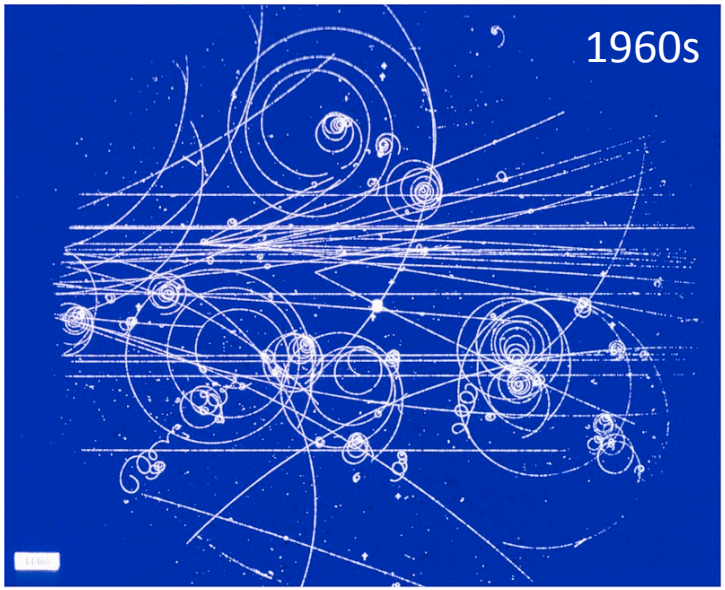
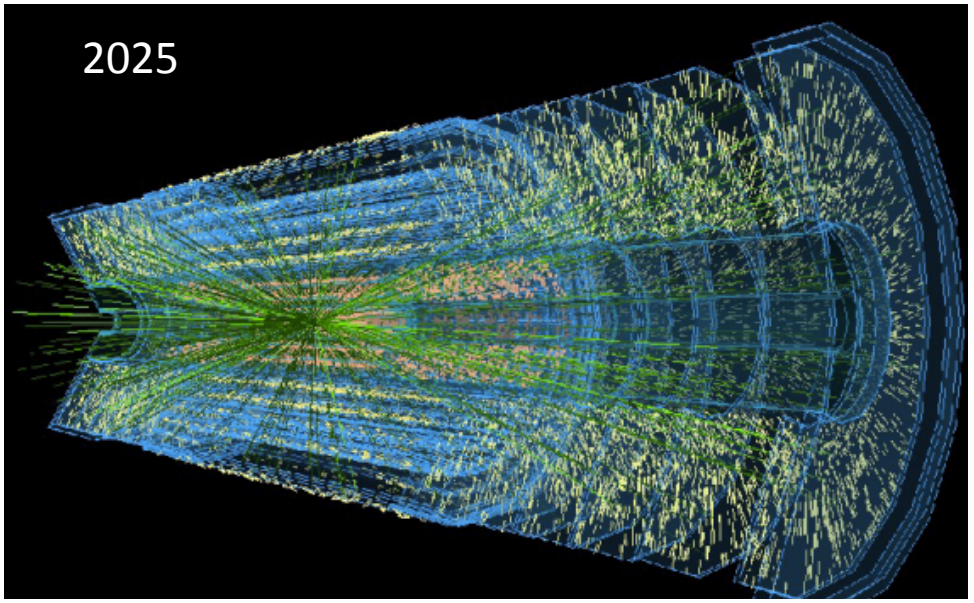
Connecting the Dots: Welcome and Introduction





Beate Heinemann

UC Berkeley and

Lawrence Berkeley National Lab

Welcome to Berkeley!

BERKELEY EXPERIMENTAL PARTICLE PHYSICS CENTER

http://bepp.berkeley.edu/

About BEPP

BERKELEY EXPERIMENTAL PARTICLE PHYSICS

Experimental particle physics addresses fundamental questions about the nature of matter, energy, and the evolution of the universe. The roots of this field go back to the 19th century with the discovery of the electron, X-rays, and the atomic nucleus. In the 21st century particle physics is a global endeavor involving teams of hundreds, or thousands, of physicists and engineers utilizing large and complex experimental systems, and massive distributed computing to address a range of basic scientific questions.

