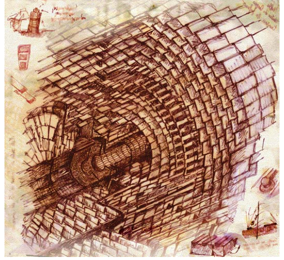


Simulation of the Tracker implementation in the electronic trigger at the super-LHC

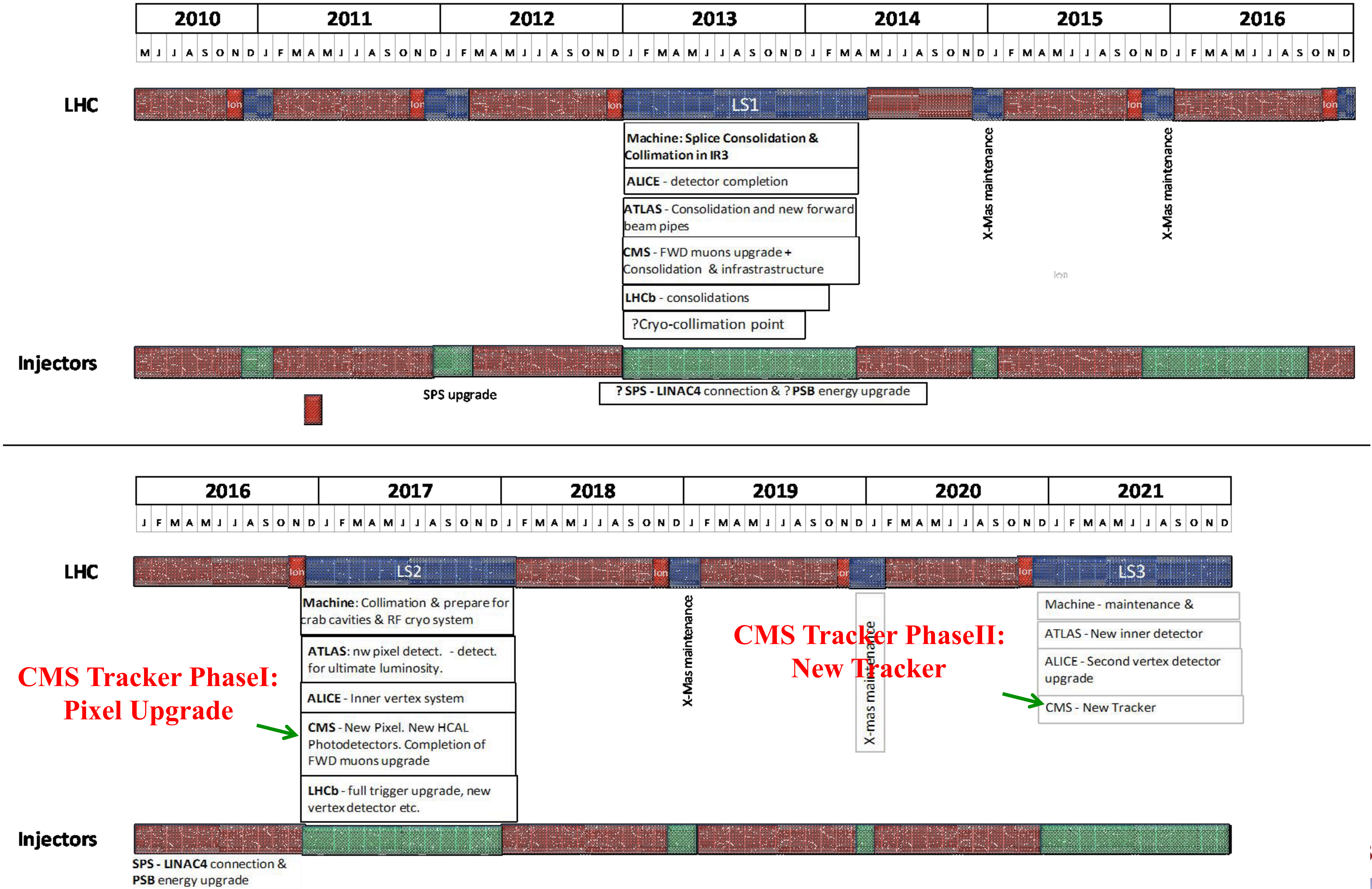
G.Boudoul

FCPPL 2011 Workshop 7-11 April 2011

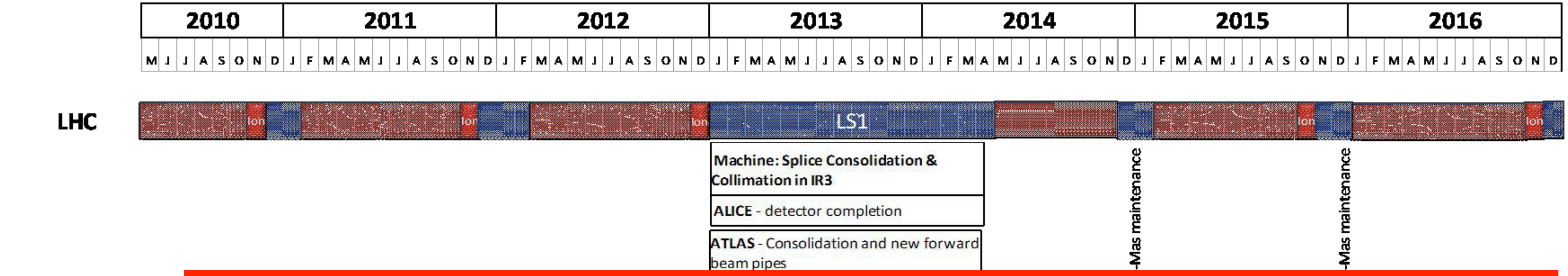
Outline

- Scenario for the luminosity upgrade
  - Machine upgrade scenarios
  - The CMS detector upgrade plans.
  - Physics potential
- CMS Tracker – Trigger for Phase II
  - Data rate reduction and requirements
  - Possible layouts
- First results with simulation and 7TeV Data
- Outlook and conclusion

