Track Trigger Integration Group

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and
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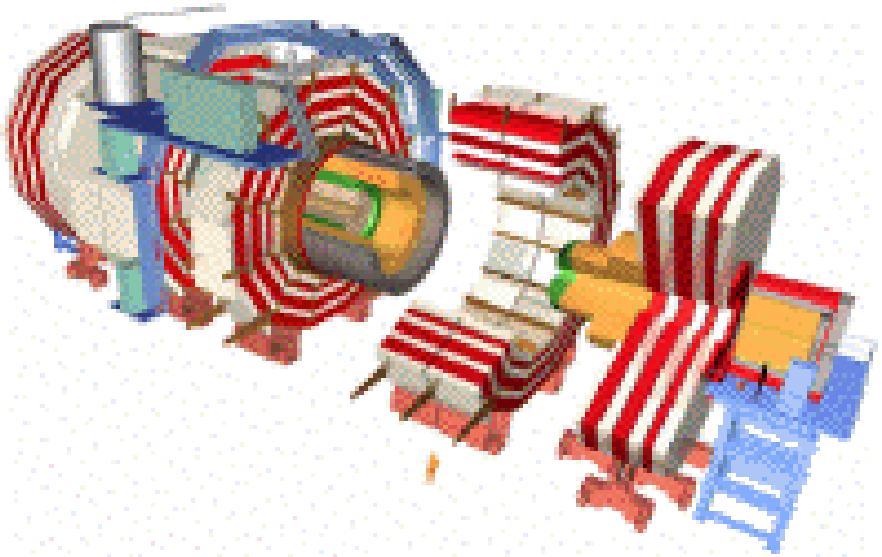
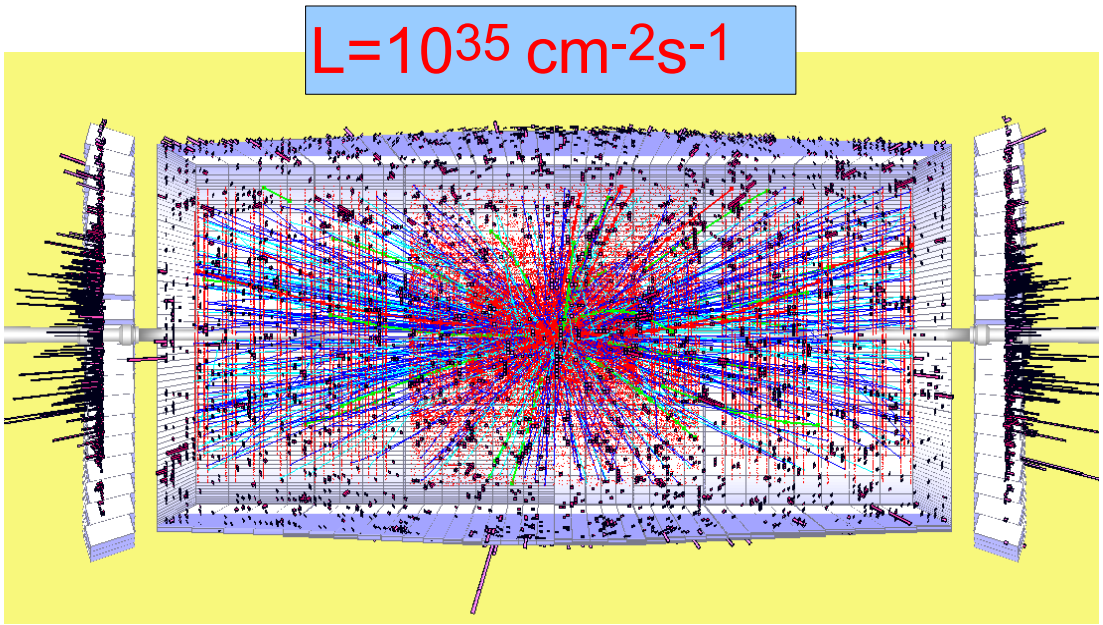
Oct. 12, 2012



Outline:

- Charge and goals
- Plans for organization
- Next steps
- Backup:Earlier work



Track Trigger Integration Group

- This is a subgroup of the Trigger Strategy and Performance Working Group (organized by Wesley Smith and Oliver Buchmueller).
- The exact charge is attached to the agenda page and the main points will be presented and discussed in this presentation. The charge was approved by the Upgrade Project Office last week.
- This subgroup was formed since the track trigger would provide very different new possibilities over the existing trigger and will require dedicated studies.
- This group will coordinate studies of how the L1 tracking information can be used to solve the challenges of triggering at the HL-LHC.

Deliverables of the TTI group

- The conclusions from the studies of this working group will provide input for the Technical Proposal on the Phase 2 upgrade by the end of 2014.
- The subgroup will provide requirements on the L1 tracking trigger, including pt resolution, need for isolation (min pt), and z-location resolution, by the mid 2013. (Upgrade week in Hamburg June 2013.)
- The subgroup will provide an initial assessment of studies and plans by the end of 2012 to the Trigger Performance and Strategy Working Group for their interrim report.

Examples of Studies Coordinated by the TTI group

- Study improved performance in benchmark channels (to be determined) by using L1 tracking information:
  - Matched to L1 muons for improved pt determination
  - Matched to L1 electrons to veto photons
  - For track based lepton isolation, including taus
  - For vertex determination and possibly PF(?) to improve jet triggers
- Assume 5e34 with 25 ns – 100 PU.
  - Consider degradation at 50 ns, or 200 PU (not explicit in charge)
- Assume L1 performance from L1 Phase 1 upgrade TDR
- Evaluate performance of the two complimentary tracker designs (long barrel vs. barrel+endcap).
- The track trigger based L1 should be compared to the HLT performance and also to the Phase 1 Level 1 trigger without track trigger.
  - The latter is crucial for making the case that the track trigger is essential.

Longer term goals

- A few more points are listed in the charge but are not as urgent or high priority:
  - Evaluate the improvement in the HLT to have the L1 tracks as a starting point for tracking.
  - Look at stand alone L1 track triggers. E.g. track based two-body decays or long lived particles with separated vertices.
  - The possibility to use the pixels in the L1 decission via regional readout.

Tools and Coordination

- The TTI group is responsible for coordinating tools and software developed to study the L1 track trigger using the trigger primitives (stubs and L1 tracks) developed by the Tracking Project.
- The TTI group will be coordinating with several groups:
  - Track Trigger subgroup of the Tracker DPG – stubs and L1 tracks (including geometries and material).
  - Muon projects for upgrade muon (trigger) performance
  - Calorimeter project for upgrade calorimeter performance
  - Relevant POGs and PAGs.
  - Upgrade simulation

Comments on Some Points in the Charge

- The requirement to provide feedback to the tracker project by next summer has some implications:
  - To study the impact on the trigger due to different resolutions and efficiencies in the tracker it is hard to do this with a fixed detector layout.
  - Hence, we envision that we need parameterized tracking where we can tune the resolutions and efficiencies simply by changing parameters and study the impact of the trigger performance.
  - Technically, developing this tool is the scope of the track trigger subgroup of the tracker DPG, but this group will be working closely with the tracker to develop these tools.