The key to success in this research is innovation in instrumentation and computing, and the development of novel analytical and numerical methods.

Instrumentation, methods, and computing, in experimental particle physics, have a long and distinguished history in Berkeley – from the invention of the circular particle accelerator, or "cyclotron", by E. O. Lawrence (Nobel Prize 1939), to critical experimental contributions to the discovery of the Higgs Boson (Nobel Prize 2013). Read more about history. Close collaboration between scientists at UC Berkeley and the adjacent Lawrence Berkeley National Laboratory (LBNL) has been an essential ingredient for breakthrough discoveries throughout this history.

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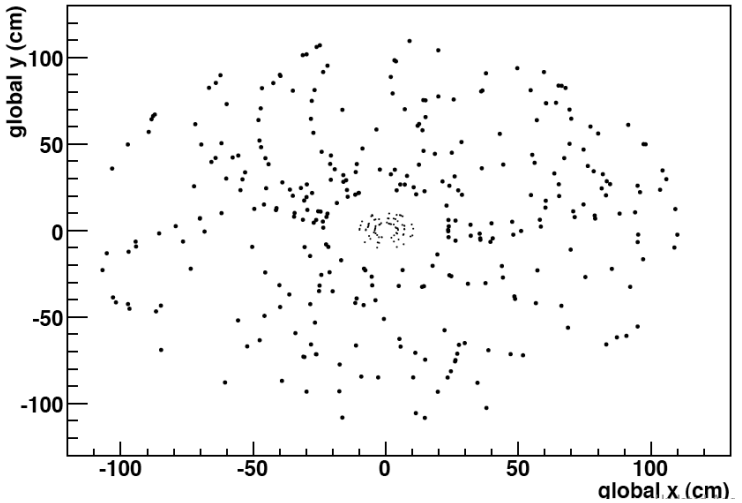
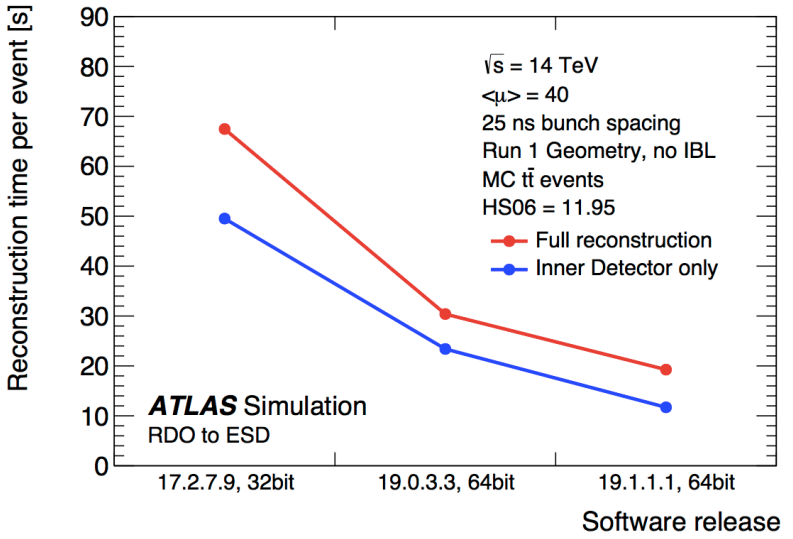
Goal of this Workshop

- BEPP workshops are in general targeted workshops
  - Addressing a specific problem
  - Aim to get leading experts in that area together
- **Pattern recognition** ("connecting the dots") is one of the most interesting, inspiring and challenging problems in modern experiments
  - Likely need innovations to be ready for challenges in a decade
    - Just Moore's law is not good enough
  - Benefit from advances in computer science in last decade?
    - Machine learning?
  - Do innovations from e.g. LHC experiments have applicability to other areas?
    - Example: see lecture by Carl Haber tomorrow!
  - Share ideas between HEP experiment (LHC, mu2e, …)
    - online and offline

"Connecting the Dots"