Draft 10 year plans (Chamonix 2011)

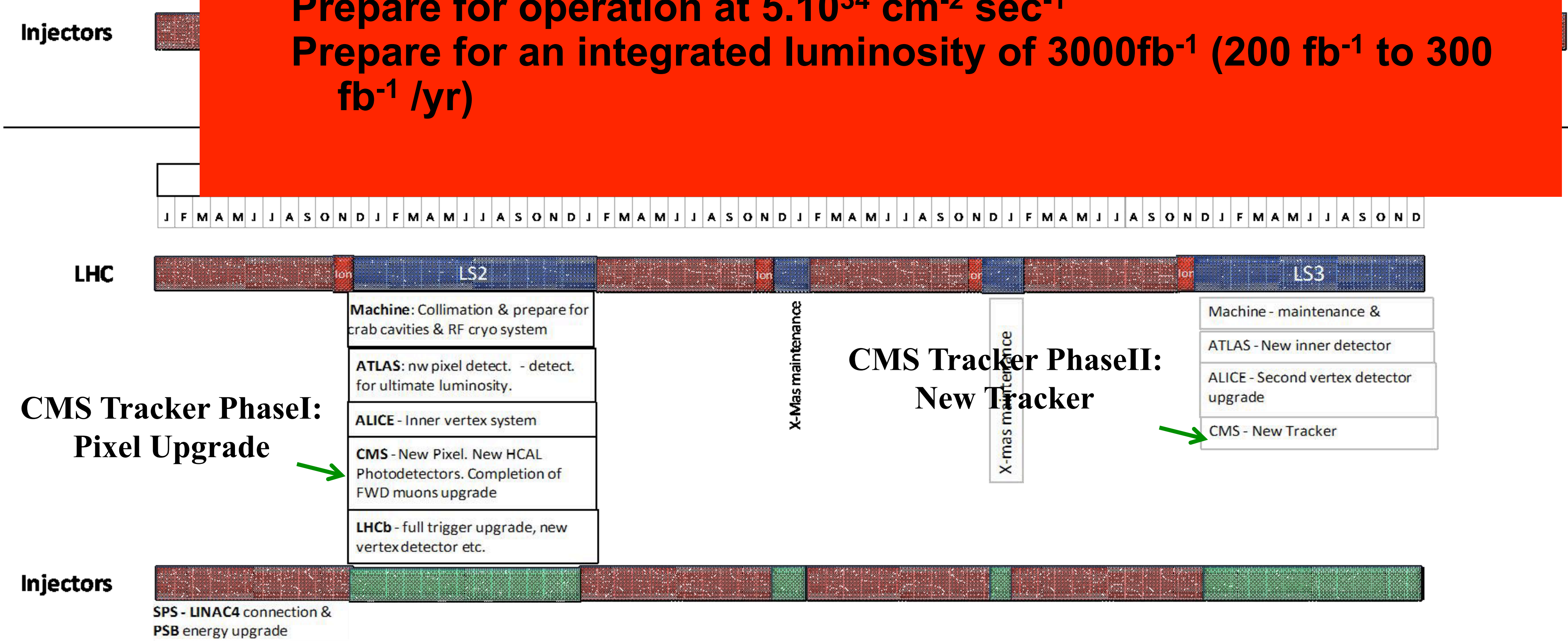


Draft 10 year plans (Chamonix 2011)



2021: High luminosity project

- Prepare for operation at 5.10^{34} cm^{-2} sec^{-1}
- Prepare for an integrated luminosity of 3000fb^{-1} (200 fb^{-1} to 300 fb^{-1} /yr)



CMS Tracker PhaseI:
Pixel Upgrade

CMS Tracker PhaseII:
New Tracker

Physics potential

- *Improve Measurements of new phenomena 'seen' at the LHC for example:*
  - *Higgs coupling and self-coupling*
  - *Properties of SUSY particles (mass, decay branch ratios, etc.)*
  - *Coupling of new Z' or W' gauge bosons*

- *Detect/Search low-rate phenomena inaccessible at the LHC for example*
  - $H_{SM} \to Z\gamma$ (BR ~ 10^{-3}), $H_{SM} \to \mu^+\mu^-$
  - *Top decays via Flavour changing neutral currents (FCNCs)*

