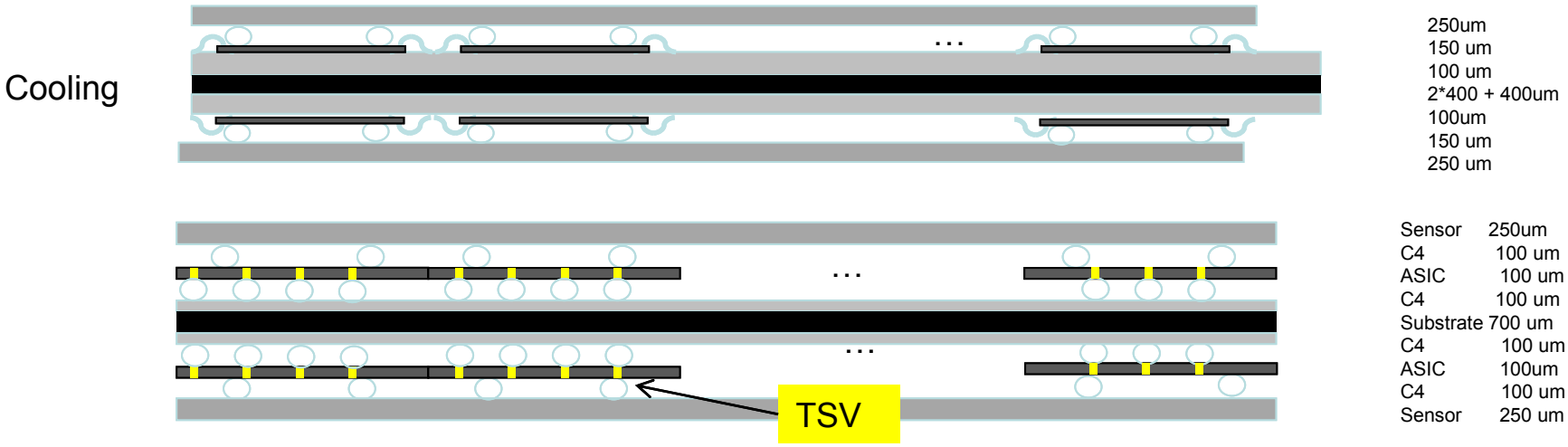


A range of Concepts for Pt Modules
Large Area Pixelated Pt Modules

Option 1: Separate Electronic layer for each Sensor

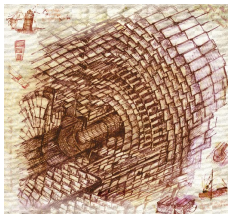
Pros:

- 1~2mm pixel length => full 3d information



Cons:

- Technologically Aggressive
- Transmission of hits/clusters & Stub Logic at module periphery Challenging



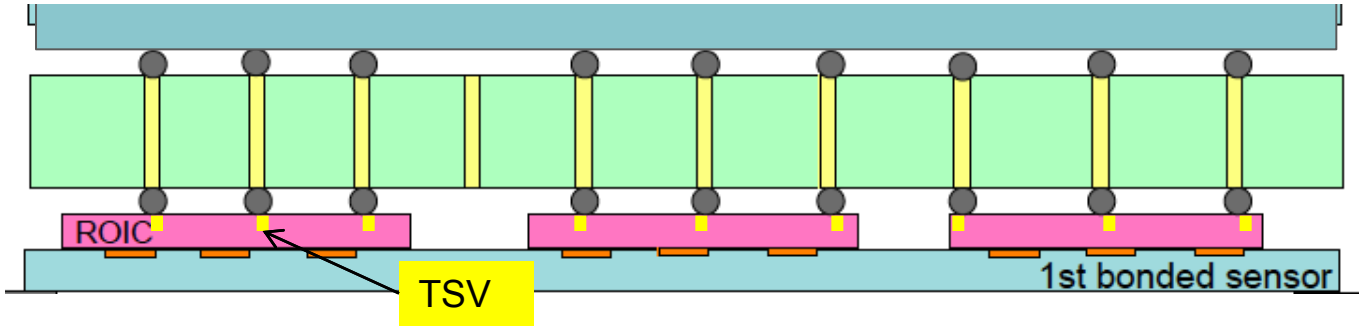
A range of Concepts for Pt Modules
Large Area Pixelated Pt Modules

Option 2: Vertically Integrated
Direct analogue connection from top sensor to bottom tier chip

Pros:

- 1~2mm pixel length => full 3d information
- Naturally brings together signals from top & bottom sensors for Local Stub Logic