'Big Picture Issues'

- There are several large scale design choices that are discussed in the Trigger Strategy and Performance Working Group:
  - Can the L1 rate be increased beyond 100 kHz? E.g. to 500 kHz or even 1 MHz.
  - Can the latency be increased from the 'default' of 6.4 us? To something like 20 us.
- These obviously have very large impact on the trigger design
  - The TSPWG will try to come up with a baseline by the end of the year.
  - Most of the work we need to do in the next 2-3 months will not depend crucially on this.
  - But in the long term they are very important for the L1 rate and e.g. a tracker seeded pixel region of interest readout.

How to organize this work?

- Several groups have been working on this since 2008 or even earlier.
  - We want to build on what has been done and move forward.
    - A few examples of work already done is in the backup of these slides and includes studies of electron matching to stubs, muon matching to stubs and tracklets, and isolation for taus.
- We will spend the next few meetings reviewing the status of these efforts and the status of software.
  - We need to merge the code for the phase 1 trigger and the track trigger to provide software recepies that are usable for the development of the L1 triggers with tracks.
- Today we want to see who are interested in contributing to this effort and in what areas.

Regular Meetings

- To make progress on this work we will need to establish regular (weekly or every other week?) meetings.
- Of course finding a time that works for everyone will not be possible. But to start exploring this challenge we have setup a doodle poll:

  http://www.doodle.com/etbib842ef7n3p53

- Please fill out this poll if you are interested in contributing to this effort.
- In addition to our regular working meetings we will also be presenting in the Trigger Strategy and Performance Working Group.
  - In particular we have a 2 hour slot on Nov. 1 during the upgrade week at CERN.
- We hope to have one or two meetings before the upgrade week to get organized.

Topics for Next Meetings

- Status of simulation software:
  - L1 track trigger primitives – Long barrel and barrel-endcap
  - Calorimeter triggers
  - Muon triggers
- Tools for parameterized L1 track simulation
- Electron algorithms:
  - L1 simulation of electrons in upgrade
  - Status of track trigger studies
  - HLT algorithms and performance
- Muon algorithms
  - L1 muon simulation
  - Status of track trigger studies
  - HLT algorithms and performance
- Tau algorithms – ideas and HLT performance
- ...

List is not meant to be in the order we deal with them in meetings necessarily, but software issues will be a priority.

Round Table

- We would like to devote the rest of this meeting to a round table discussion where people interested in this work can describe there interest and if applicable describe what they have worked on.
- A few people were not able to make this meeting due to conflicts and I have listed them on the next page.

Excuses

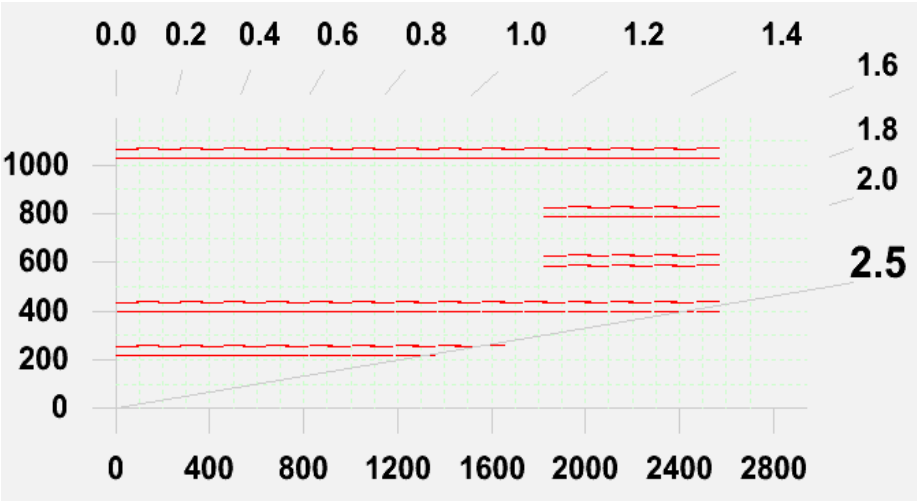
- David Newbold and Jim Brook
  - Will provide expertise in upgraded L1 trigger as they work on L1 TDR for phase 1. Very busy now with TDR, but should have more manpower to work on this in early 2013.
  - Other groups, e.g. Rutherford are interested.
- Marcello Manelli
  - Involved since a long time with the track triggers and coordinator of the track trigger task force.

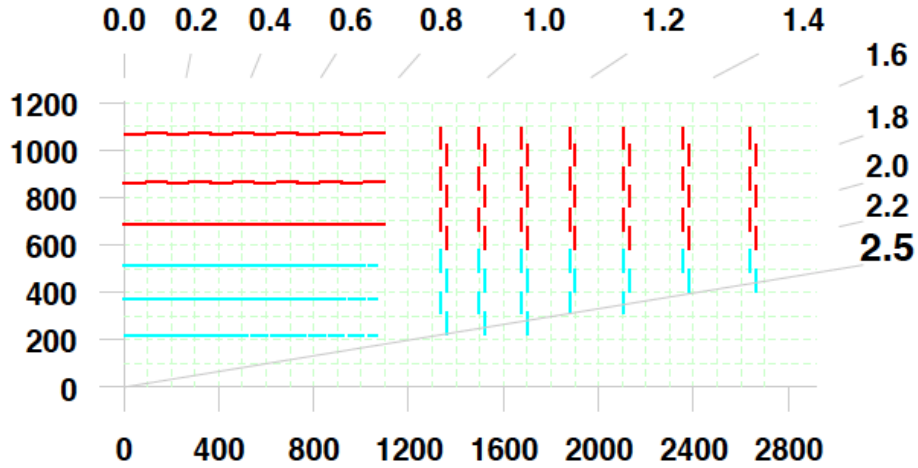
BACKUP

- Tracking information in L1 will provide many tools in the L1 trigger that currently are only available in the HLT.
- In this presentation an overview is given to the tracking information that is available in the L1 trigger.
- Some L1 trigger studies has been started:
  - Electrons
  - Muons
  - Taus
- Next steps

