Tracking Detector Challenges

Observations "based" on lessons learned, perhaps the hard way.

Direct Experience

Friendly Spies, Talks, Rumors…beware!

P. “Cassandra” Collins, ICHEP 2002

Silicon for tracking: Large Systems

Whoops...

P. Collins
“Future Detector Systems”
ICHEP 2002

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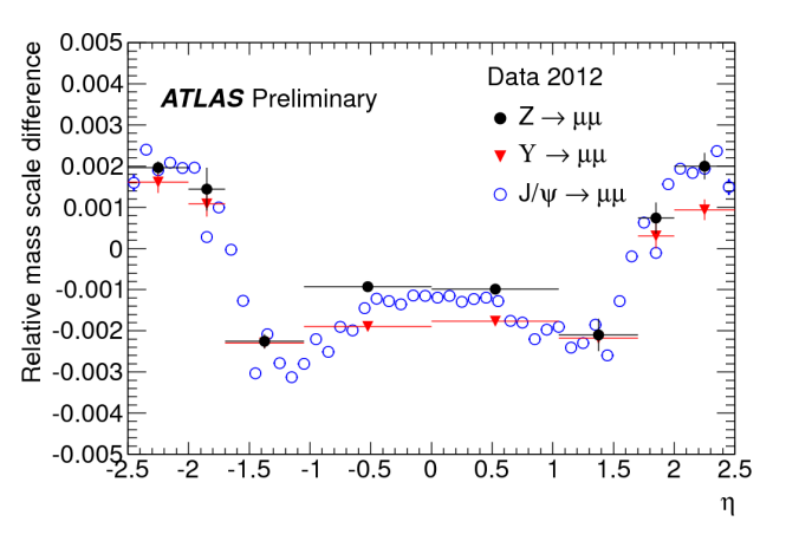
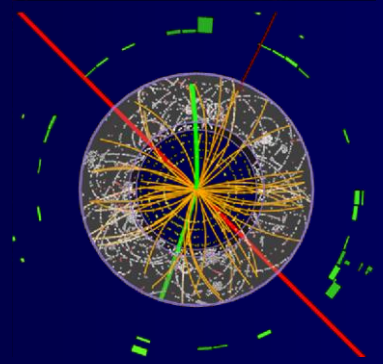
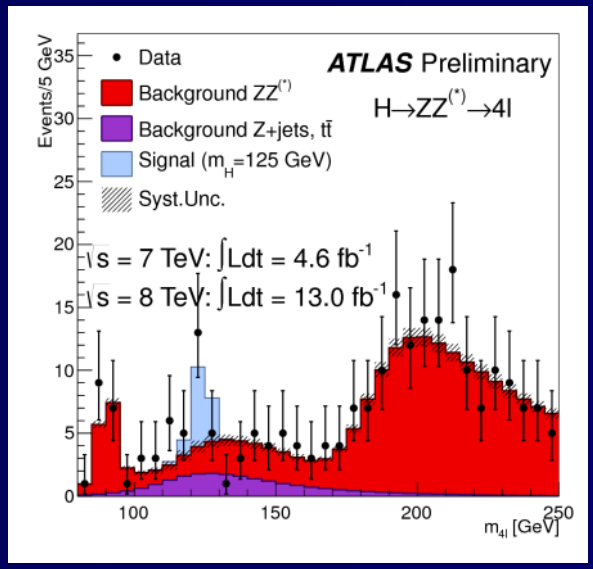
Fortunately, not true