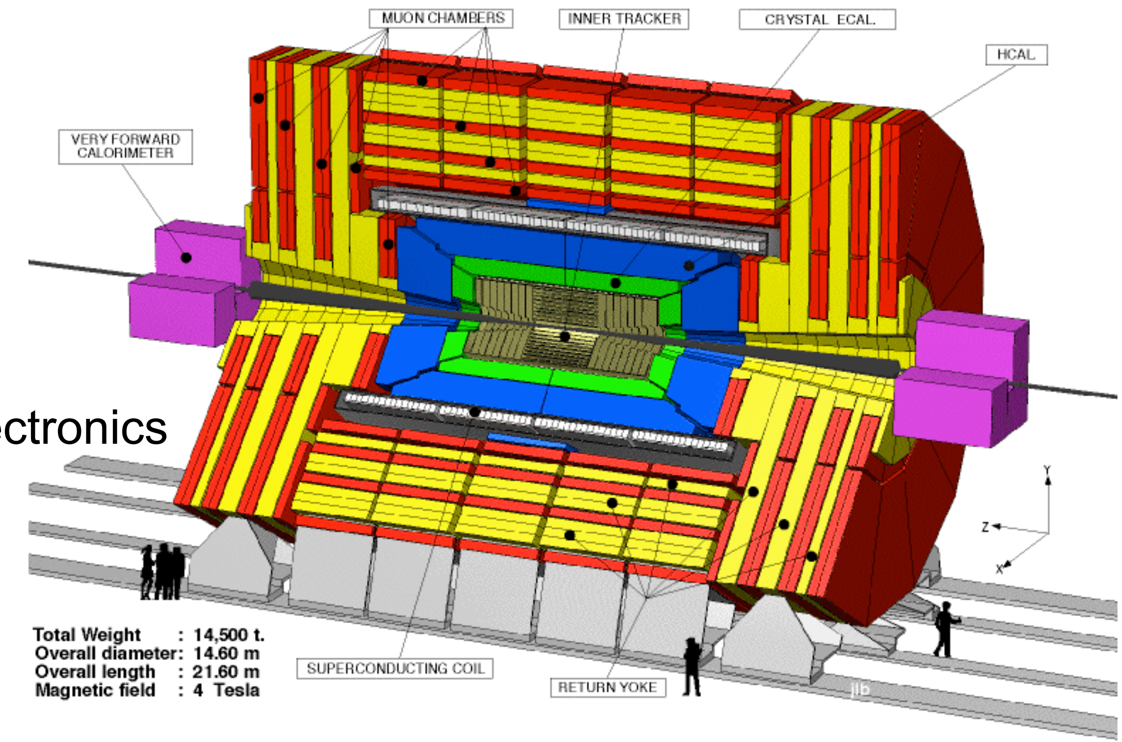
- *Push Sensitivity to new high-mass scales, for example*
  - *Quark substructure*
  - *New forces : Z', W'*

- *Extra dimensions*
  - *Reach 6TeV for 300fb^{-1} (LHC) , ~7.7TeV for 3000 fb^{-1} from direct observations*

REQUIRE FULL PERFORMANCE DETECTORS

CMS Upgrades scenario

- *2013 Shutdown:*
  - Begin installing forward muon systems
  - HO SiPMs (hadronic Calorimeter Tail Catcher)
  - HF PMTs (Forward Hadron Calorimeter eta 3-5)
  - Pixel Luminosity Telescope
  - Install new beampipe
- *2017 Shutdown:*
  - Install new pixel detector
  - Install HB/HE photo-detectors
  - Install new trigger system
- *2021 Shutdown:*
  - **Install new tracking system**
  - Trigger system upgrade
  - Major consolidation/replacement of electronics systems
  - Calorimeter Endcaps
  - DAQ system upgrade

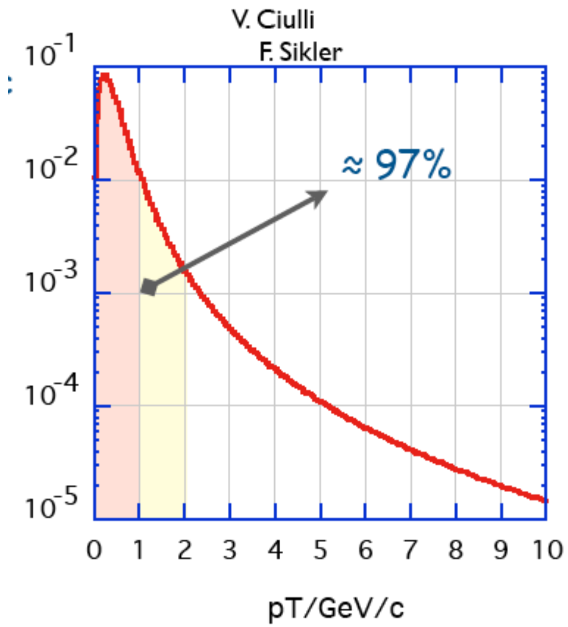


Current CMS detector

Tracker-trigger for Phase II

- At SLHC luminosities, the total L1 trigger rate, without use of Tracker data, is expected to exceed the nominal limit of 100kHz by a large factor, probably exceeding an order of magnitude.
  - Having tracking information available in trigger Level 1 (L1) would provide a new handle in the trigger to reduce the L1 rate
  - Without the Tracker it would be hard to maintain an open L1 trigger