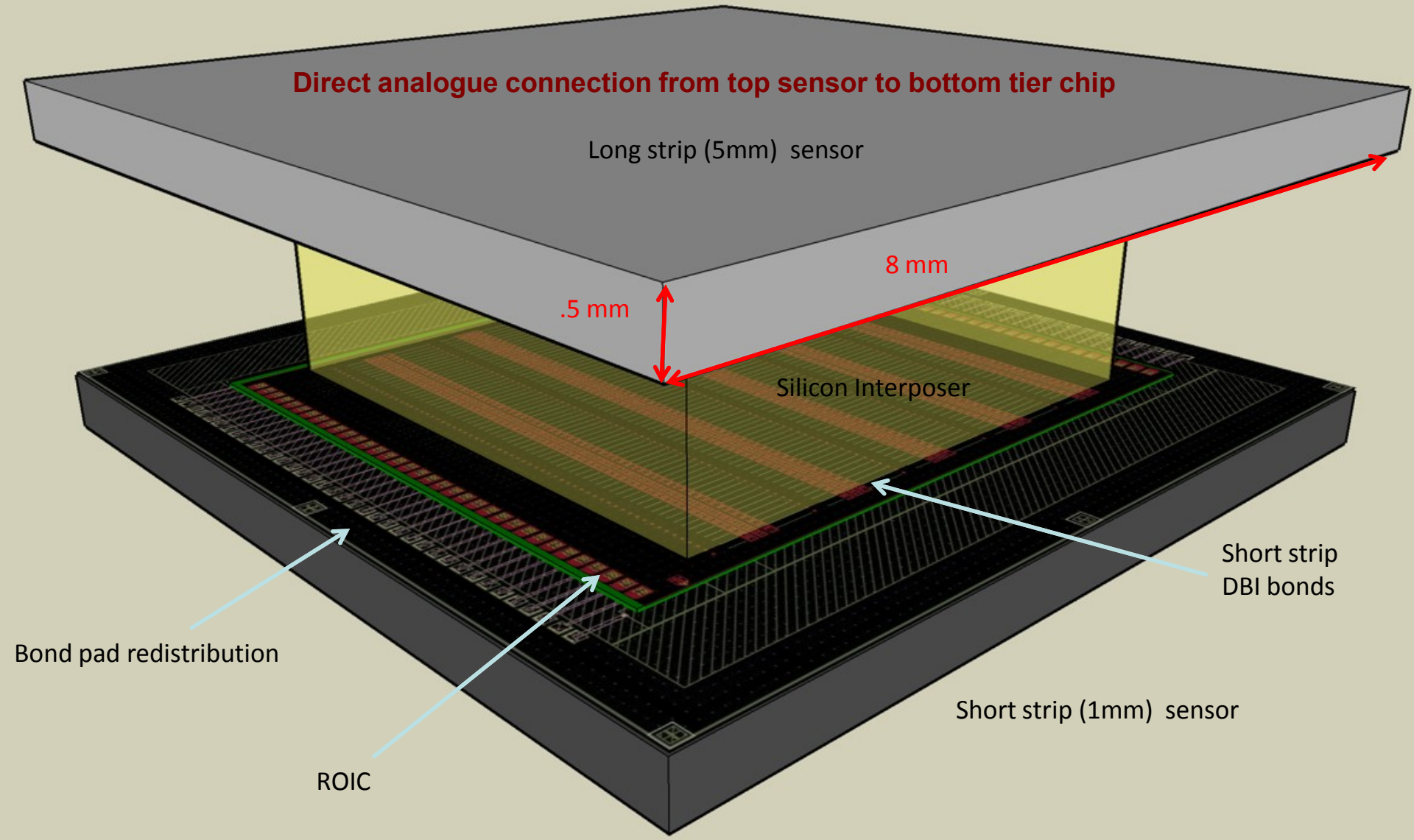
TSV



Cons:

- Technologically Aggressive
- Isolating analogue signal from possible noise circuits Challenging

Single Chip Demonstration Module based on FNAL 3D technology



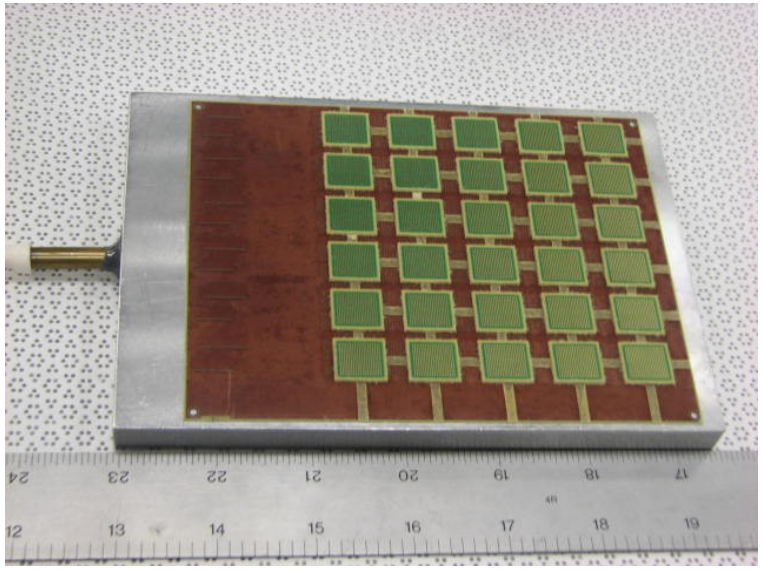
Large Area Pixelated Pt Modules

Large Area PCB based Interposer prototype
for
direct analogue connection from top sensor
to bottom tier chip

Arlon 55N (kevlar) – CTE similar to silicon

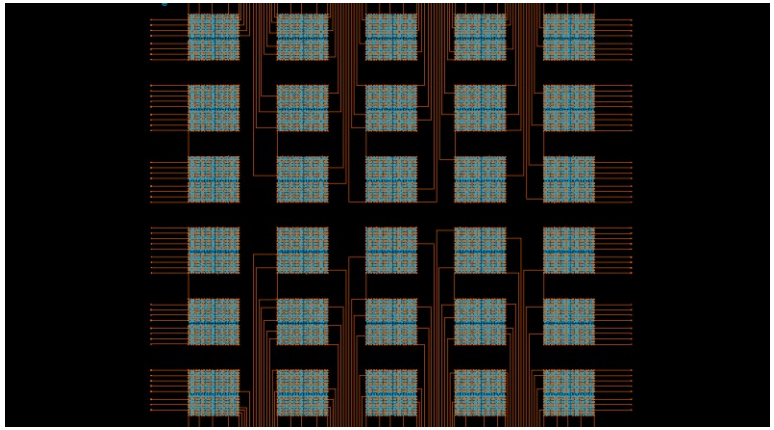
Top to bottom analogue connections
concentrated in islands