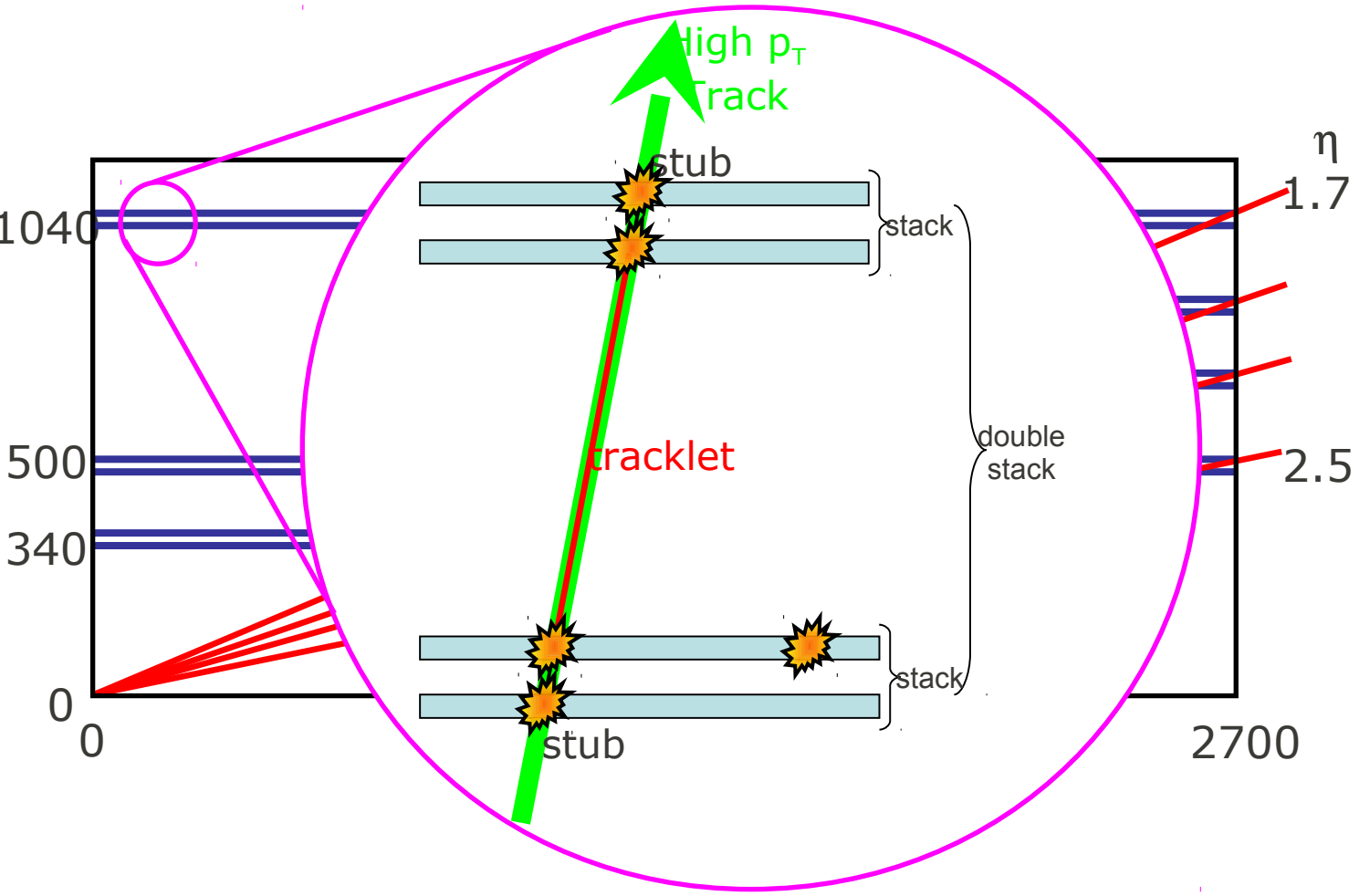
Detector Concepts

- Long Barrel:
  - 10 layers of stacks
  - Organized as 5 double stacks with ~4 cm separation
  - 100 μm pitch with 1 mm long pixels.
- Barrel-End cap:
  - Inner layers use pixel+strips modules (blue)
  - Outerlayers use strip-strip modules (red)





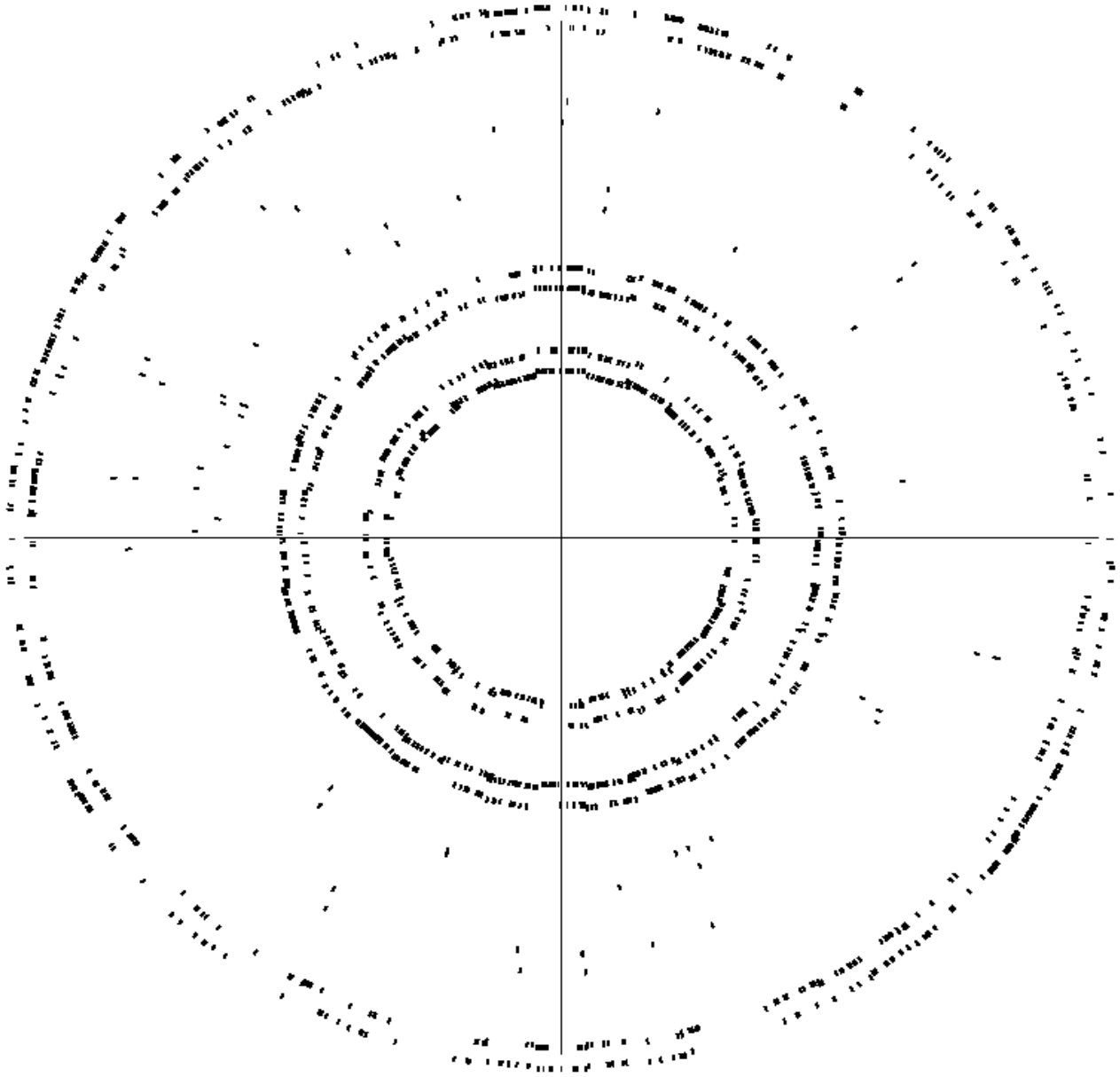
Trigger Primitives: Stubs & L1Tracks



Stack:pair of closely spaced sensors (~1mm)
Stub:correlated pair of hits in stack
Double stack:Two stacks separated by few cm. Also referred to as a beam.
Tracklet A matched pair of stubs. Used to seed the L1 track finding.

A layer is one stack in this talk.