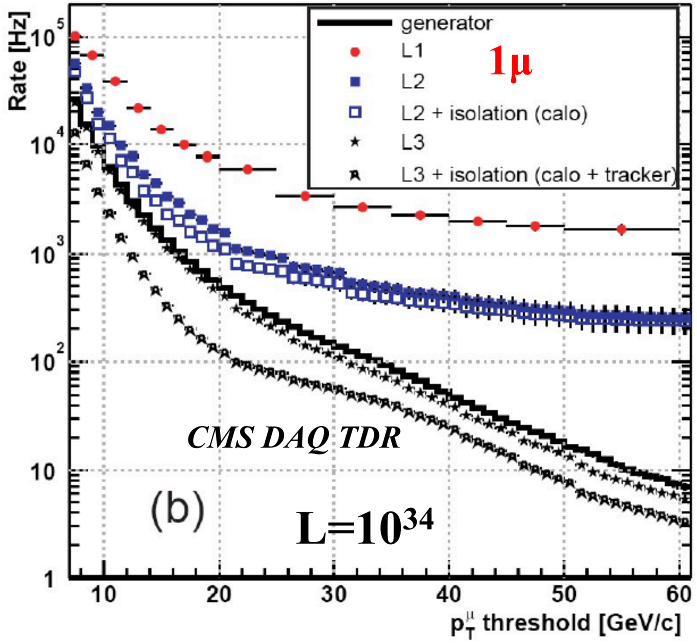
- About 90% of the charged particles produced in minimumBias collisions have Pt<1GeV/c and ~97% have Pt < 2GeV/c



→ **Reject Hits from low Pt tracks on detector**

Tracker-trigger for Phase II

- At SLHC luminosities, the current L1 trigger for basically all trigger object (muons, electrons, taus) needs to be improved
- We need improved resolution for the Level1 itself by using the tracker data
  - Attach tracker hits to improve Pt assignment precision
  - The tracking trigger should provide a track matching and isolation for tau and electron identification

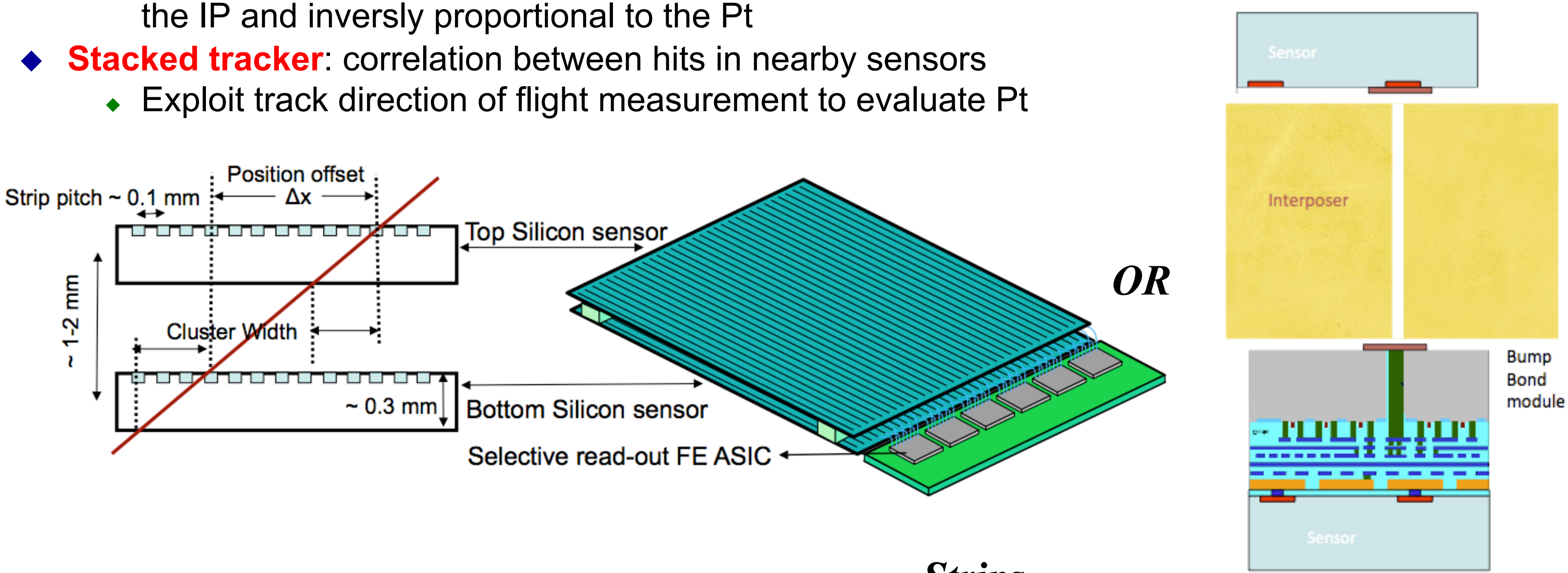


Note limited rejection power (slope)
Without tracker information

→ **Provide tracking info in L1 (trigger primitive up to eta=2.5)**

Tracker-trigger : How to reduce data volume

- Two possibilities to reduce data volume (based on the track deviation in the plan perpendicular to the CMS magnetic field):
  - **Cluster width approach**
    - Cluster width (number of contiguous strips) is proportional to the radial distance of the sensor from the IP and inversly proportional to the Pt
  - **Stacked tracker**: correlation between hits in nearby sensors
    - Exploit track direction of flight measurement to evaluate Pt