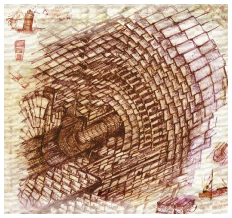
Material removed between via islands



Layout of Dummy top sensors

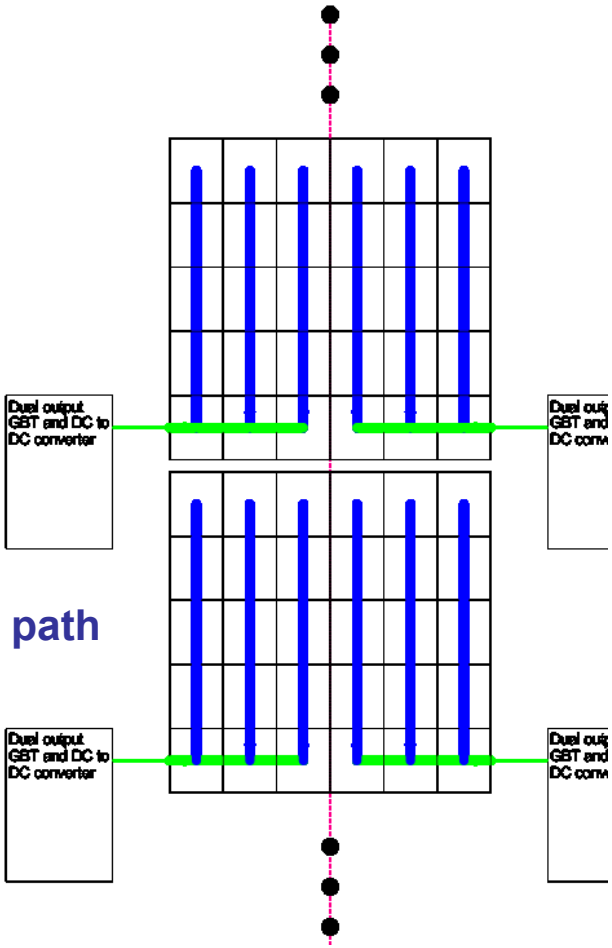
2nd metal layer used to rout connection to islands

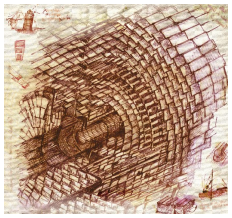




A candidate detailed Design Study for the Vertically Integrated Pixelated Pt Module

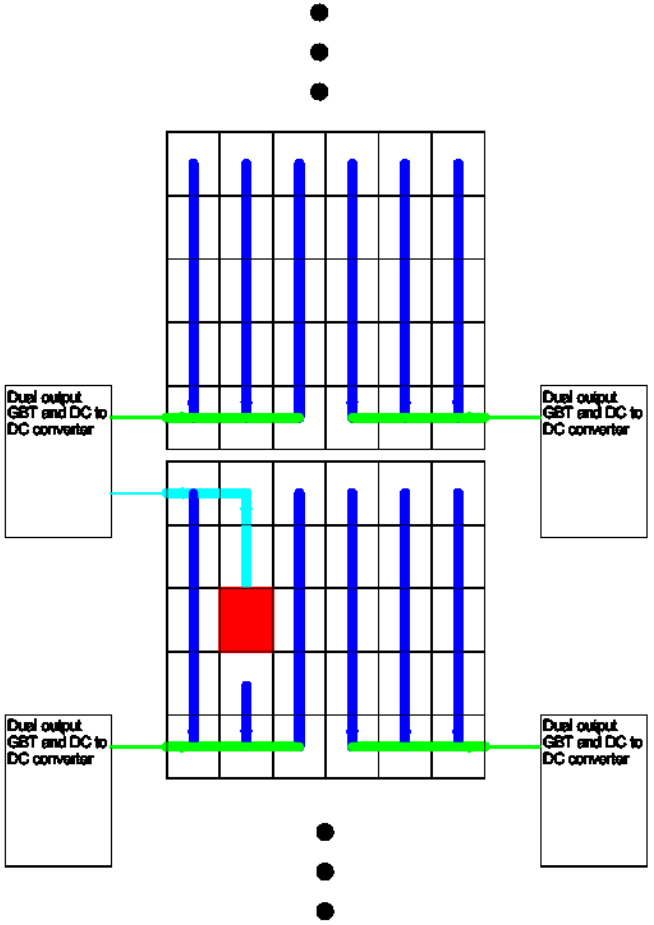
- **Main Operations, at Bunch Crossing Frequency:**
  - Form Clusters in Z-phi
  - Find up to 4 Stubs for tracks with Pt > 2GeV
  - Encode stub addresses
  - Transmit them to edge row (blue arrows)
  - Transmit them to GBT (green arrows)
- **Architecture:**
  - Completely Asynchronous Logic
  - Hit encoding uses Mephisto encoders
  - Communication & readout use micropelines
  - Event Data and Trigger are readout on the same path

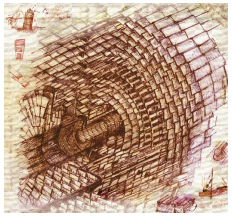




A candidate detailed Design Study for the Vertically Integrated Pixelated Pt Module

