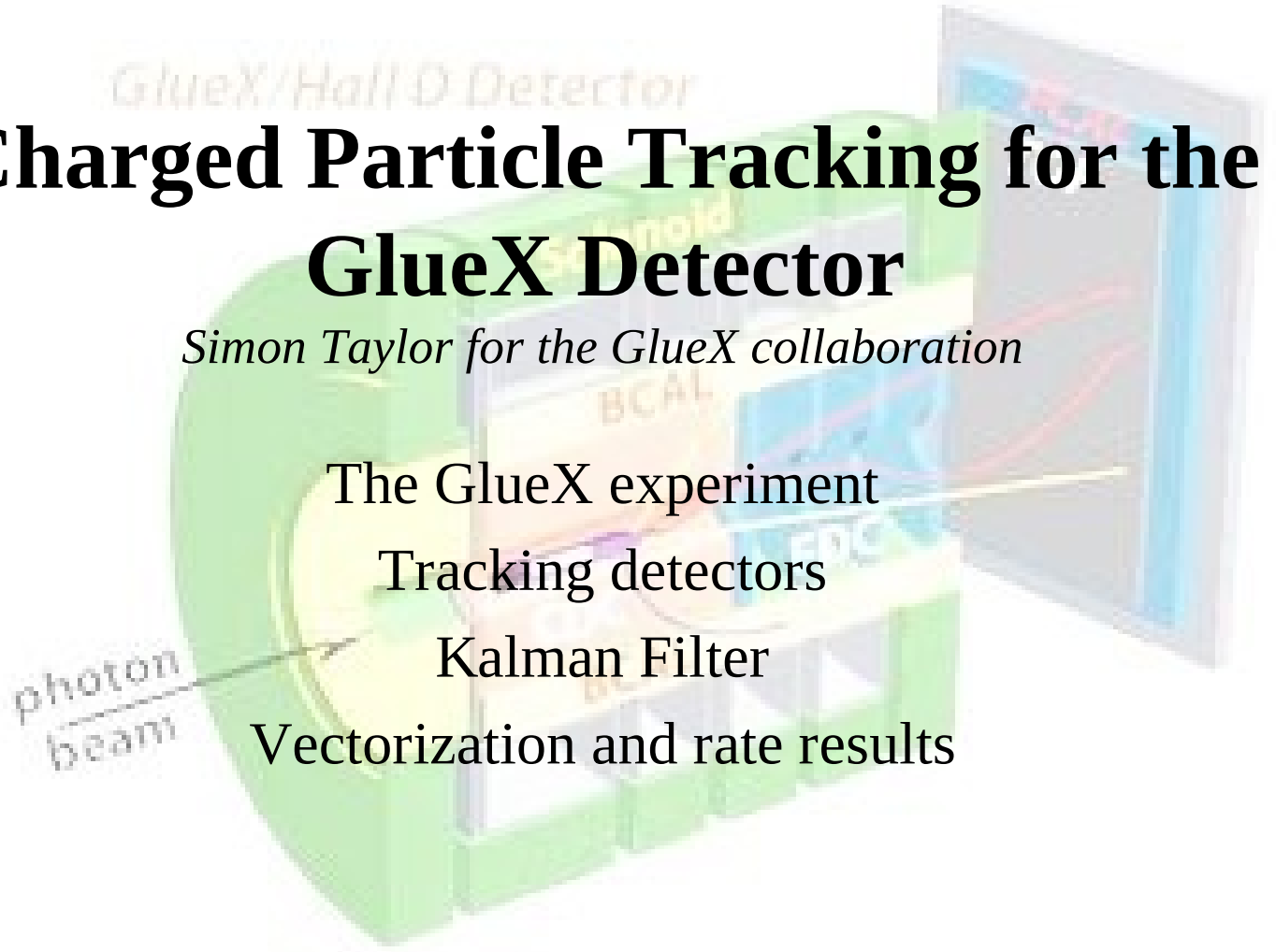
# Charged Particle Tracking for the GlueX Detector