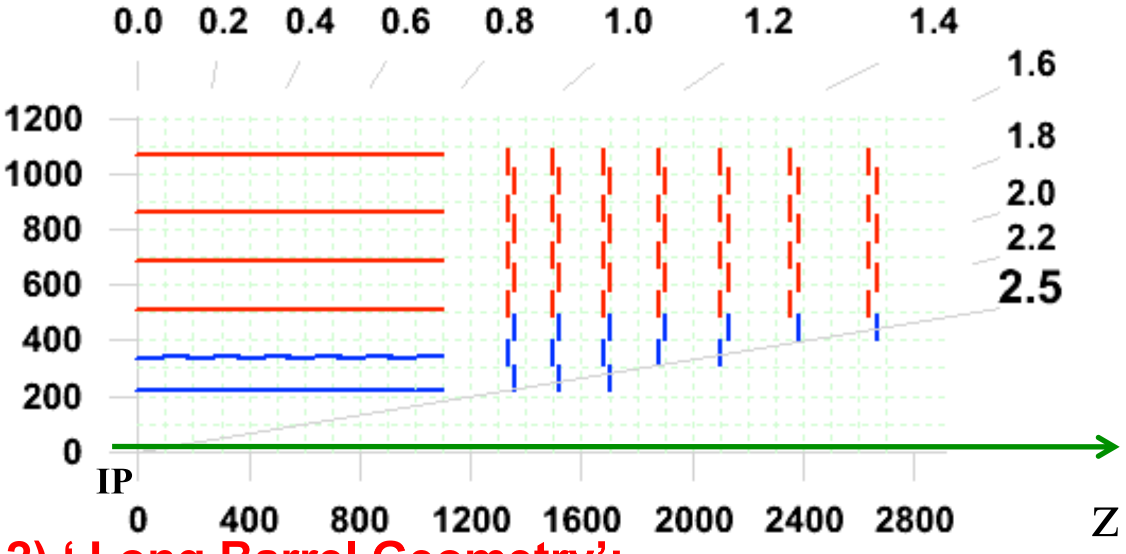
Strips

Pixelated module

- **The location and geometry of the triggering layers have to be integrated into the layout of the 'outer' Tracker**
  - These layers are the most challenging
  - Will require very dense services (power, cooling, readout)
  - Note, triggerring layers should also contribute to 'regular' tracking

Layouts under study

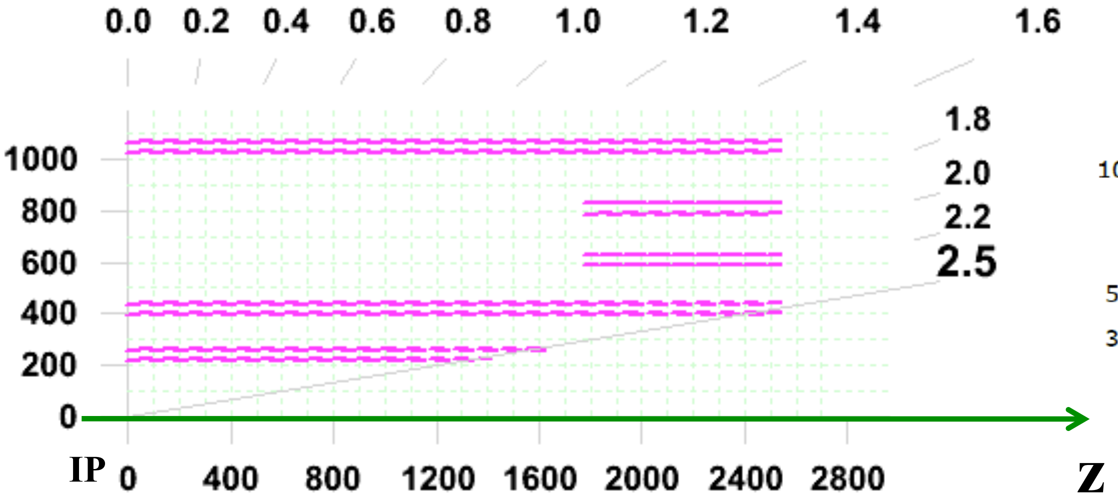
1) Layout with Strip stacked modules ('Strip Pt Layout'):

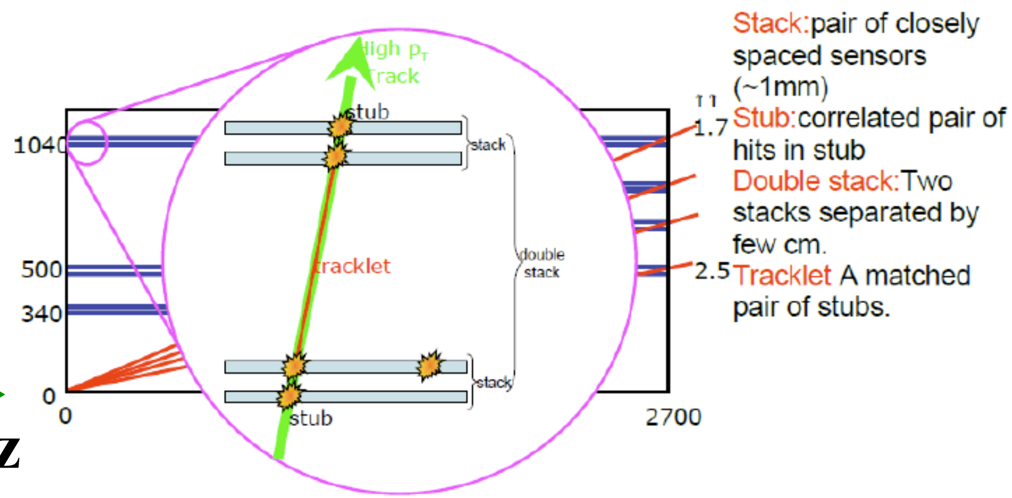


The outer part (red) is populated by Strip stacked Modules ('pt modules')
The number of endcap disk is optimized for tracking performance.
Possibility to improve z resolution under study.