Stubs in long barrel – 100 PU



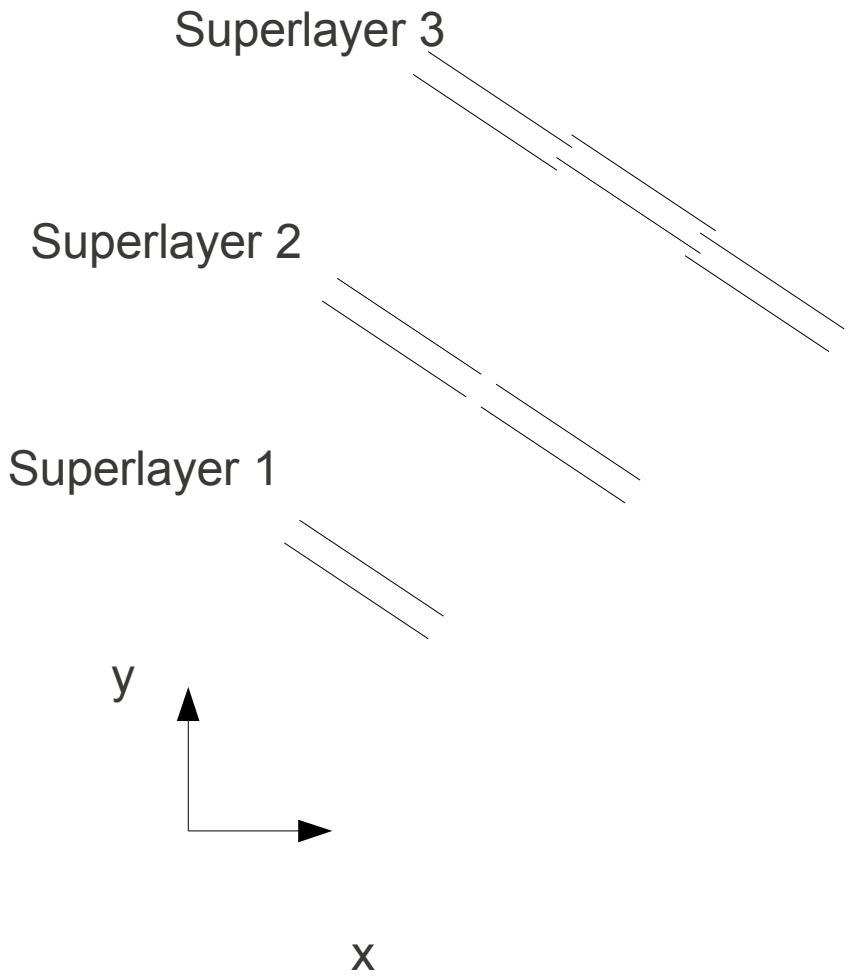
Typical event with 100 PU have between 2000 and 3000 stubs.

We want to perform a pattern recognition and quick track fit every 25 ns.

Algorithm should be able to handle twice the occupancy (50 ns operation).

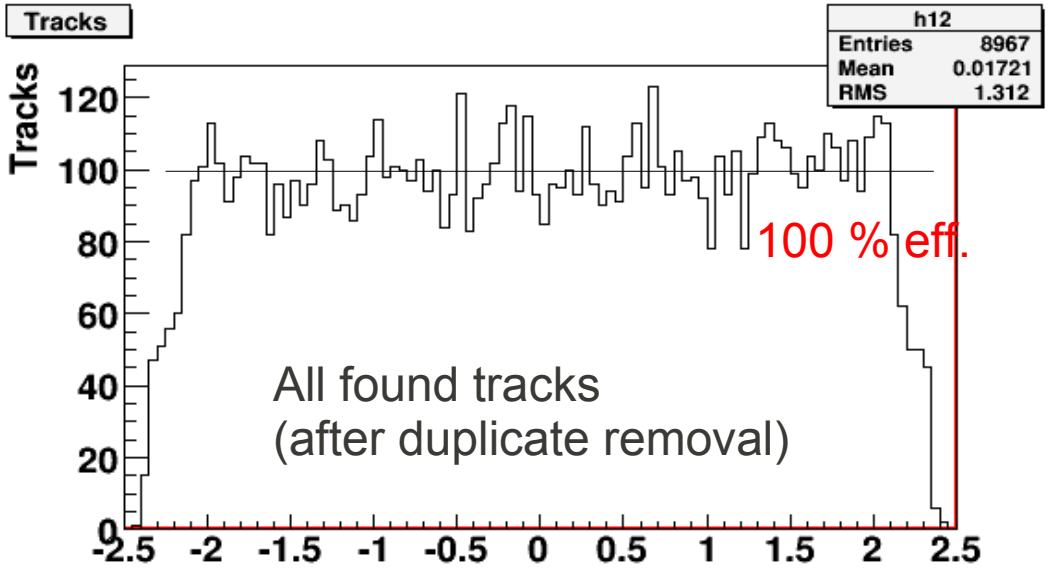
L1 Tracks

- Seed the track finding using tracklets found in superlayer 1.
  - Also start seeding in SL2 and SL3
- Propage tracklets to other layers and look for matching stubs.
- Perform a trackfit to get optimal momentum resolution.
- Duplicate removal.