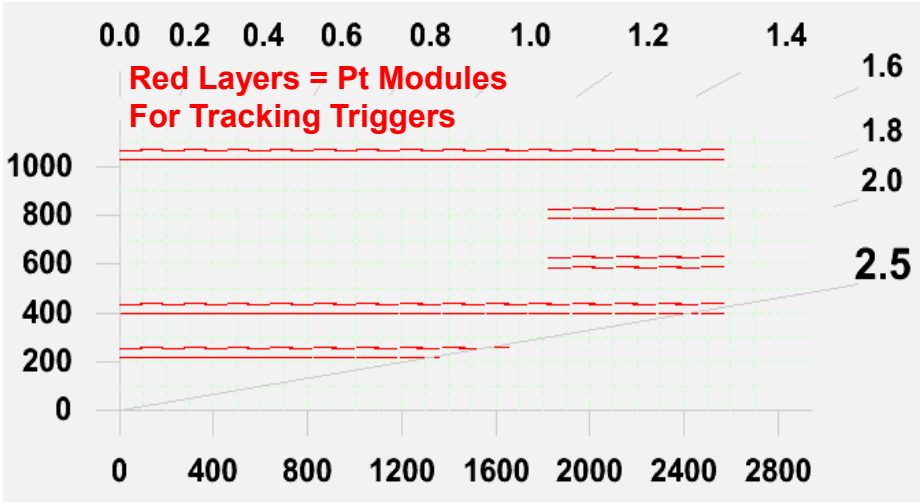
- **Main Operations, at Bunch Crossing Frequency:**
  - Form Clusters in Z-phi
  - Find up to 4 Stubs for tracks with Pt > 4GeV
  - Encode stub addresses
  - Transmit them to edge row (blue arrows)
  - Transmit them to GBT (green arrows)
- **Architecture:**
  - Completely Asynchronous Logic
  - Hit encoding uses Mephisto encoders
  - Communication & readout use micropelines
  - Event Data and Trigger are readout on the same
- **Aim to build in Redundancy:**
  - Readout pipelines are reversible
    - Use secondary channel of GBT?

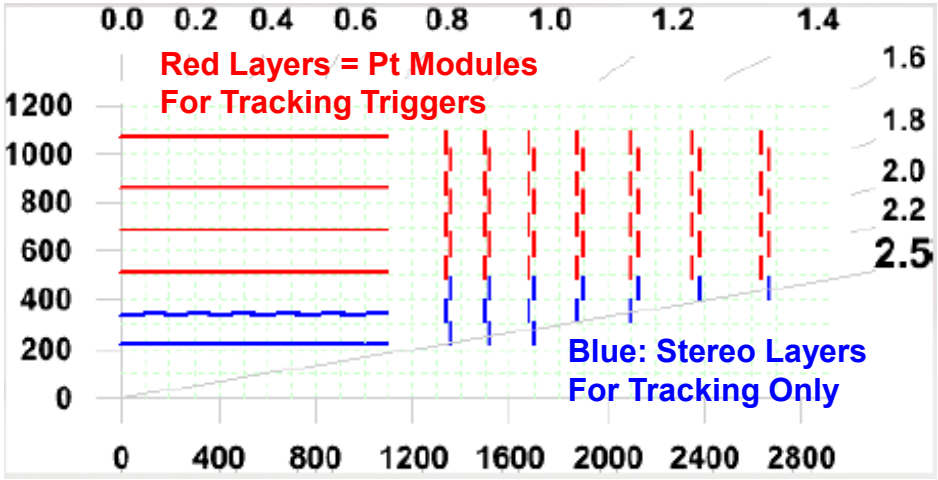


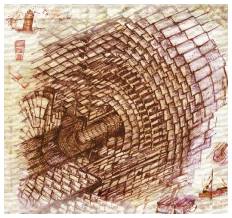


Complementary Layouts

- **Complementary Layouts => compare qualitatively different possibilities**
  - **Long Barrels vs End-Cap Discs**
  - **Pt module deployment at different radii**
    - Strip Pt modules limited to region above R ~ 50cm
  - **Different distribution of Pt Layers**
    - Super Layers: closely spaced pairs of Pt Layers => Stubs -> Tracklets -> L1 Tracks
    - Independent Pt layers => External Seeds + Stubs
    - Different architectures & performance potential







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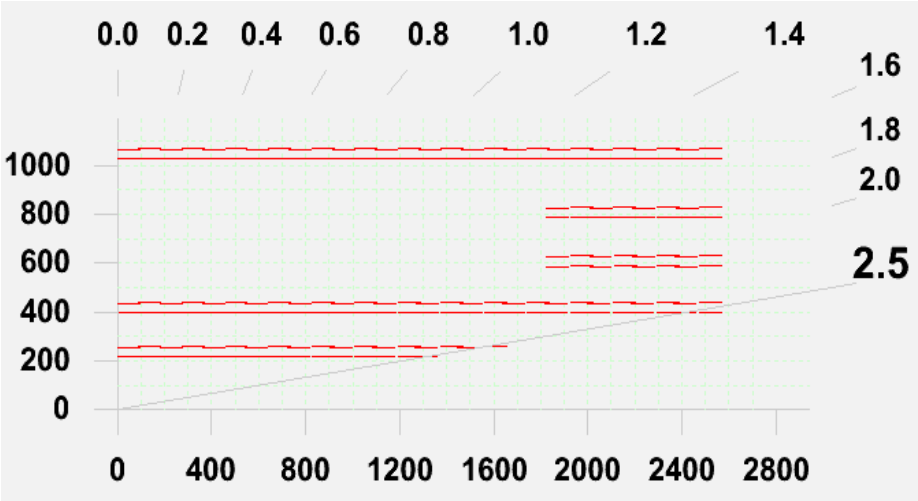
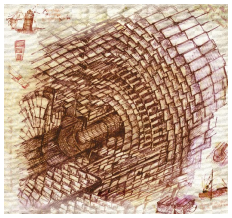