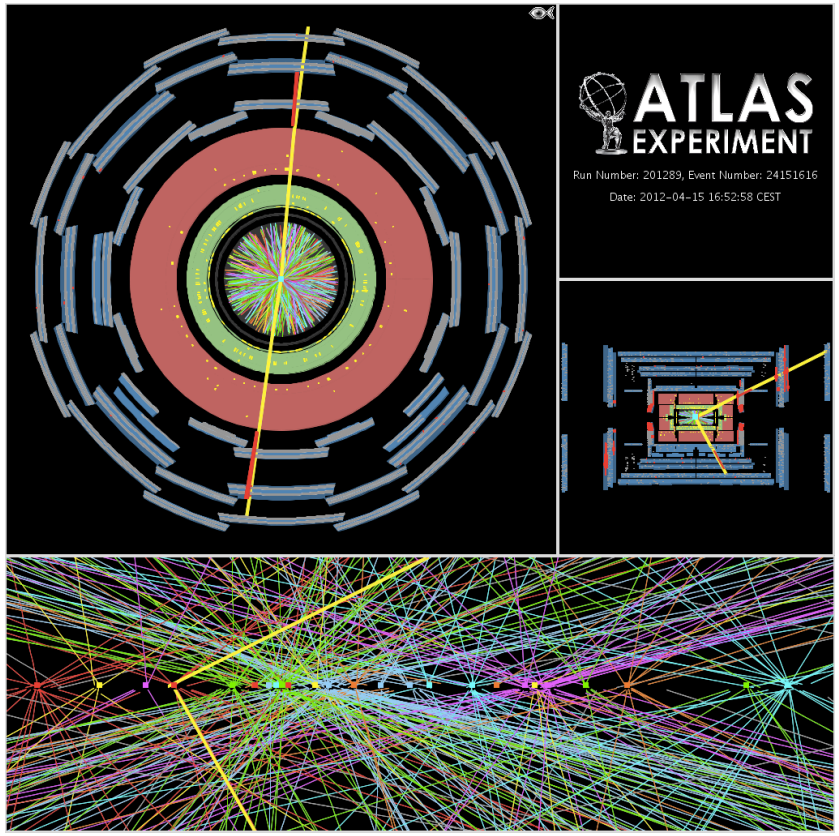
- At LHC charged particle identification relies on identifying trajectories based on rather few (precise) measurements
  - Main CPU consumer in experiments
  - Will become even more serious constraint in ~10 years
    - More events taken and each event more dense





CPU offline needs

- Current LHC (~2015):
  - 30 tracks per collision
  - 30 collisions per event
  - 1000 events/s
  - Need to find **1M tracks/s**
- Future LHC (~2025):
  - 30 tracks per collision
  - 200 collisions/event
  - 10000 events/s
  - Need to find **>60M tracks/s**