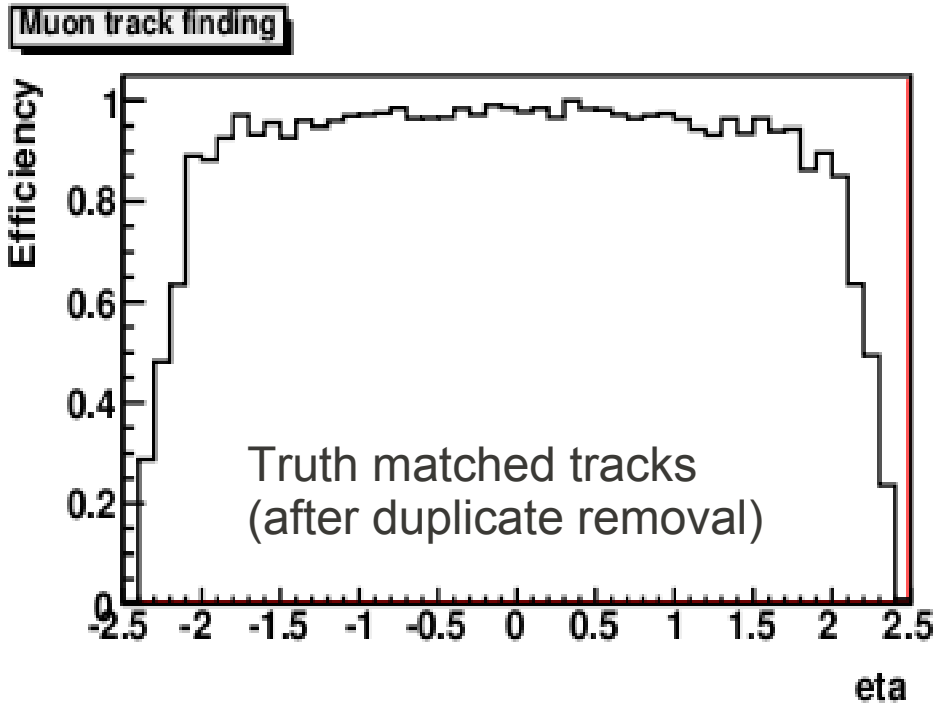


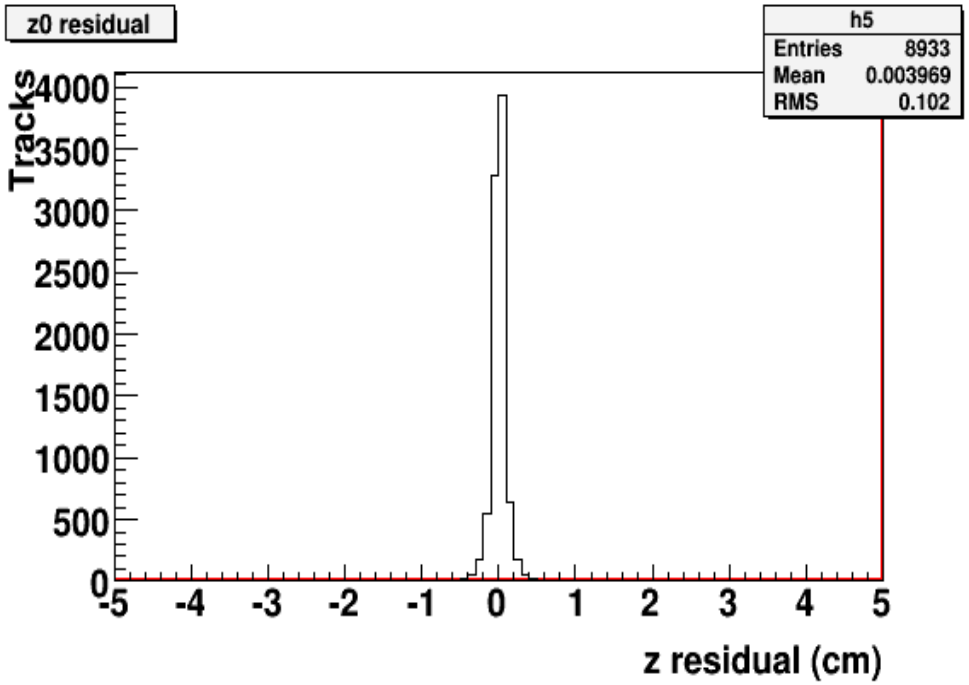
Details of this is not the subject of this presentation. Some more material in the backupslides, but this is still work in progress.

Tracking Performance (Single μ)



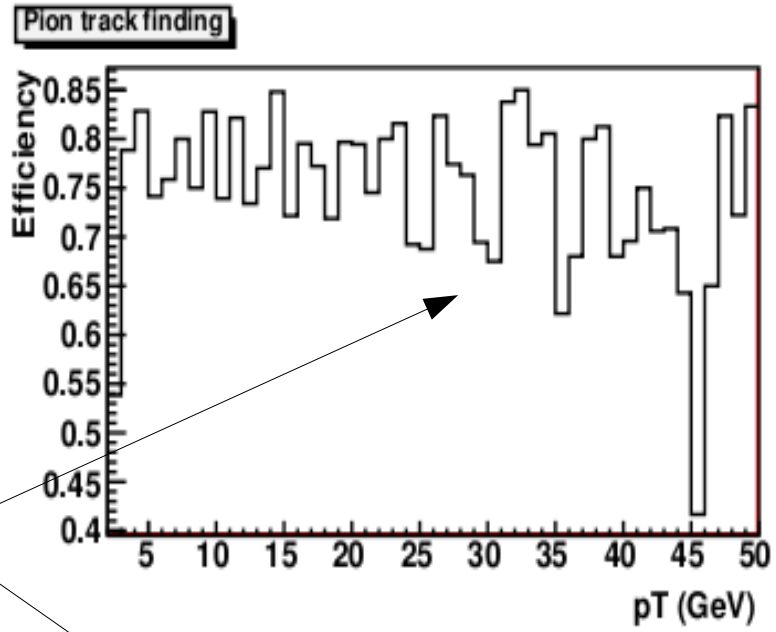
- Near 100% tracking efficiency for |η|<2
  - Optimization needed for larger eta.
  - Some inefficiency in truth matching.
- Z resolution about 1 mm
- Efficiency for pions drop to about 95%