2) ' Long Barrel Geometry':

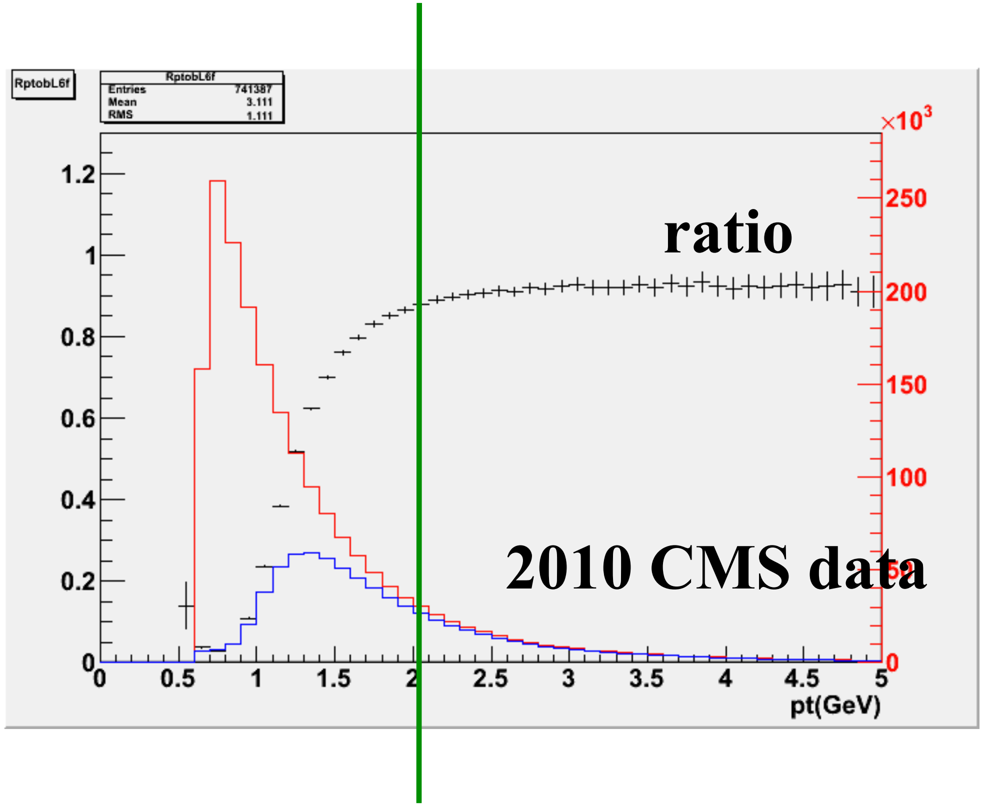
Long closely spaced layers with coincidence beween layers allow a Pt cut to be applied
(Full long Barrel outer tracker of stacked triggering layers)
Cluster positions in z direction provided (pixelated modules).



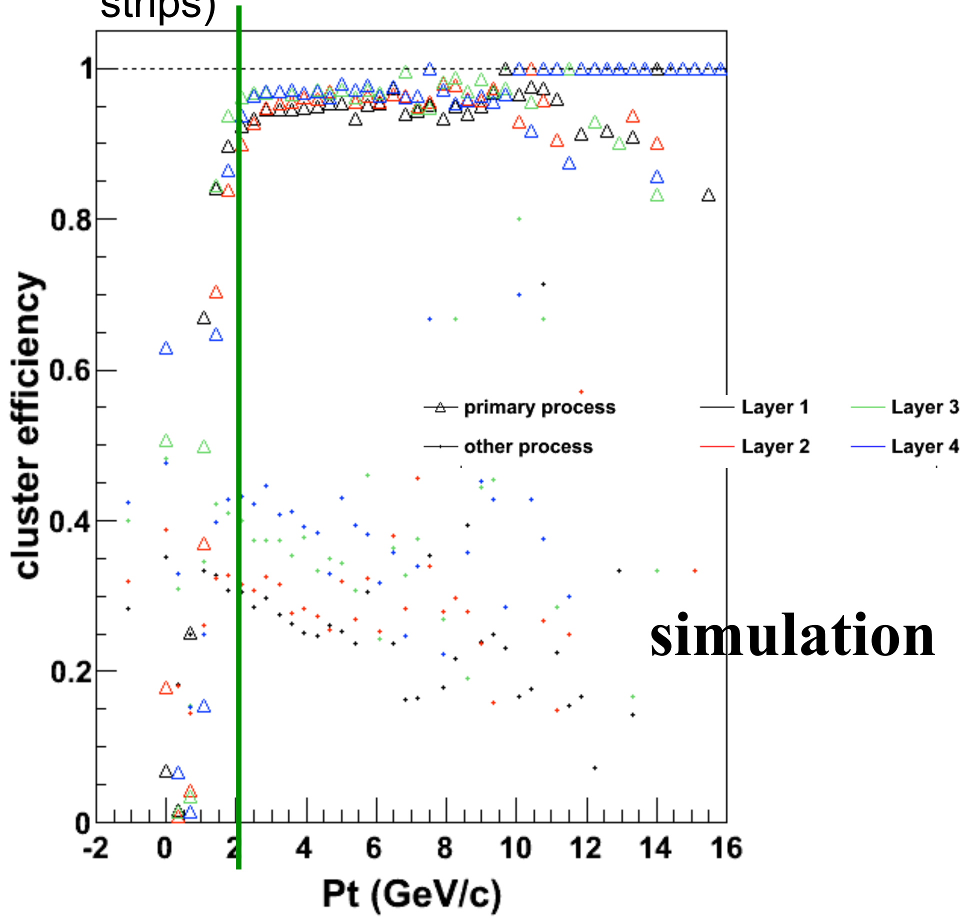


Cluster width (CW) approach and Pt selection

- **Validation with real data (CMS 7TeV data)**
  - Pt distribution *before* and *after* cluster width cut (width<3 strips) :



