# Computing for Experimental Nuclear Physics at JLab

## EXTREEMS-QED Program Visit


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# Overall Drivers of Computing Need

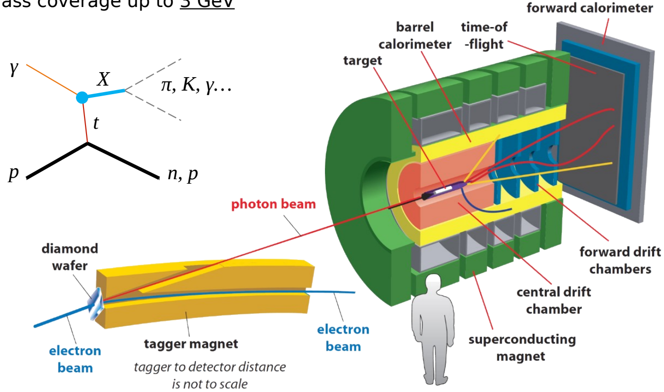
- data rate/data volume
- need for simulated data
- computing load per event

# Computational Problem Domain

- events: beam-target collisions recorded by detector
  - beam mostly misses target
  - simulated events as well
- quantum mechanics $\Rightarrow$ probability and statistics
- events are statistically independent $\Rightarrow$ embarrassingly parallel

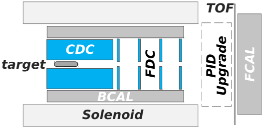
# GlueX: Study **Glu**on **Ex**citation

- High luminosity linearly polarized photon beam: 8.4~9 GeV
- Liquid Hydrogen target
- Mass coverage up to 3 GeV
- Hermetic detector system for multiple particle final states
- Partial wave analysis



# Tracking

- Central Drift Chamber (CDC) – CMU
  - Straw tube design – single end readout
  - 28 layers (16 stereo layers – ± 6º), 3522 tubes
- Forward Drift Chamber (FDC) – JLab
  - Traditional drift chamber, readout from both cathode strips and anode wires
  - 4 packages, 24 readout planes – 3 orientations, 12672 channels


# Computational Tasks

Will only describe two:

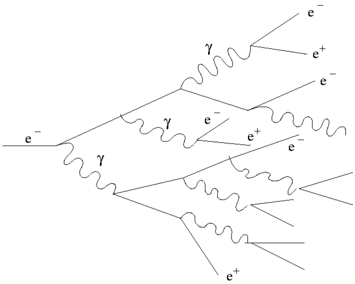
1. event simulation
2. charged particle tracking

# Event Simulation

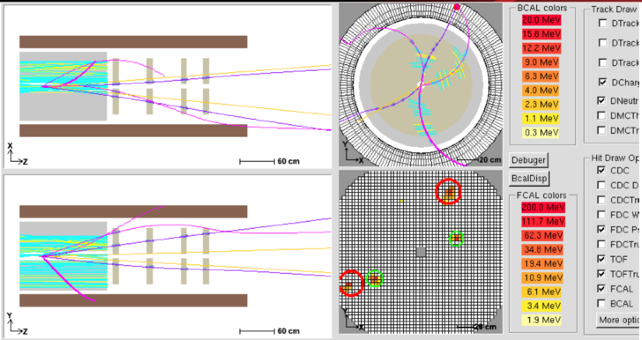
- purpose: study how detector distorts events
- gaps, resolution, confusions
- two types of confusion
  - within an event
    - particles messing up detection of other particles
    - event particles vs. other event particles
    - non-event particles vs. event particles
    - event particles vs. themselves
  - event mis-classification
    - wrong particle roster
    - "background"

# Simulated Physical Processes

- initial data: list of particles and their momenta
- propagate through detector
- simulate interactions with detector material:
  - Charged Particles
    - multiple Coulomb scattering
    - energy loss
    - hadronic interactions
  - Photons and Electrons: showers (expensive)



# A well-reconstructed $b_1\pi$ event




Track Info

Thrown

| trk: | type: | p: | theta: | phi: | z: |
|---|---|---|---|---|---|
| 1 | Pi+ | 0.6251 | 19.19 | 1.272 | 54.63 |
| 2 | Pi- | 3.315 | 8.546 | 1.482 | 54.63 |
| 3 | Gamma | 0.6388 | 4.607 | 0.3927 | 54.63 |
| 4 | Gamma | 0.7631 | 6.511 | 3.665 | 54.63 |
| 5 | Pi+ | 0.5956 | 29.46 | 0.06897 | 54.63 |
| 6 | Pi- | 2.662 | 9.916 | 3.972 | 54.63 |
| 7 | Proton | 0.5815 | 45.62 | 4.522 | 54.63 |
| 8 | Muon+ | 0.02979 | 81.05 | 6.004 | 235.8 |
| 9 | Neutrino | 0.02979 | 98.95 | 2.863 | 235.8 |