*Simon Taylor for the GlueX collaboration*




The GlueX experiment

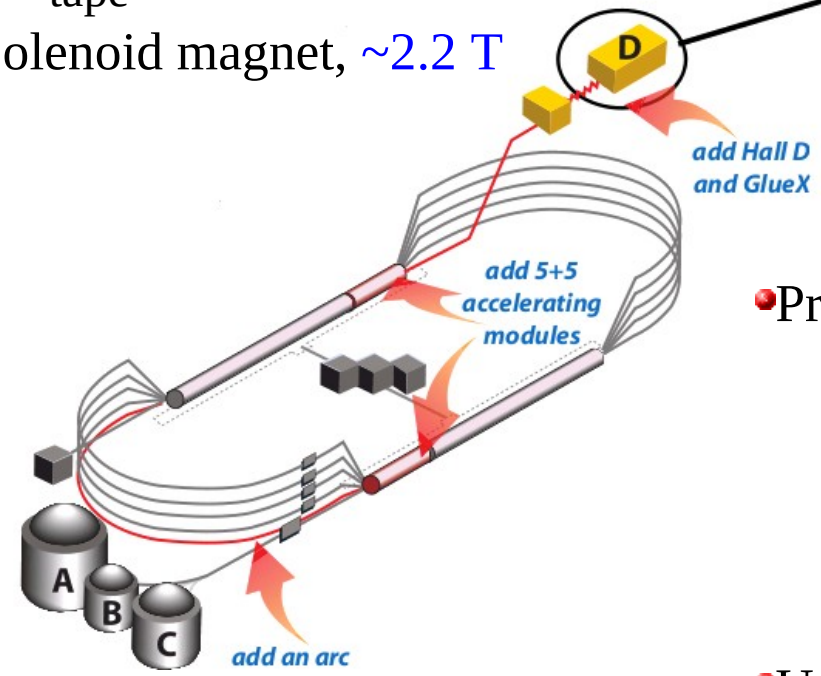
Tracking detectors

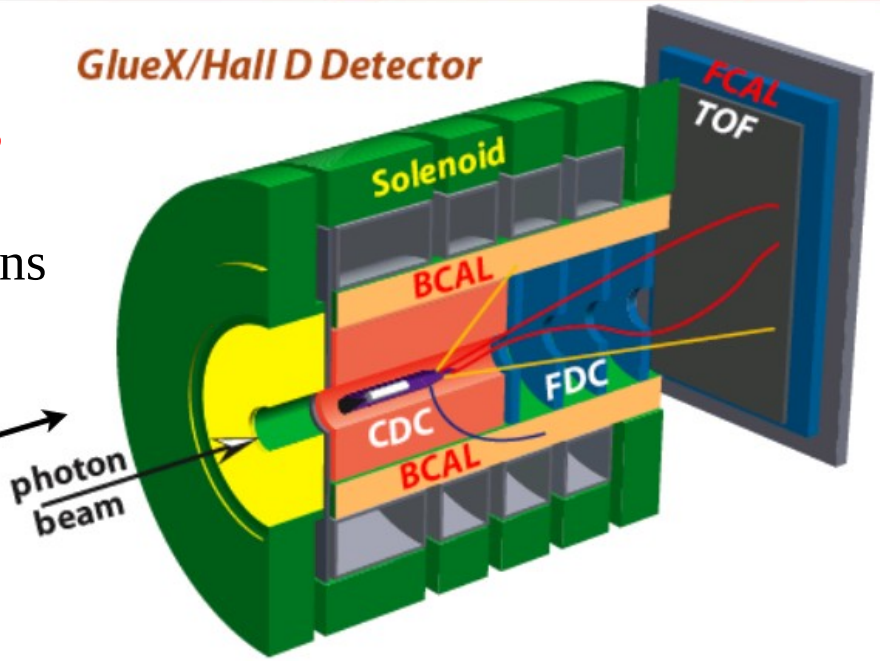
Kalman Filter

Vectorization and rate results

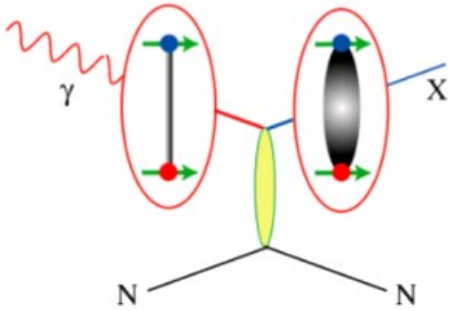
# The GlueX experiment

- Use 9 GeV polarized photons on a proton target to produce hybrid mesons
  - Use 12 GeV electrons and a diamond radiator to produce 9 GeV polarized photons
    - $10^7$ – $10^8$ γ/s on target
    - 300 MB/s data rate, 20 KHz event rate to tape
  - Solenoid magnet, ~2.2 T