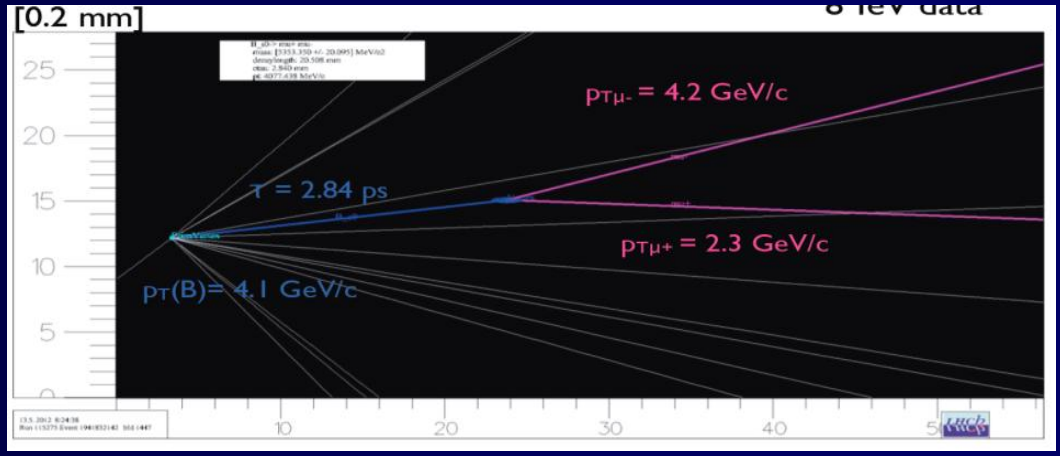
- **Momentum Resolution**

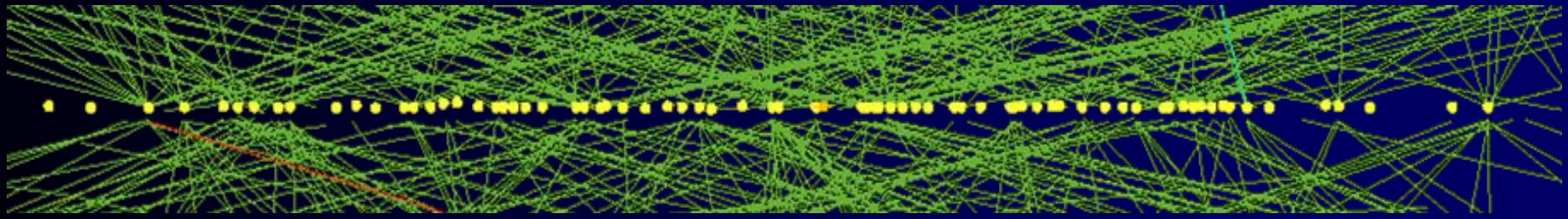






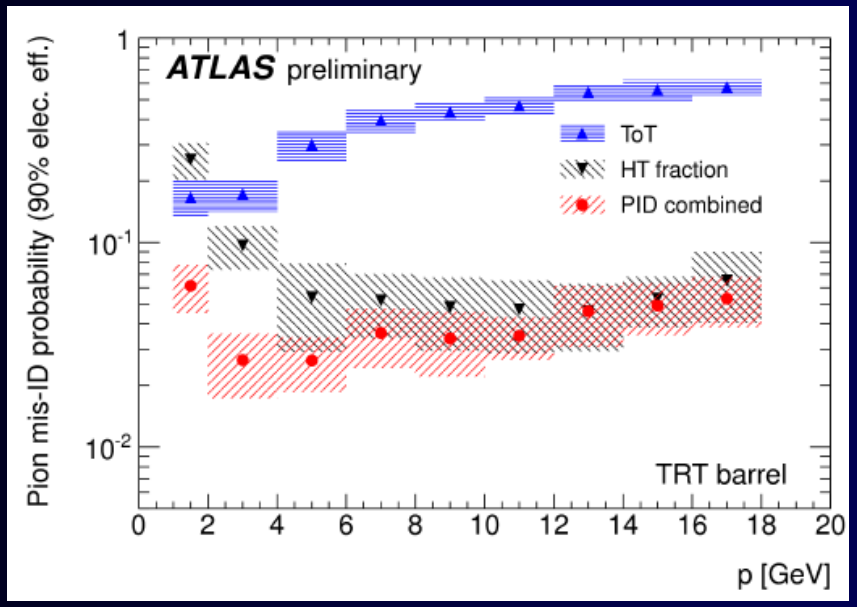
- **Vertexing**

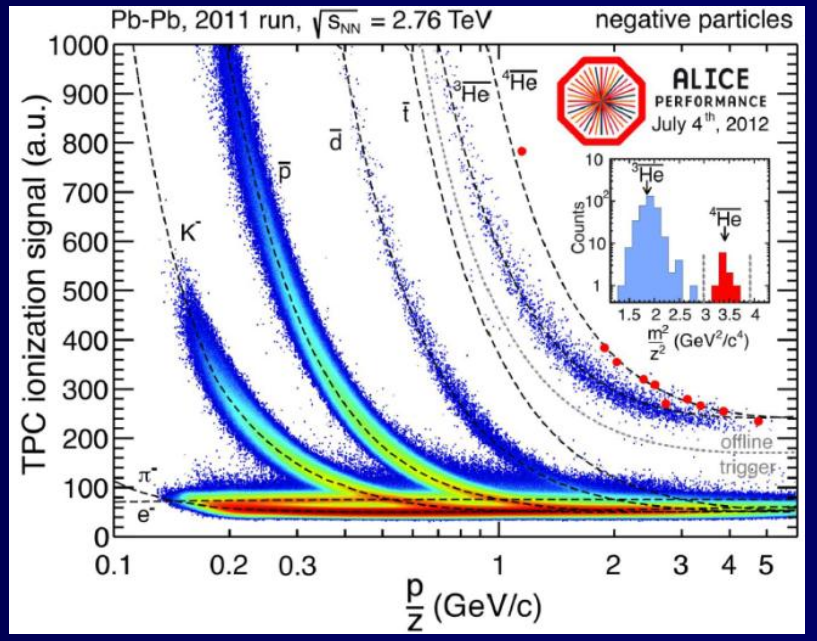




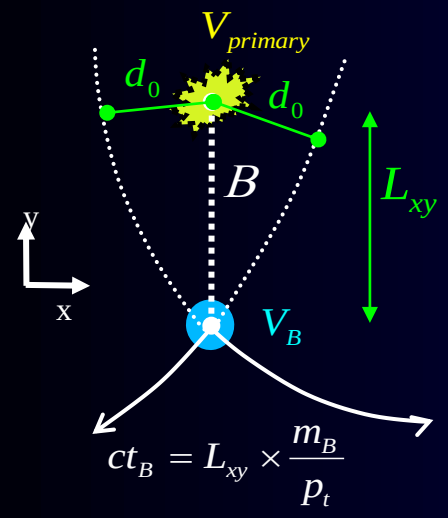
Fortunately, not true

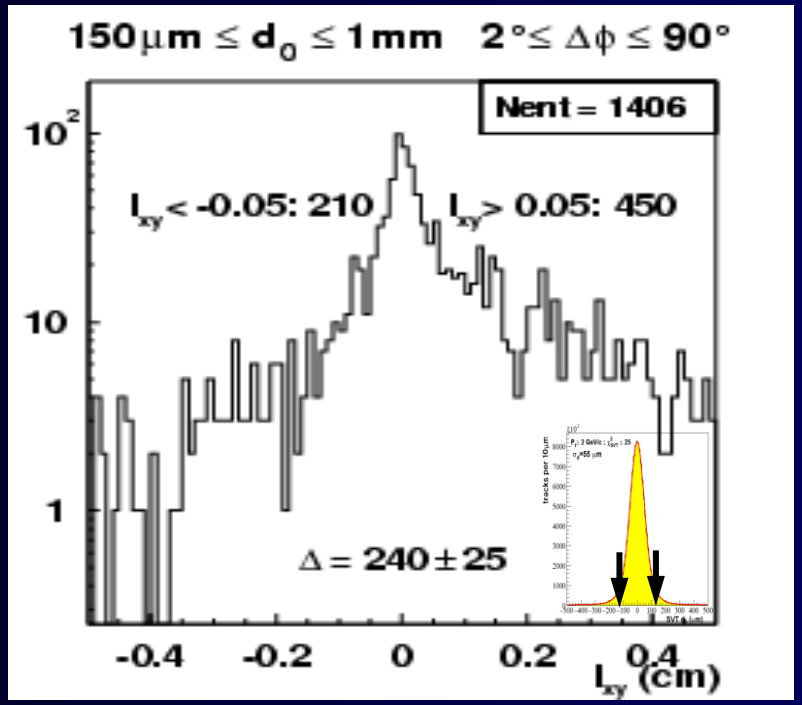
- **PID**

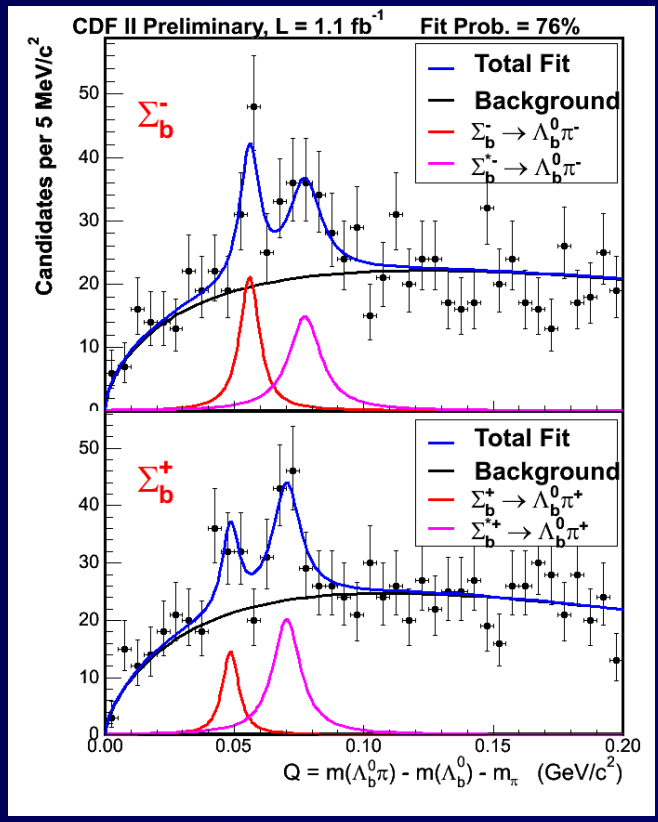




- **Trigger**



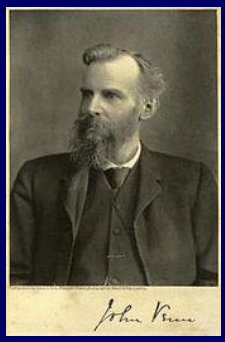




Overall, Excellent Performance

- **Running Trackers**
  - **Operational fraction (100-ε_{dead}) ε_{dead} ~ 2-5%**
  - **Track and Vertex efficiencies (100-ε_{lost}) ε_{lost} ~ 0.1-0.5%**
  - **Momentum Resolution sub-percent level**
  - **No (publicized) catastrophes**
- **Retired Trackers**
  - **Fully functional for 5× expected lifetime in both years and dose (!?!)**
- **"Challenges" ≡ what are the current/recent *common* threads between the various detectors**

Potential Challenges (one possible, and possibly incomplete factorization)



- **From Physics**
  - **Signal to Noise**
    - Gets all the focus
    - Physics dependence?
  - **Multiple Scattering**
    - Thinner = better, but constraints vs infrastructure
  - **Spatial resolution/Alignment**
    - Push beyond ~ few μm?
  - **Radiation Damage**
    - When do things "die"
    - Acute damage!
- **From Operations**
  - **Bandwidth/Occupancy**
    - Balance of efficiency and deadtime
    - Implication on Pattern reco too
  - **Robustness**
    - Redundancy, Efficiency, Resiliency, Rapid Recovery
  - **Power and DAQ paths**