- **Simulation with MinimumBias events**
  - Cluster efficiency vs Pt After cut (width <3 strips)



Two main parameters need to be optimized:

-The cut on number of strips (cluster width)

-The ratio between the layer radius and the pitch

Generaly speaking, the typical cut value is at ~2 GeV

Occupancy and rejection factors

- First results from Simulation based on the StripPt layout
  - 200pp interactions pile-up (5.10^{34} cms^{-2}s^{-1} at 20MHz LHC Clock)
  - Silicon Sensors parameters:

Sensor thickness	Strip pitch	Strip length
320 µm	90 µm	4.76 µm

Layer radius (cm)	**50**	**70**	**90**	**110**
Strip occupancy(%)	1.6	0.8	0.5	0.26
Cluster occupancy (%)	0.4	0.2	0.12	0.06
CW reduction factor	2.3	2.5	2.3	2.1

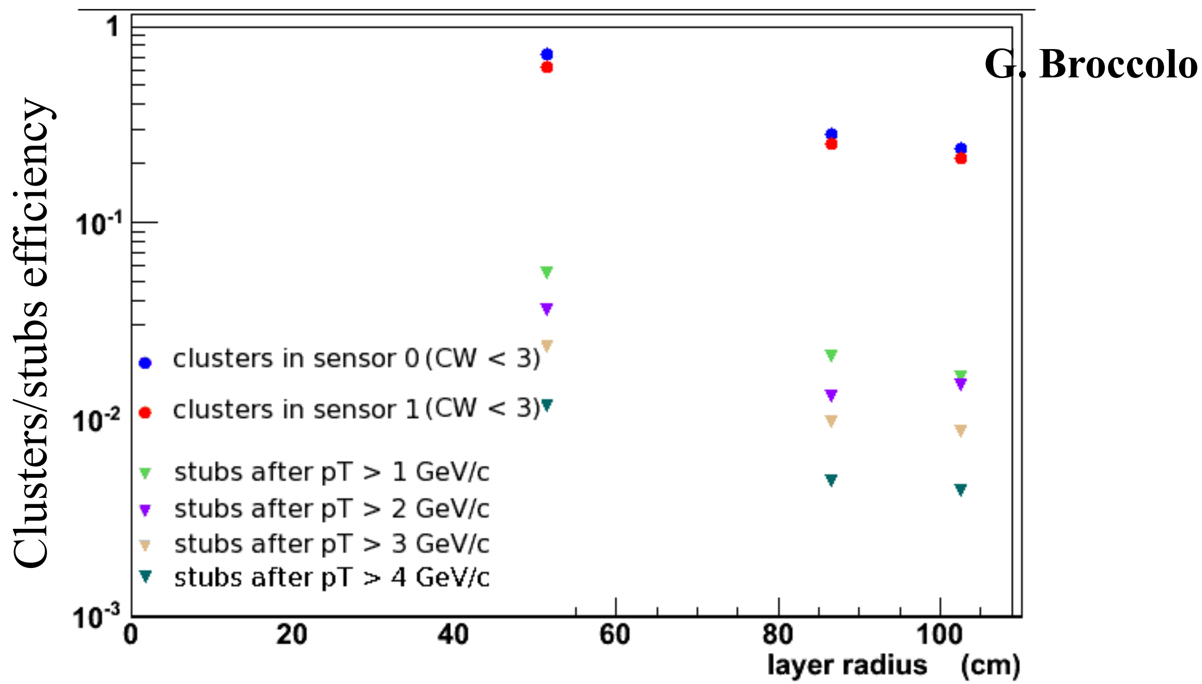
Cluster Width method is a less demanding solution but the transverse momentum selection efficiency will be limited essentially by the sensor thickness (typically 300 microns) and by geometrical effects in the tracker end-cap regions where detectors are perpendicular to the beam axis

Cluster width approach and position correlation

- **7Tev Data** : Tracker outer barrel Layer 2 (stereo modules, offset 1 mm) to simulate <u>stacked modules.</u> Layer radius : 70mm

Pt Module reduction factor	13.8	15	13.8	12.6

- **First results from simulation** : Clusters and Stub (pair of associated clusters in the two sensors of Pt-modules) efficiency from simulations (offset 2mm):



Rejection factors
Ranging from 25 to 200

- **Full simulation with strip Pt Layout geometry is needed.**

Selective read-out electronic

- Thanks to the simulation, one can estimate the needed bandwith (5.10^{34} $cm^{-2}s^{-1}$, 20 MHz LHC Clock, X2 safety margin):

½ modules (8 chips)	L1 (50 cm)	L2 (70 cm)	L3 (90 cm)	L4 (110cm)
Cluster Rate (MHz)	1.6	0.8	0.5	0.3
Stub Rate (MHz)	10.8	4.8	3.6	1.6

- IPNL is developing a full front end ASIC chip (128 channels) including the selective readout functionalities.
  - First version developed, tests in the coming months

- Thoughtputs can be estimated from simulations:

½ modules (8 chips)	L1 (50 cm)	L2 (70 cm)	L3 (90 cm)	L4 (110cm)
Cluster flow (Mbps)	28	15	11	6.5
Stub flow (Mbps)	250	110	58	37