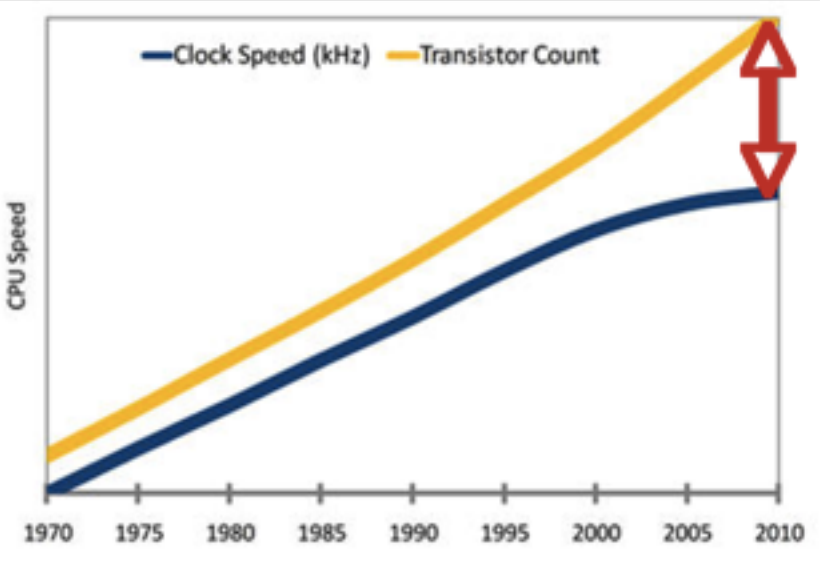
To cope we need

a) CPU increase to be at most linear with N_{track}

b) Moore's law to continue

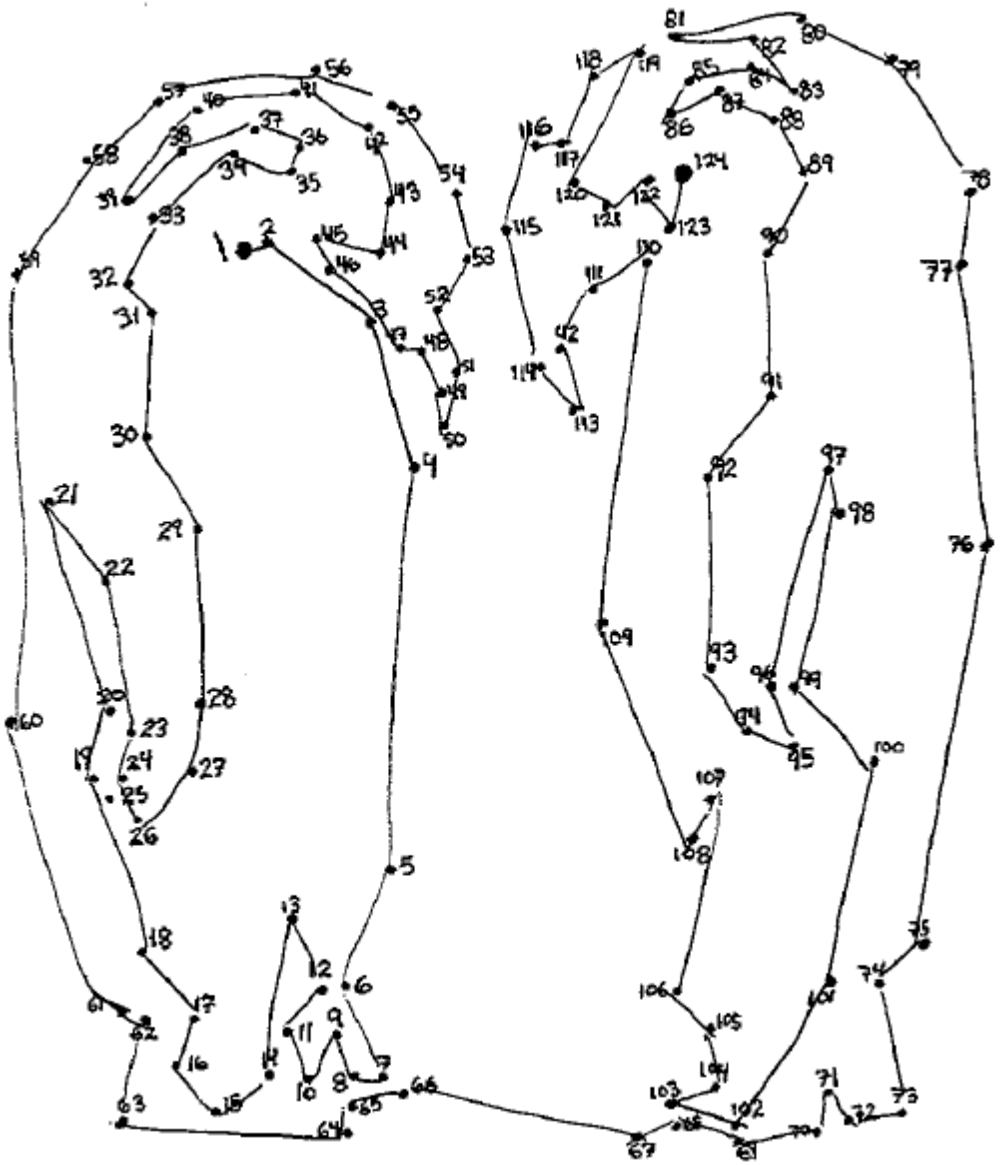
In the last decade

- Huge advancements in machine learning and automated pattern recognition
  - E.g. facial recognition SW, voice recognition, …
- Slowdown of clock speed
  - But increase in number of transistors
    - CPU increase continues (so far)
    - Need to rewrite code to exploit it