    - Meet specs w/minimal complexity, cost
  - **Cooling/Environment**
    - Avoid melting, condensation …
    - Be a good neighbor

Biggest Bugaboo: Dull, drab infrastructure

- **Temperature and Humidity Control**
  - **CDF: ISL Blocked lines, Added "baggy" late in game**
  - **CMS: Leaks in Cooling Plant, Adding "baggy" …**
- **Physical Connections**
  - **CDF: Delicate electrical connections, Bad Crimping**
  - **CMS: Bad Crimping**
  - **ATLAS: Similar concerns with inner connections, cabling (A. Grillo, private communication)**
- **Power supply systems, monitoring**
  - **Treated as a necessary evil**
- **Majority of operations and planning today involve refurbishing the "boring" things**

Fixing without access

- **Detector is unreachable**
- **Emphasis put on redundancy paying off**
  - **Remotely configured detours for commands, data**

    Lacking in Tevatron experiments (at least CDF)

- **Much work on "curing symptoms" externally**
  - **CMS, CDF – making firmware/hardware robust against corruption, excessive occupancy**
  - **Everyone – fast recovery time for intermittent problems**

Wishlist: Realistic conditions

- **Ingredients missing during Integration Tests**
  - **Interfaces: eg. Trigger, Event Building systems**
    - **Limits capability, Hides protocol misunderstandings**
  - **Statistics: Slice tests rely on homogeneity**
    - **Misses "worst offenders" which hold up DAQ**
  - **Rate: Cosmics don't come at 20 MHz**
    - **Need to test at rates commensurate with ASIC timescales**