- **More simulation are needed to consolidate mean rates and margins**

Outlook and FCPPL Project

- Full simulation of the detector with the standard CMS software in needed in order to:
  - Evaluate the data reduction (cluster width study and position correlation),
  - Validate clustering features implemented in the front end readout chips,
  - Optimize configuration parameters (strip pitch length, sensor thickness and spacing between modules).
- Simulation of the track reconstruction from reduced data (Best algorithm and granularity to be implemented in tracking trigger electronic card)
  - Coupling tracker information to the other CMS sub-detectors (global acquisition trigger)
  - Such a step can be performed on the basis of a pattern comparison of cluster maps with a bank of pre-defined tracks or by construction of local track stubs propagated among tracker layers.
- Simulations of physics signals
  - Want to provide both Tracking Trigger and Optimal Tracking in future Tracker

Conclusion

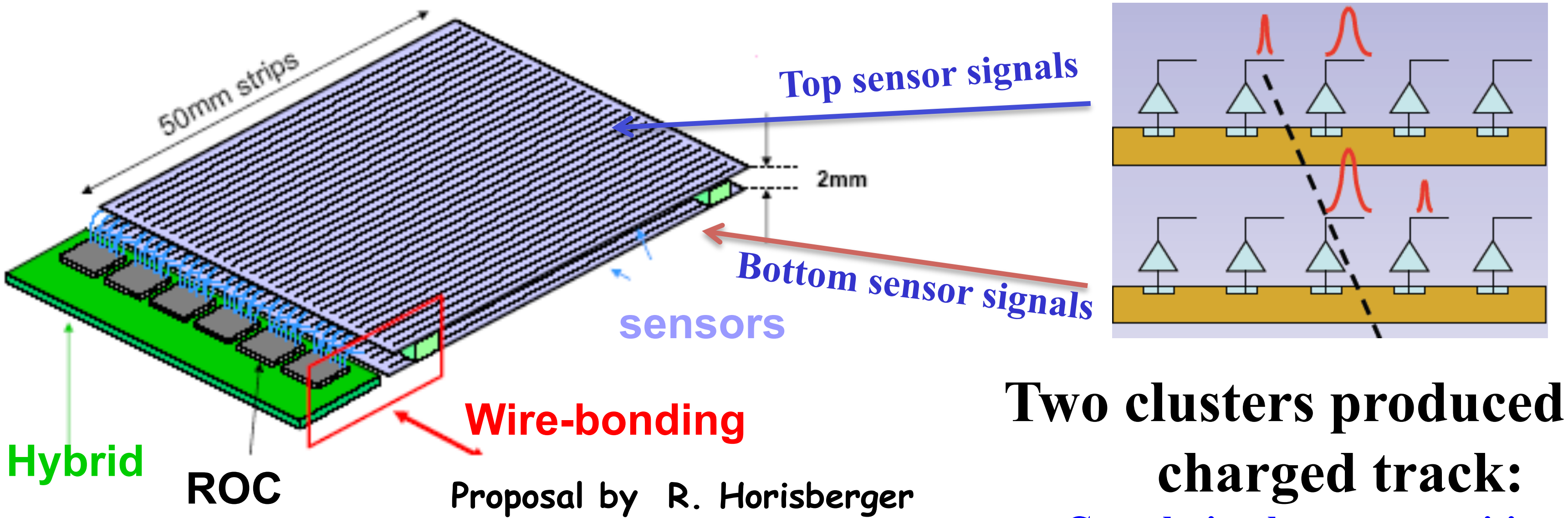
- SLHC would allow to extend significantly the LHC physics reach.
  - Inner/forward parts of the detector must be changed/hardened/upgraded
- Tracker in particular must maintain performances similar to present ones
  - New requirement for trigger functionality
  - Additional challenge of the operation environment
- Simulation activities are coupled with other R&D activities, in particular:
  - Electronic front-end development
  - Mechanics
  - Cooling
  - Data Acquisition system

in order to design a complete detection unit from sensor up to aquisition. The full readout chain could also be tested during dedicated beam tests

BACKUP

Strip Pt Modules

Two micro-strip stacked sensors assembled in a single readout unit
Same basic concept as pixellated Pt modules
For ull size modules, strip length limited to >=5cm



Proposal by R. Horisberger

Two clusters produced per charged track:

- Correlation between sensitive planes

Two-in-one module design optimizes the common use of:

1) Assembly infrastructures: mechanical, material, ROC, cooling, cabling, ….
2) Read out electronics: simple logic to correlate hits, no need of high speed links or external correlation circuits, saving power,….

➔ **Maximize Benefit/Cost**

Tracker Upgrade for Phase II : R&D activities

TK simulation and software

- Layout modelling
- Tracking trigger performances
- Explore, study and validate trigger concept, compare different layouts
- Noise, material, occupancy , cluster size, resolution, data rate
- Tracking performance of conceptual Phase2 geometries
- Development and maintenance of simulation codes (geometries, pile-up,…)

Electronics

- Front-End ASICS
- Hybrids and interconnects
- Data links
- FE Driver and Controller Hardware
- Electronic System Architecture
- Test/commissioning hardware

Power distribution

Activities/topics

- ASICS evaluation
- System development
- Integration and system tests

Sensors

- HPK sensors
- Irradiations
- 3-d silicon
- Diamonds
- …

Beam tests

Activities/topics

- Hardware development and maintenance
- Planning/running tests

Mechanics

Qualification of materials

- 3d modelling
- Thermal modelling / lab tests
- Deformation analysis
- …

CO_2 cooling

- Process qualification
- Modelling
- Components / system design
- Engineering of pixel system
- …