In what follows focus on peculiar features of

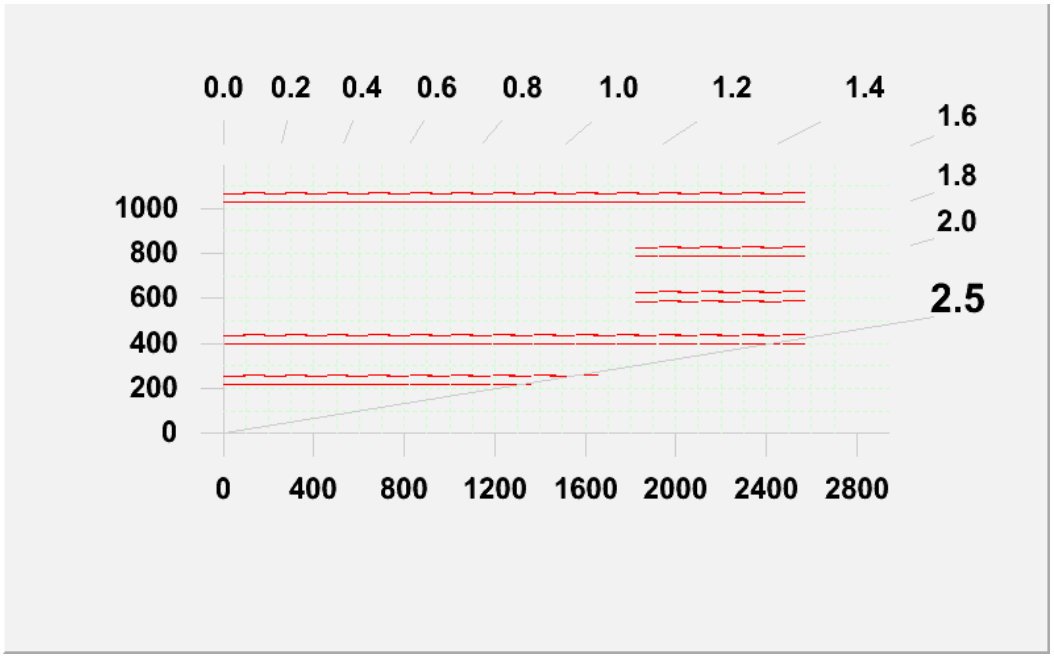
Long Barrel Straw Man,

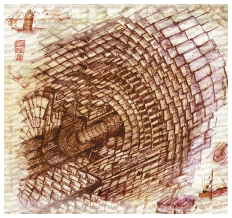
To illustrate some of the basic Strategies currently being studied



Long Barrel Straw Man

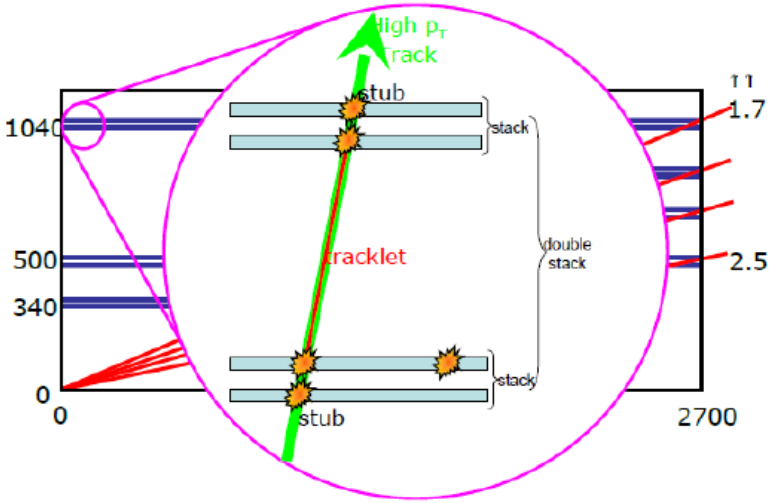
- **A Hierarchical Scheme for Localizing Pattern Recognition & Data Reduction**
  - **A possible concept for simultaneously optimizing Tracking Trigger & Tracking Performance?**

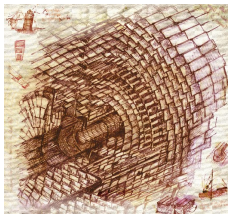




A Hierarchical Scheme for Localizing Pattern Recognition & Data Reduction

- **Pt Module: Two closely spaced sensor layers ~ 1mm**
  - **Pairs of Cluster -> Stubs (pt > 2GeV)**
    - Reduce rate to manageable level; starting point for Pattern Recognition
- **Super Layer: Two closely spaced Pt module layers ~ 4cm**
  - **Pairs of Stubs -> Tracklets**
    - Seeds for L1 Tracking Trigger
    - 4 Vectors which can be projected to other Super Layers