  - **Environment: No B field, No Beam, No other detectors**
- **LHC vs. TeV: "Incident" silver lining**
  - **Extra time in situ to suss out problems**

Resiliency

- **Strive to make sure nothing goes wrong, what happens when it does?**
  - **Out of Spec by 2σ (Voltages, Clocks, Optical levels)**
  - **Cooling/Gas flow not adequate**

    ATLAS: VCSEL Tx, CiS Sensors

    CDF COT: Wire Aging
- **How long will the detector last?**
  - **Chronic radiation damage well scrutinized**
    - **Monitoring archive needs to be reliable**
  - **What about acute radiation?**
    - **Dump a bunch of charge in your detector, what happens?**

Person power!

- **LHC Exodus to analysis with the arrival of data**
  - **Secondary exodus → Upgrades with detector running**
- **Few practice fields**
  - **100% operational excludes development**
  - **"If it ain't broke, don't fix it" limits time for learning**
    - **No "playing" with precious detectors**
- **How to better recognize "hardware" contributions**
  - **Often contrasted with "Physics"**

Conclusions?

- **State of the current/recent detectors is pretty good**
  - **Producing the physics they were designed for**
    - **Little disparity between expectation and performance**
- **Challenges are dealing with the residual sources of inefficiency**
  - **Redressing mundane or marginal issues**
  - **Lessons for how to improve next time**
- **Is there something CPAD can do to help this?**

  Detector Integration center?

  Promotion of Instrumentation Importance

  …<your answer here>