Reconstructed

| trk: | type: | p: | theta: | phi: | z: | chisq/Ndof: | Ndof: | FOM: | cand: |
|---|---|---|---|---|---|---|---|---|---|
| 1 | pi- | 3.202 | 8.547 | 1.485 | 54.79 | 2.008 | 16 | 0.0096134 | 1 |
| 2 | pi+ | 0.6023 | 29.66 | 0.06739 | 54.97 | 0.5528 | 10 | 0.85327 | 2 |
| 3 | proton+ | 0.649 | 36.13 | 0.2573 | 65.95 | 4.342 | 4 | 0.0016407 | 2 |
| 4 | pi+ | 0.6119 | 46.75 | 4.533 | 55.09 | 2.5 | 8 | 0.0103295 | 3 |
| 5 | proton+ | 0.5864 | 46.78 | 4.521 | 55.43 | 0.6125 | 6 | 0.720533 | 3 |
| 6 | pi- | 2.661 | 9.998 | 3.974 | 55.44 | 0.8265 | 11 | 0.613443 | 4 |
| 7 | pi+ | 0.8549 | 18.85 | 1.296 | 53.79 | 1.164 | 15 | 0.292535 | 5 |
| 8 | proton+ | 0.8759 | 18.82 | 1.301 | 53.65 | 1.111 | 15 | 0.339296 | 5 |
| -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- | -------- |

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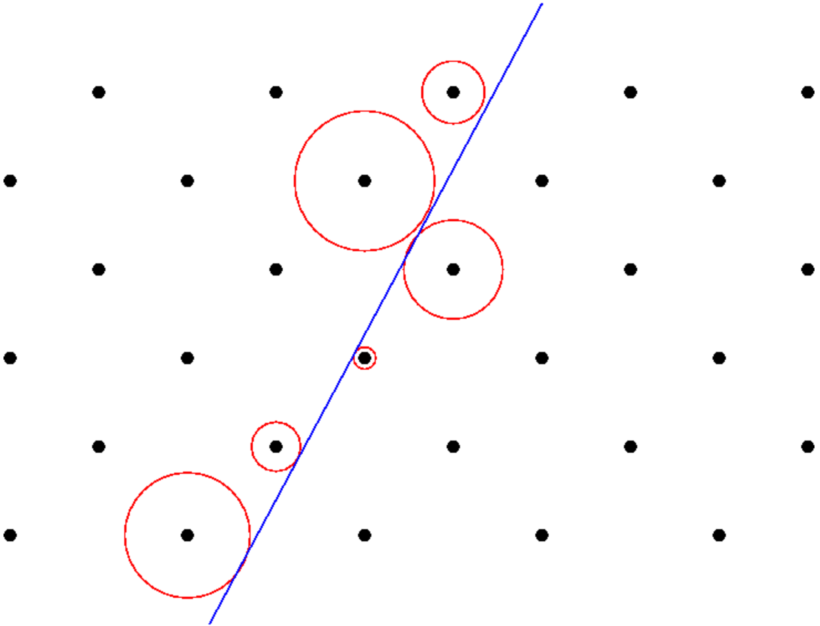
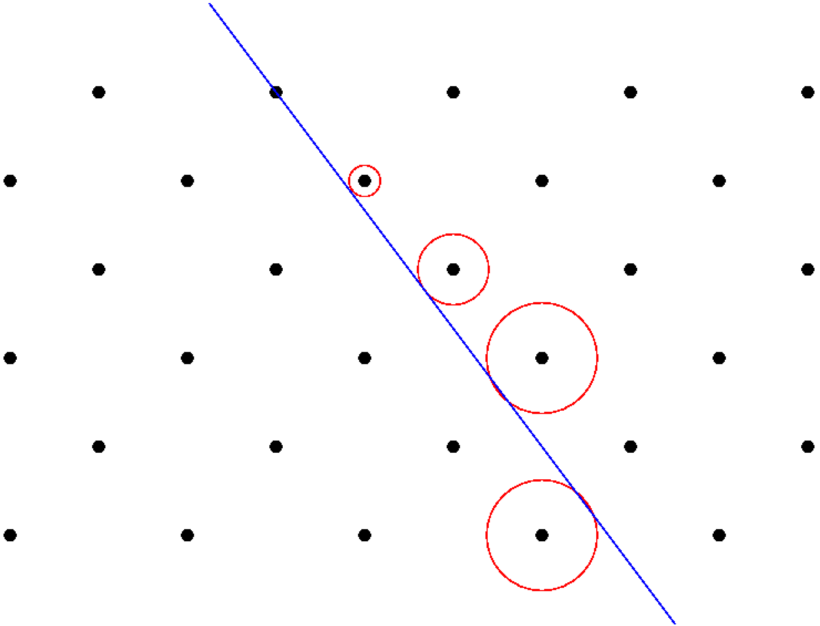
# Charged Particle Tracking

Part of reconstruction of events, real or simulated

- assigning "hits" to particles: track finding
- extracting physical properties from hit patterns: track fitting
  - drift chambers measure time of arrival of electrons from ionization of gas by particles
  - time $\Rightarrow$ distance-from-wire measurement
  - find best track parameters: minimize chi-squared





# Complications

- real problem is in 3-D
- particles bend in magnetic field
- if field non-uniform, no analytic representation of trajectory
  - solve partial differential equation numerically
  - trace trajectory in small steps, of order cm at a time (expensive)
  - iterate process to minimize chi-squared

# Some Rough Numbers

- raw data rate: 20 k events/s or 300 MB/s
- computing time per core per event: 0.13 s
- computing time to create simulated event: 0.07 s
- planning 10 k cores for Hall D
- expect to write 8 PB/y to magnetic tape

# Amplitude Analysis

- detected: set of final state particles
- same set can be reached by more than one set of intermediate states/particles
- each scenario represented by a complex amplitude
- probabilities obtained by the modulus squared of the sum of amplitudes
- fit for parameters of amplitudes to reproduce observed probabilities
- in principle:
  1. for each event, calculate probability density (expensive)
  2. multiply probabilities for all events
  3. adjust amplitude parameters
  4. iterate