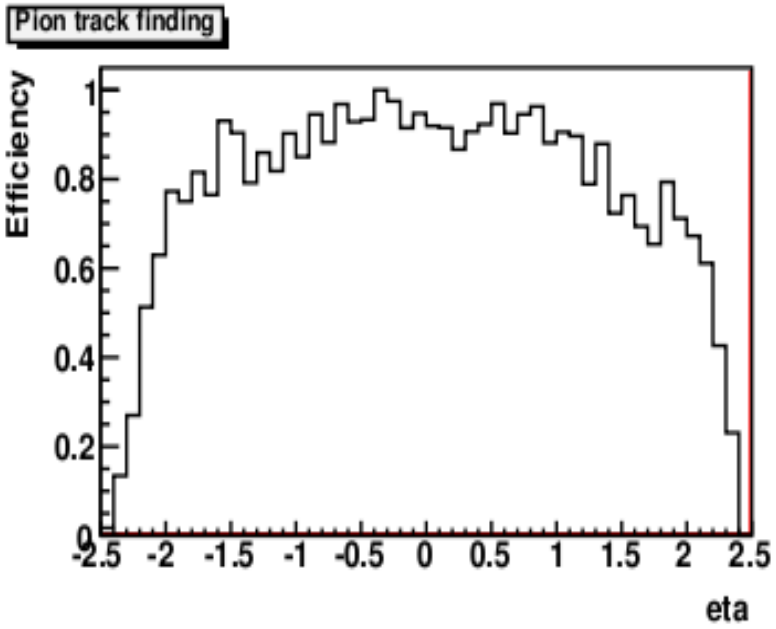


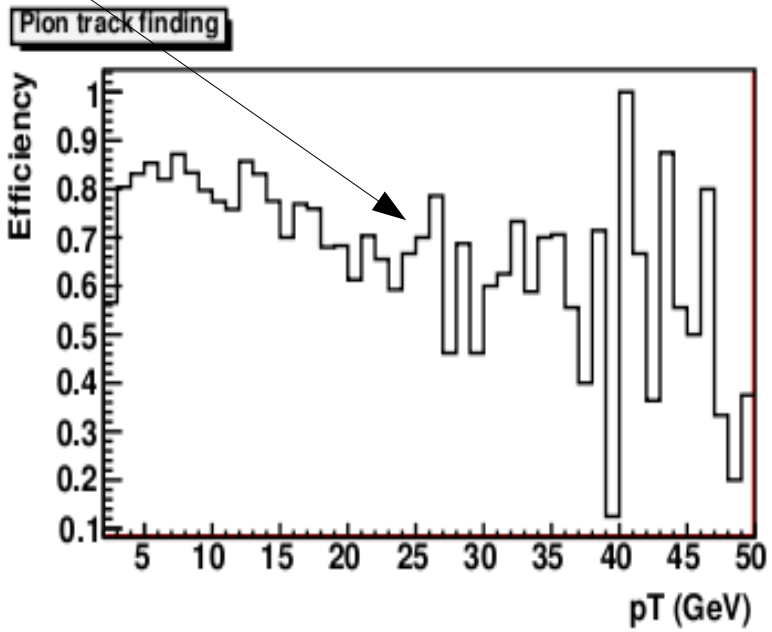


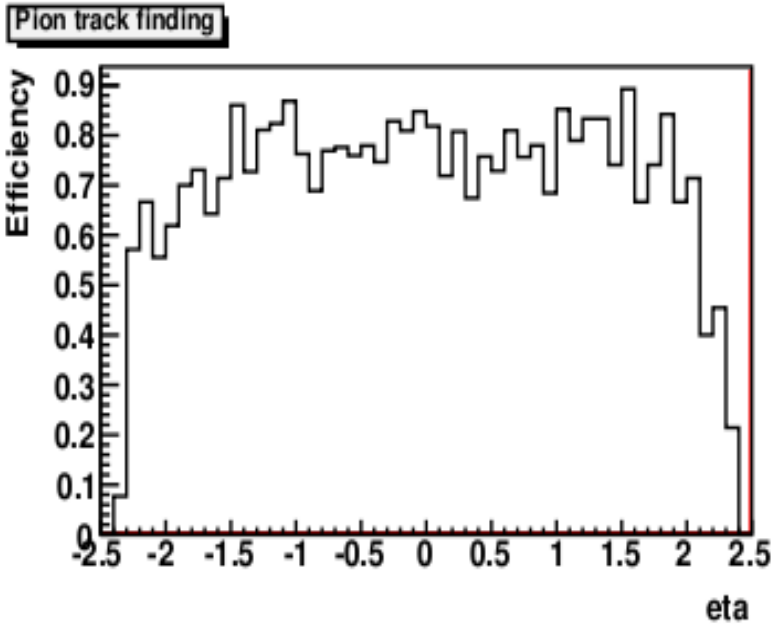
Tracking Performance (Jets)

Efficiency drop due to MC truth matching?









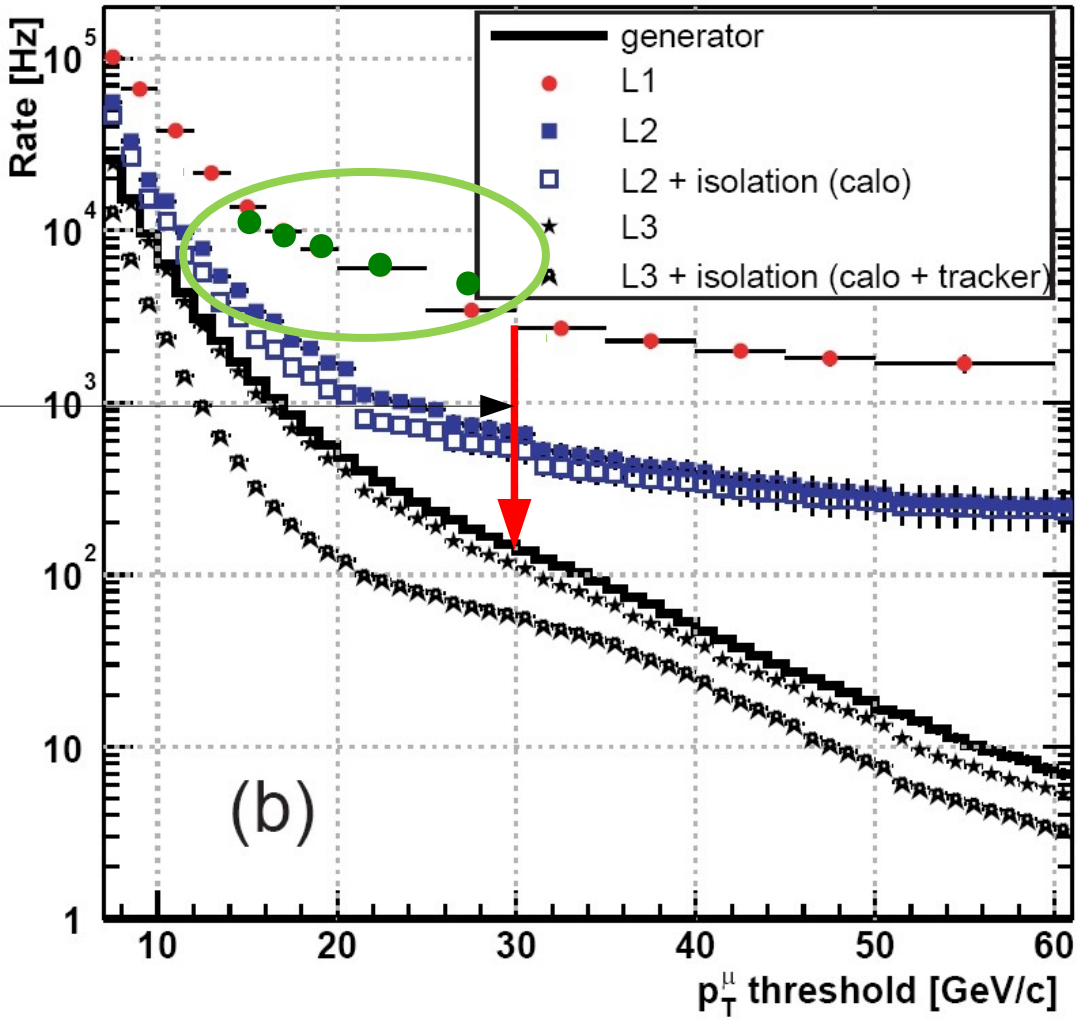
L1 Triggers

- L1 Tracks (or stubs) by themselves are not envisioned to provide the primary trigger – rather tracking information is expected to augment the calorimeter, muon, and jet triggers:
  - Muons tracking provides a precise pT measurement
  - Electrons matched to tracker hits rejects photons
  - Taus can be cleaned using tracker isolation
  - Jets – vertex determination and PF?

Effect of Tracking on Muons

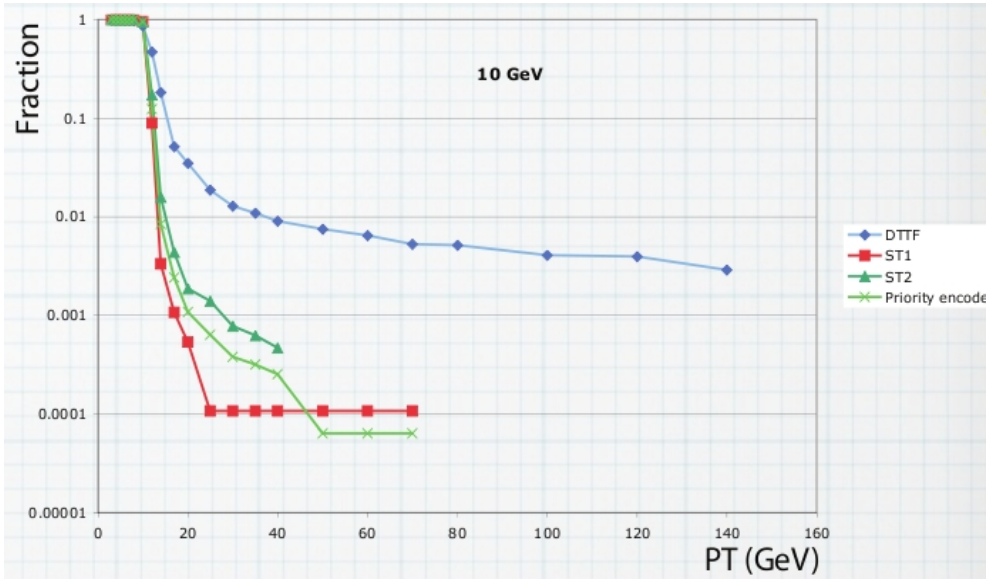
- Most muon triggers are real muons, but with a missmeasured pT
- Adding tracking information allows a precise momentum measurment and reduces the by at least one order of magnitude in the HLT
  - Expect similar performance with L1 tracking

Simulated rate at 1e34



Green data point from D. Acosta. (8 TeV Data compared to 14 TeV simulation.)