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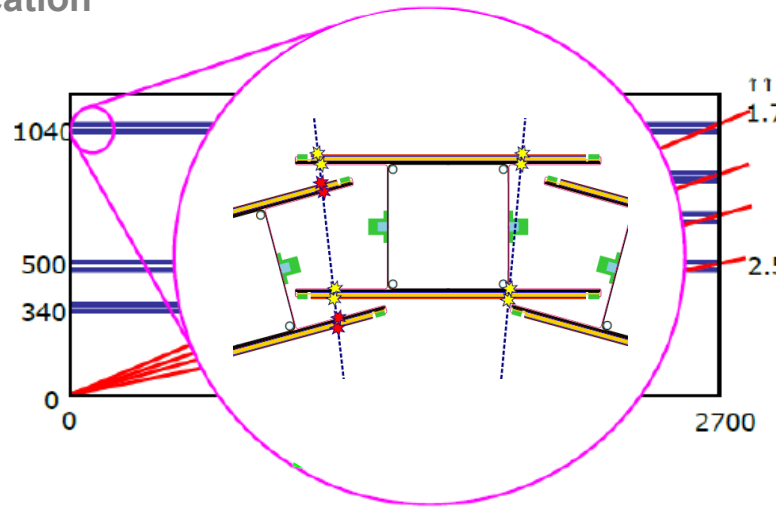
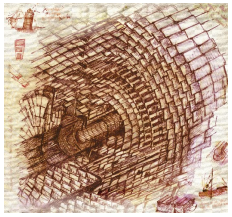
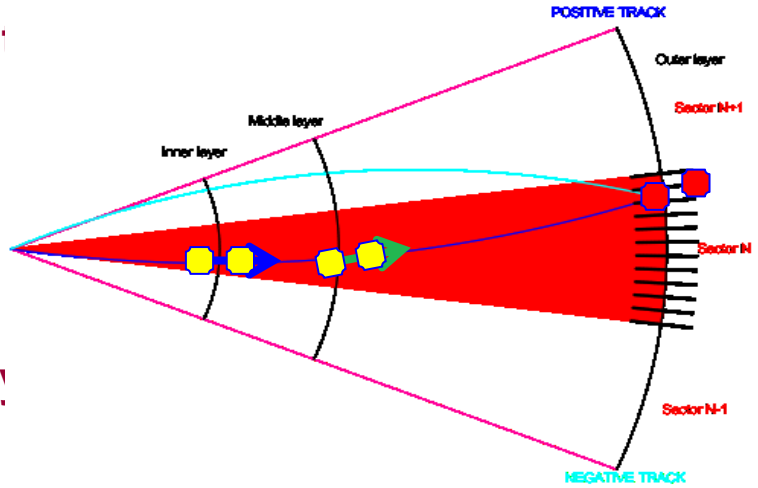
  - **Pairs of Stubs -> Tracklets**
    - Seeds for L1 Tracking Trigger
    - 4 Vectors which can be projected to other Super Layers
  - **Arrange Pairs of modules in r-phi Hermetic RODs**
    - No cross-ROD communication



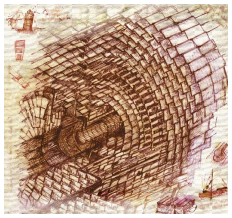


Projecting Tracklets to Other Layers

- **Minimizes the track search region**
  - Greatly reduces number of equation sharing across modules
- **Allows use of single stub in destina**
  - Reduces impact of inefficiency

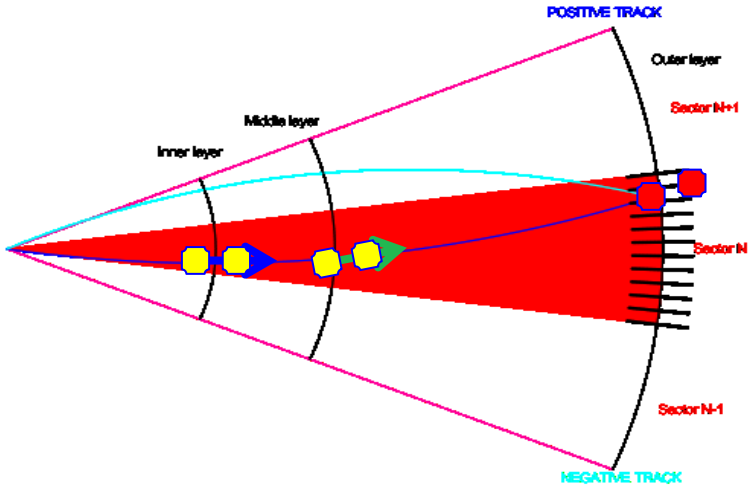


- **Project every Tracklet independentl two layers**
  - Finds the best possible measureme track if some sensors are missing
  - Potentially finds the same track 3 tir
- **Provides redundancy and Robustne**
  - Requires Duplicate Removal Logic

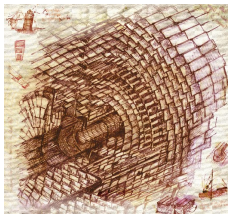


Projecting Tracklets to Other Layers

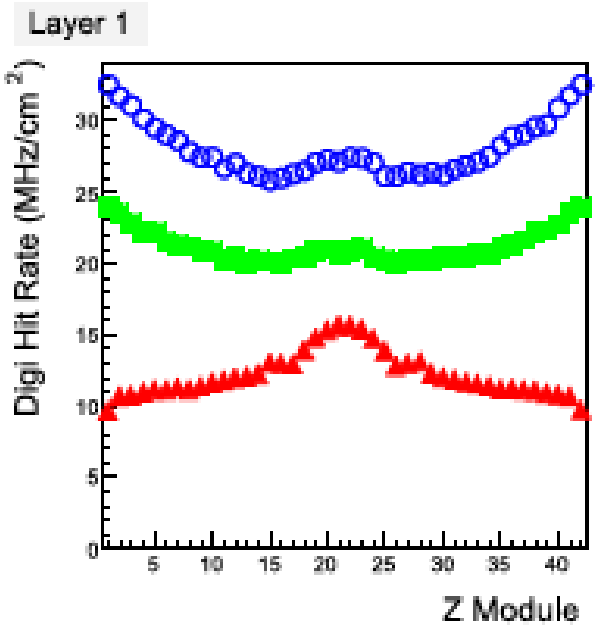
- Present design uses FPGAs to find tr
  - FPGA size requires subdividing 15 de
  - Preliminary designs fits each SubSect