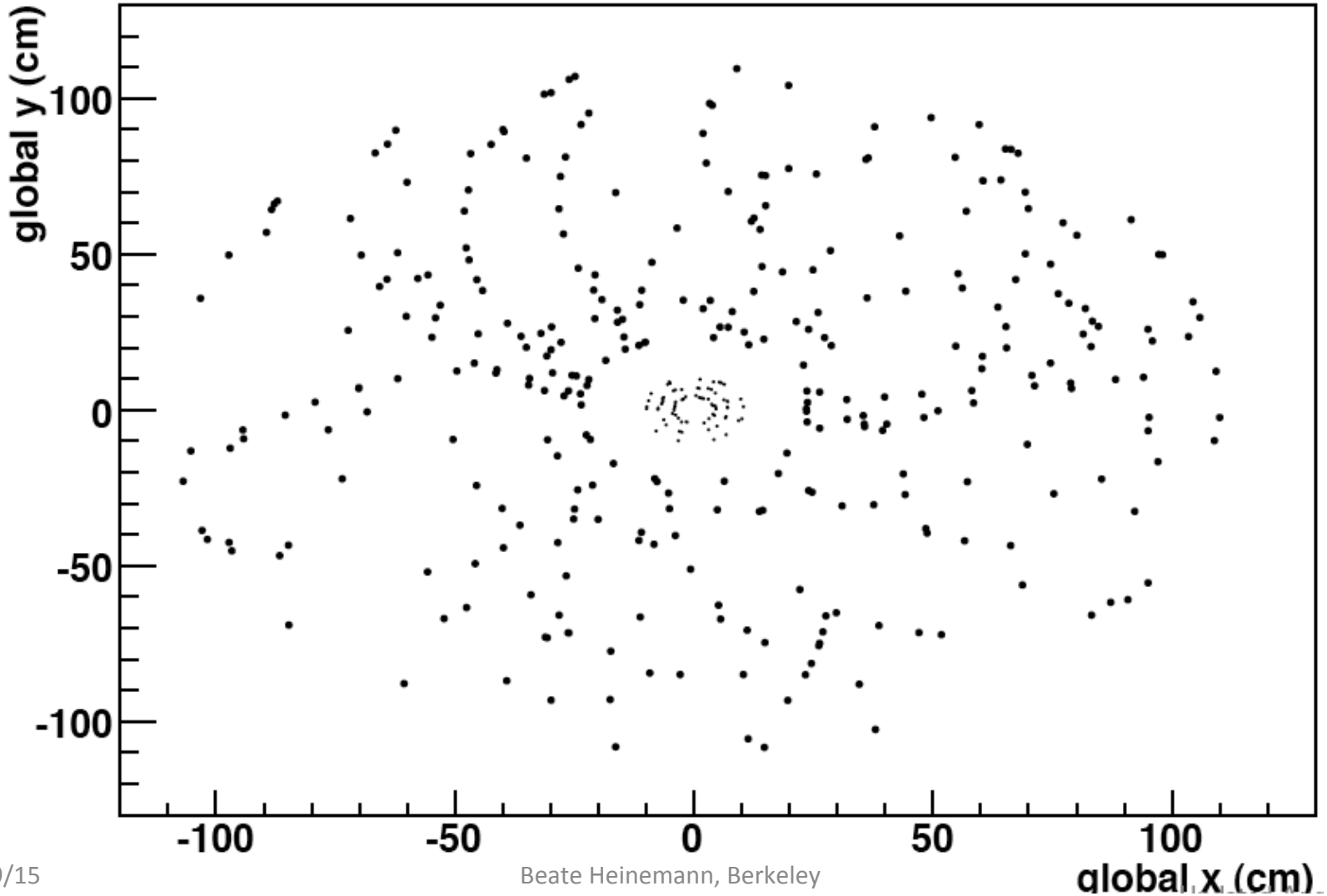
Can you recognize this?

It’s two penguins!