Muon Studies with L1 Tracking

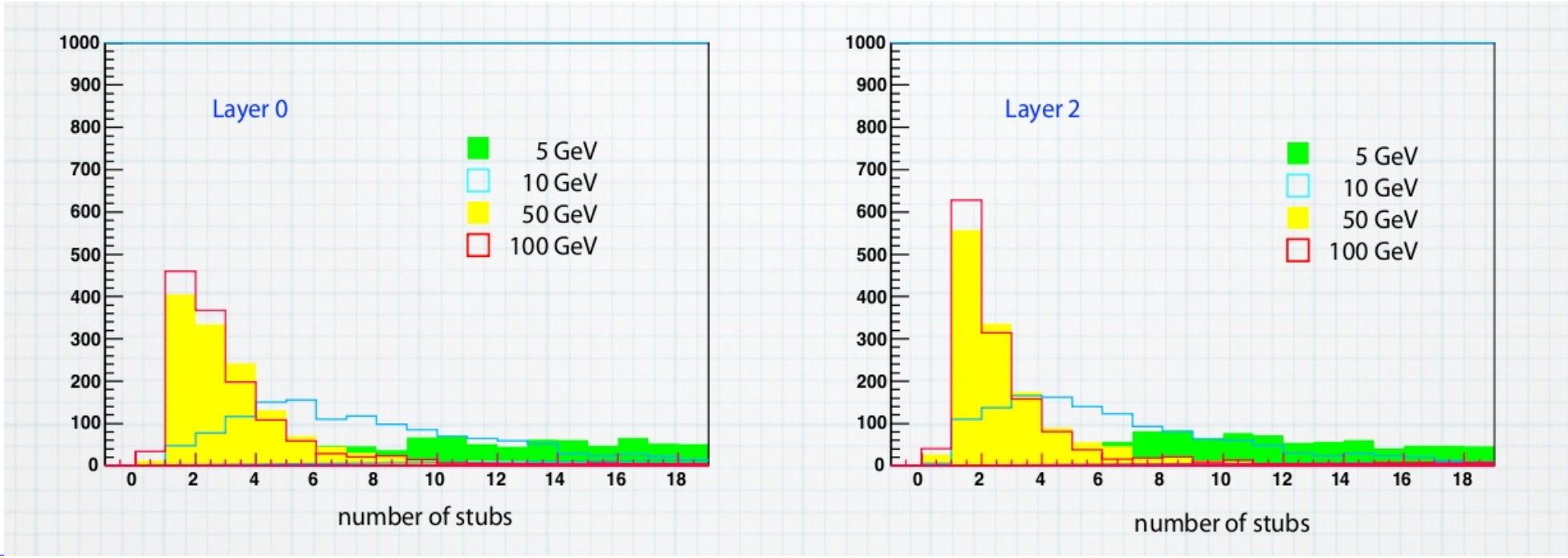


I. Lazzizzera, S. Vanini, and P. Zotto

Studes have been done with stubs and tracklets matched to muon candiates:

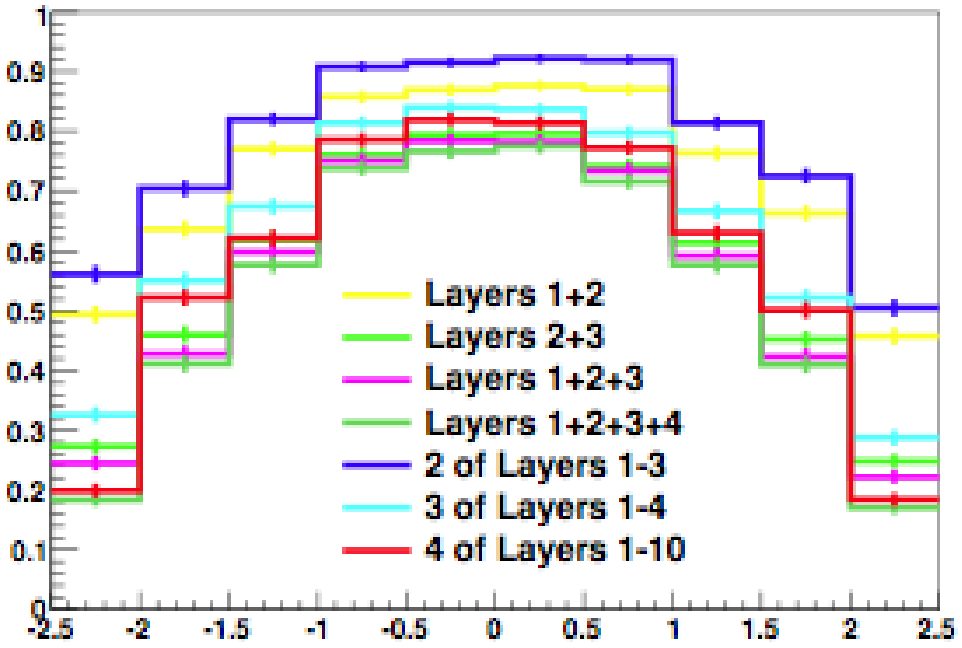
- As exoected the momentum measurment is improved with these hits
- However, the search window is large and combinatics an issue