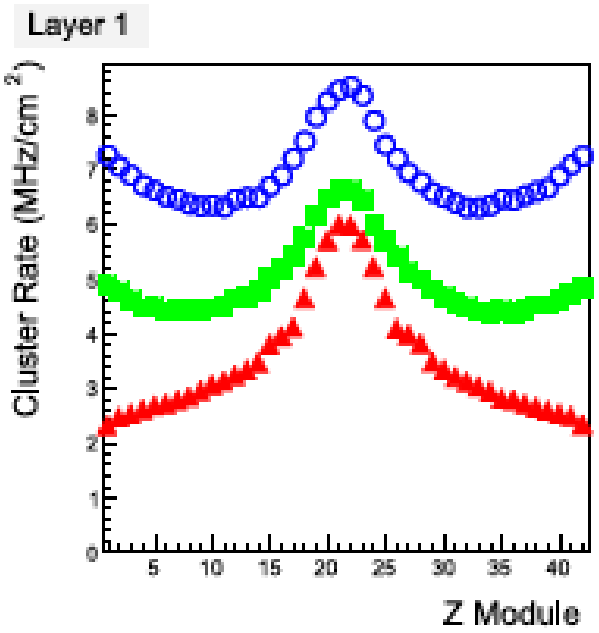


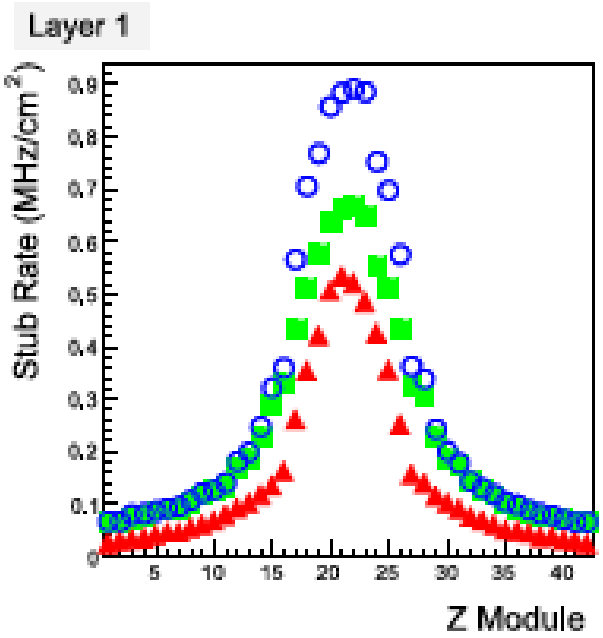
- Exploring the use of Content Address
  - Possible reduction in number of sub s
- Final output is precise momentum vectors of tracks above 2.5 GeV/c



Local Occupancy/Rete reduction from Hit -> Cluster -> Stub





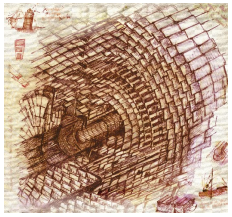


Blue: Full Simulation with Out of Time Pileup

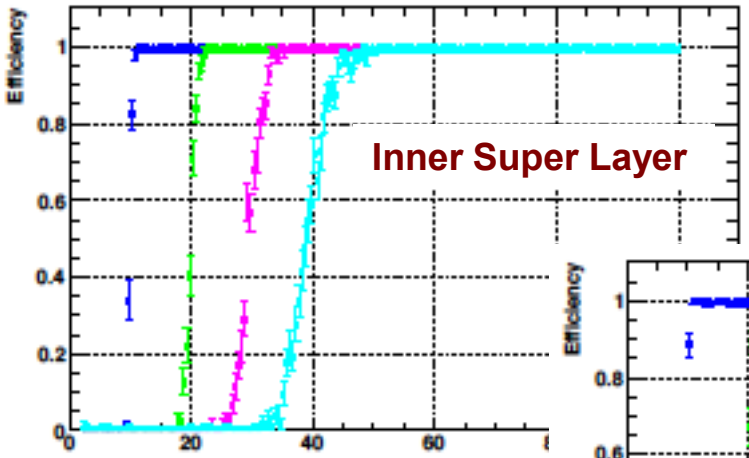
Green: Full Simulation no Out of Time Pileup

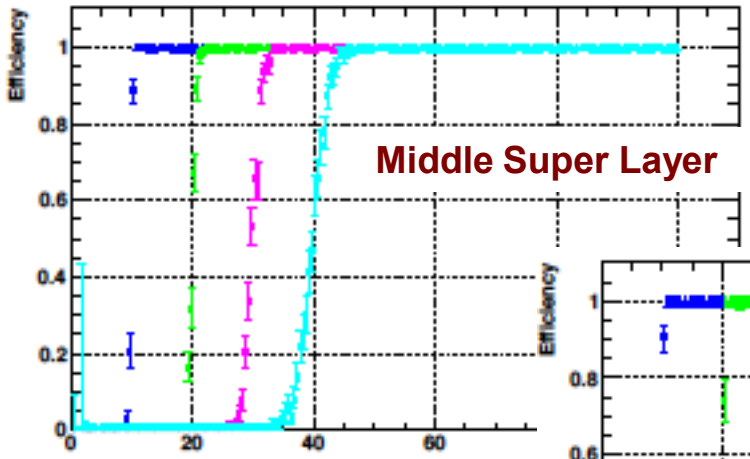
Red: Fast Simulation no Out of Time Pileup