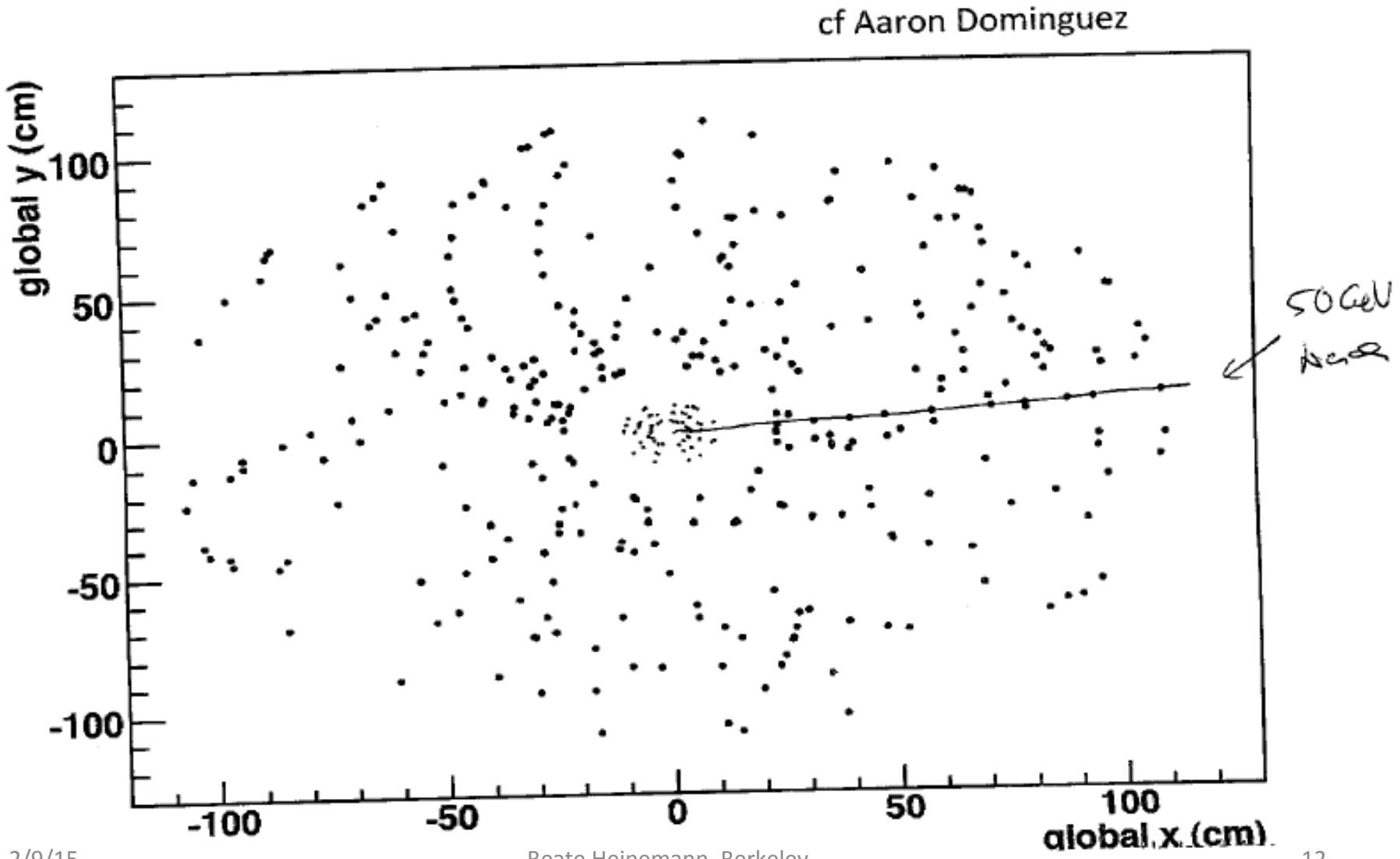


Can you find the 50 GeV Track?