Next step is to look at L1Tracks



Electron + L1 Tracking Studies

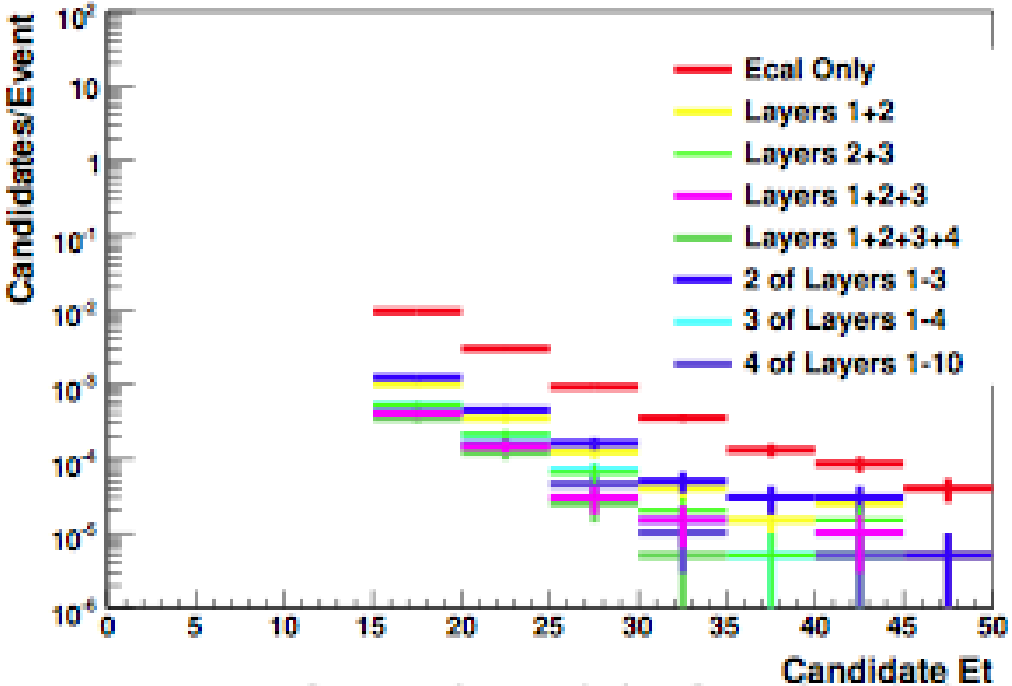
Match stubs to L1 electron candidates



(From L. Field and E. Salvati. Now being redone by A. Modak.)

- Efficiency is about 80-90% in the central region.
- Efficiency falls in forward region due to material

- Rejection factor with 100 PU is about 6.
- Fakes are largely real tracks in jets.
- Better calorimeter positions would improve performance



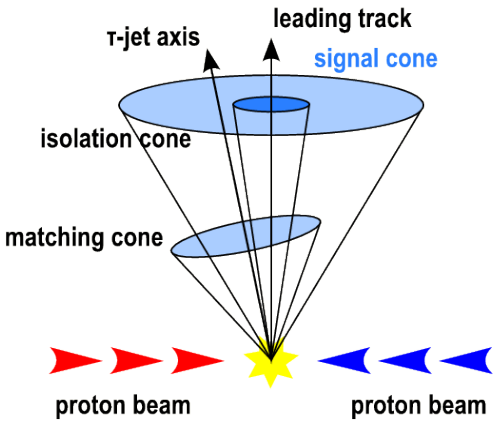
We are considering other combinations such as 2/3 or ¾ layers

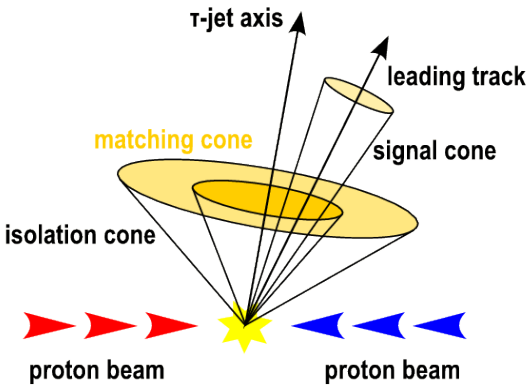
Using L1 Tracks

- Both the muon and electron studies were done with matcihng stubs to the electron or muon candidate
  - For muons matching to tracks should work well; we have a high efficiency for finding tracks from muons.
  - For electrons it might be the case that working with matching to stubs will work best.

τ Trigger

N. Pozzobon





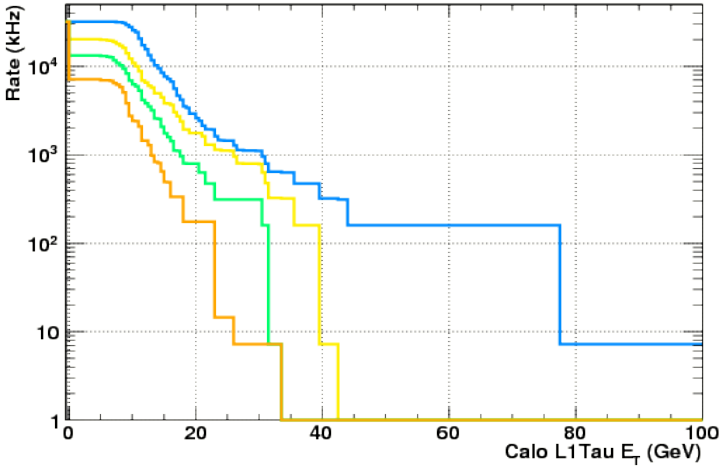
Current τ trigger at CMS finds Level 1 calorimeter candidates, which are matched to tracks in the HLT.

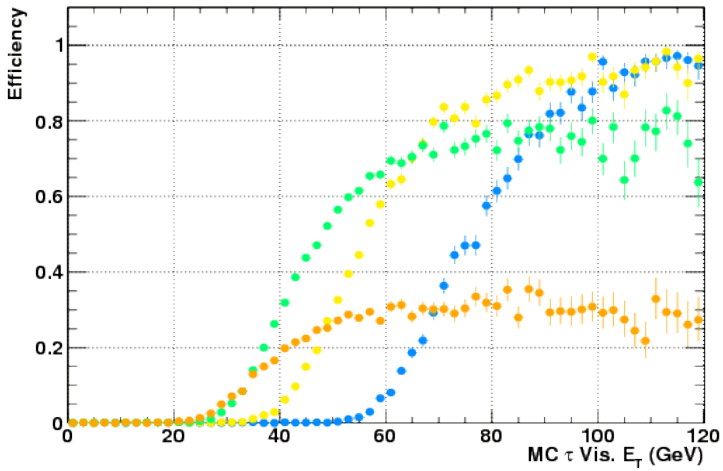
τ candidates require isolation in HLT, based on the amount of tracks within a signal cone and an isolation cone.

Phase 2: exploit Level 1 tracking trigger to check isolation of calorimeter τ candidate.

Level 1 tracks in τ decays are contained within narrow cones (R = 0.2) and share extrapolated *zVTX* within 5 mm.

200 PU scenario





E_T>60 GeV

E_T>40 GeV + trk. conf

E_T>30 GeV + Vertex isolation

Phase2 algorithm

Tool Status

- Stubs and lower level objects are reasonably well developed; for the long barrel geometry they are documented in DN-12-003.
- L1 track finding algorithm for the stacked tracker (LB) has been developed
  - Still not fully CMSSW integrated.
  - Algorithm makes use of the long barrel geometry 'double stacks' to seed the track finding.
  - Studies underway to understand how to realize this in hardware
- For the barrel-endcap work is underway to use associative memories to do the pattern recognition.

- Should develop objects (tracks, stubs) that are common to both detector concepts to simplify performance studies.

Next steps (my view)

- L1 tracking algorithms needs to be further developed to be fully understood.
  - However, what we have available now should allow starting to use the L1 tracks in L1 Trigger studies.
- Muons studies with L1 tracks.
- Electrons studies L1 tracks vs stubs.
- Tracker Isolation: taus and other leptons
  - How does HLT algorithms compare to what can be done in L1
  - Study HLT with 2 GeV pT threshold.
- Need to work with experts on calorimeters and muons.
  - The initial results from the electron trigger studies has shown that the limiting factor is the L1 calorimeter object positions.
- Vertex consistency in multi-object triggers
- A little later:
  - Performance on benchmark channels
  - Use of stubs in HLT for offline tracking?