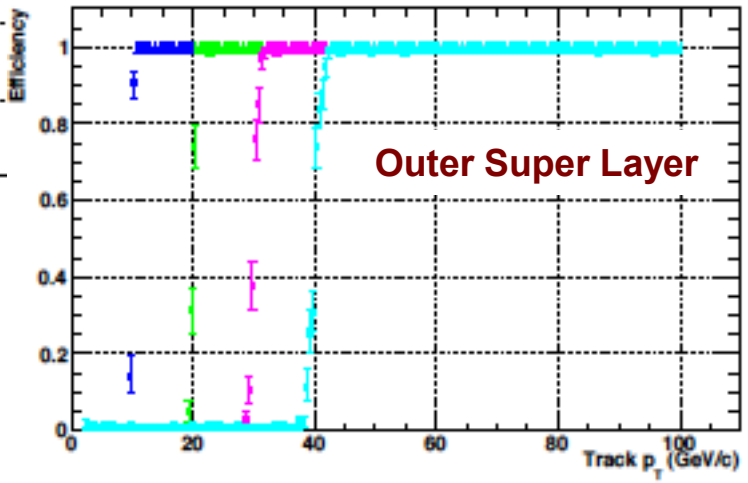
Nb Rates Estimated at 10^{35}

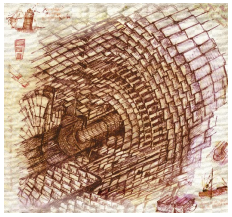


Tracklet Pt Threshold Curves



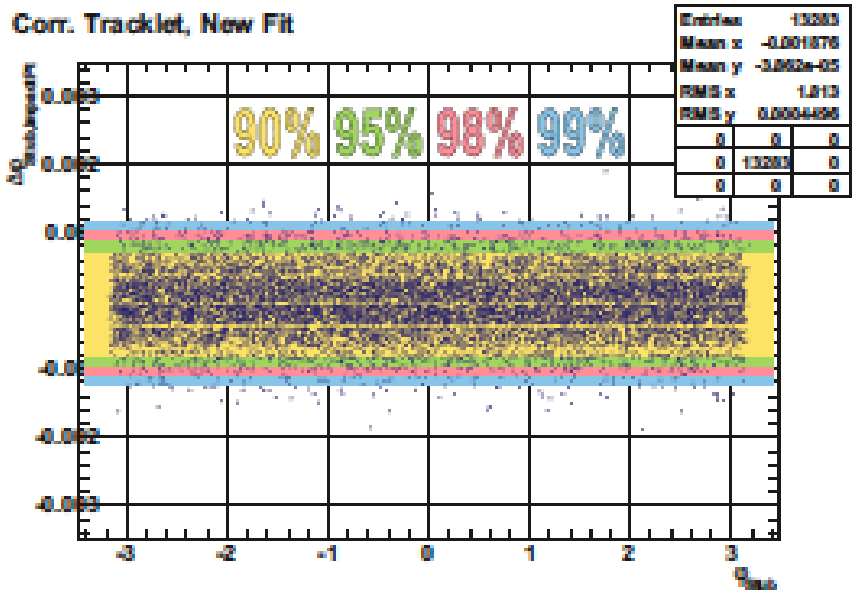


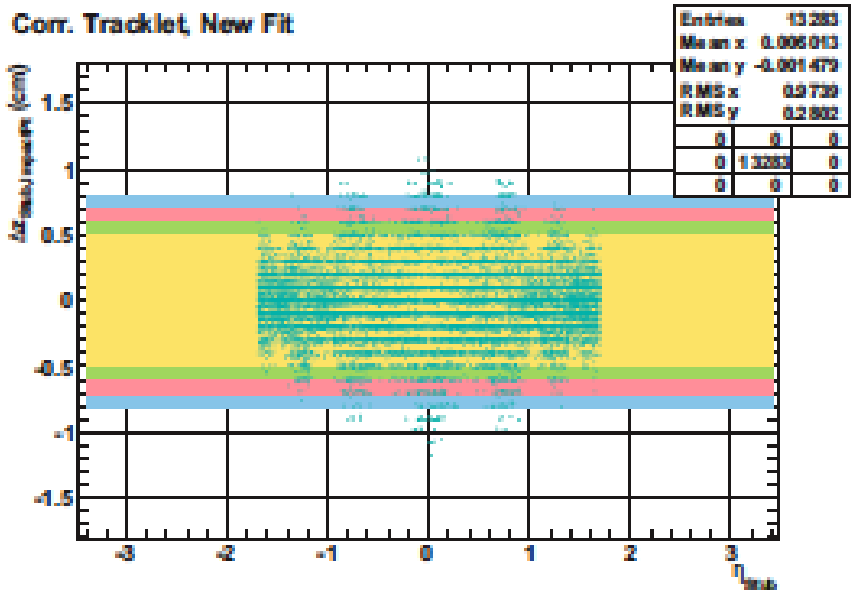




Tracklet Extrapolation Widows From Middle to Outer Super Layer

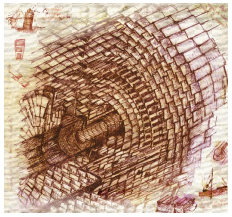
10 GeV muons





99% Acceptance Azimuthal Window ~ +-1.5 mm

99% Acceptance Z Window ~ 1.5 cm



Summary and Outlook

- CMS is actively pursuing a Tracking Trigger for SLHC
- Key Areas of Development include
  - Pt module and associated technologies
  - Pt module architecture & detailed design studies
  - High Bandwidth, low mass & low power data transmission
  - Hierarchical Schemes for Localizing Pattern Recognition & Data Reduction
  - Architecture & technologies for back-end Tracking Trigger System
- There is Encouraging Progress across these Key Areas
  - Need to substantially ramp up the effort to successfully lay the grounds for Phase II CMS Tracking & Tracking Trigger system in the next 2 ~ 3 years