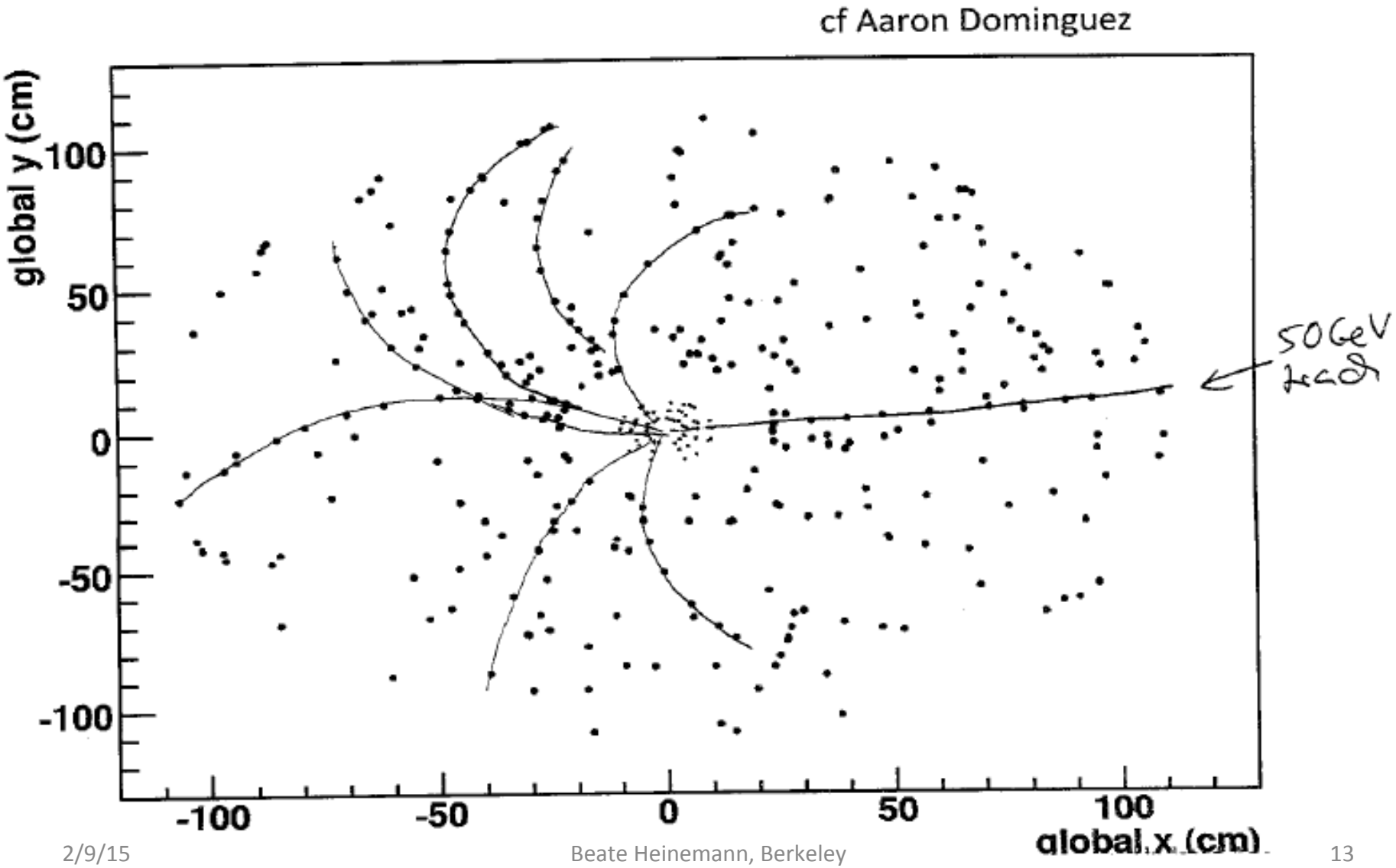
cf Aaron Dominguez



There it is!


cf Aaron Dominguez
global y (cm)
100
50
0
-50
-100
-100
-50
0
50
100
global x (cm)
50 GeV

… and some more low-P_T ones



Have a great workshop!

- Many talks but also allocated time to discuss and exchange ideas
  - Many HEP experiments
  - Offline tracking
  - Online triggering
  - Jet reconstruction
  - Data analysis
  - …

Have a great workshop!

"You can't connect the dots looking forward; you can only connect them looking backwards. So you have to trust that the dots will somehow connect in your future."

Steve Jobs
1955-2011