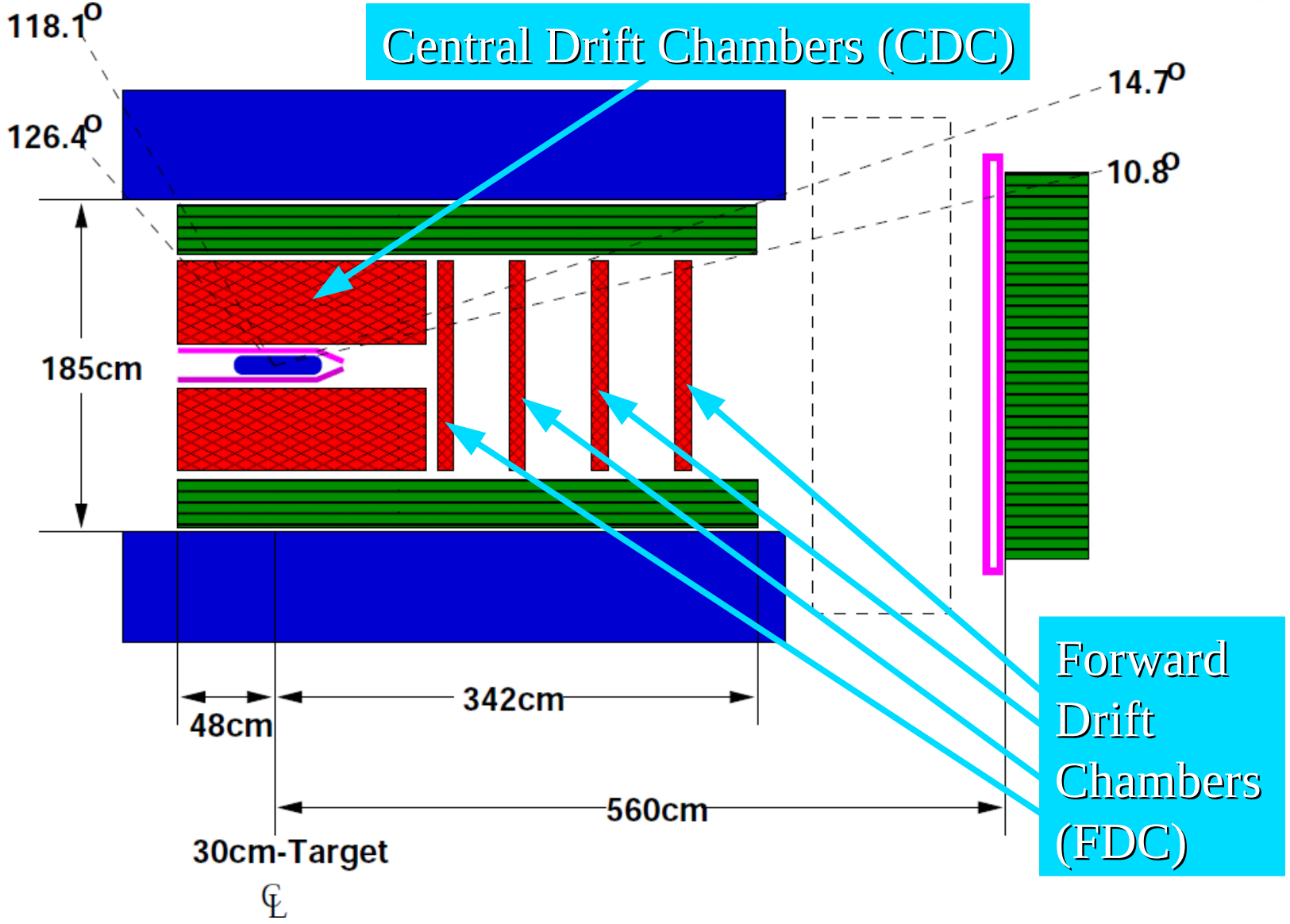




- Produce hybrid mesons with exotic $J^{PC}$:

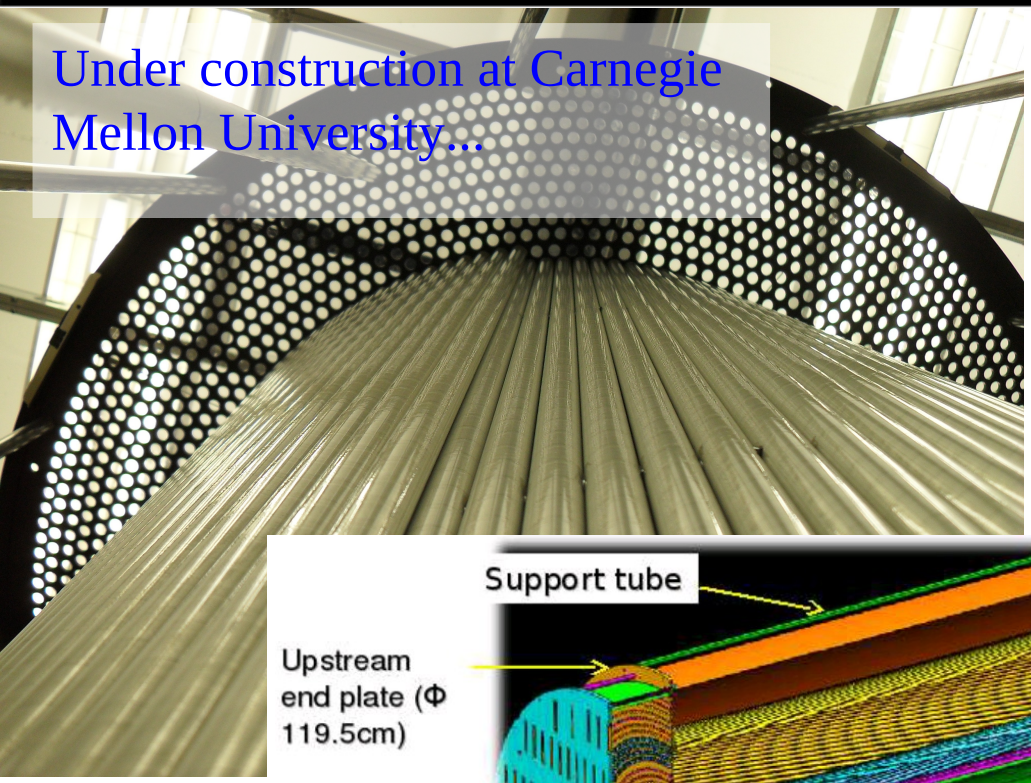



- Use "amplitude analysis" to distinguish $J^{PC}$

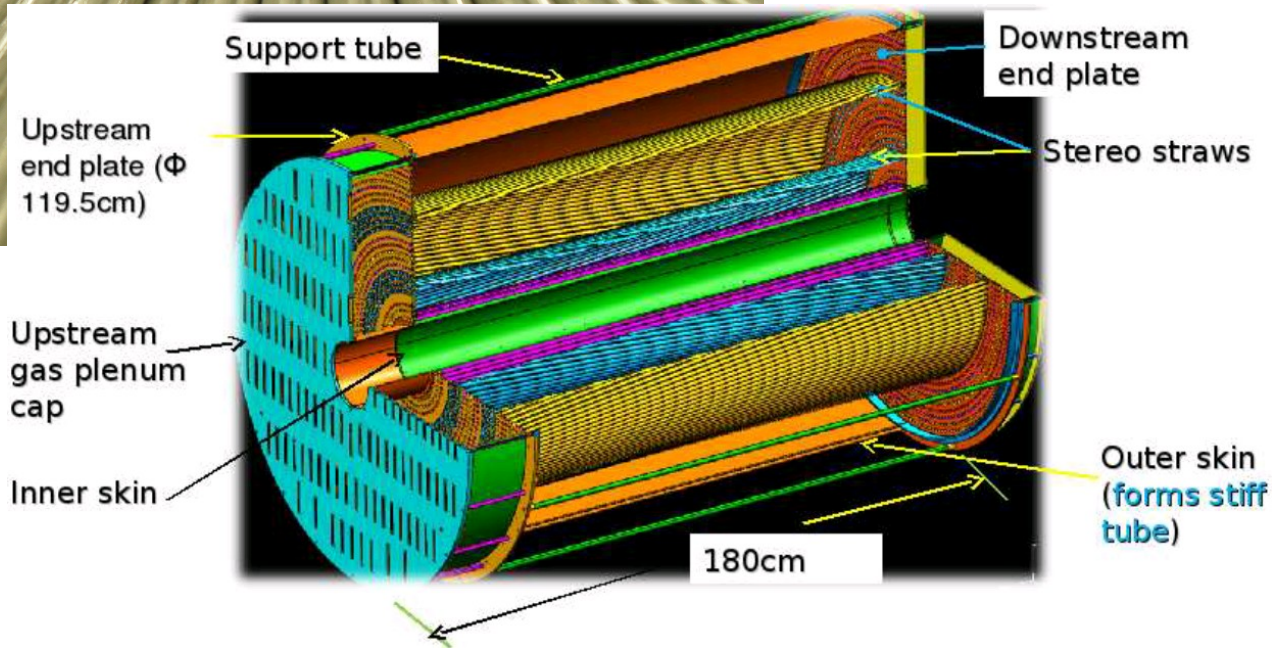
# The GlueX detector



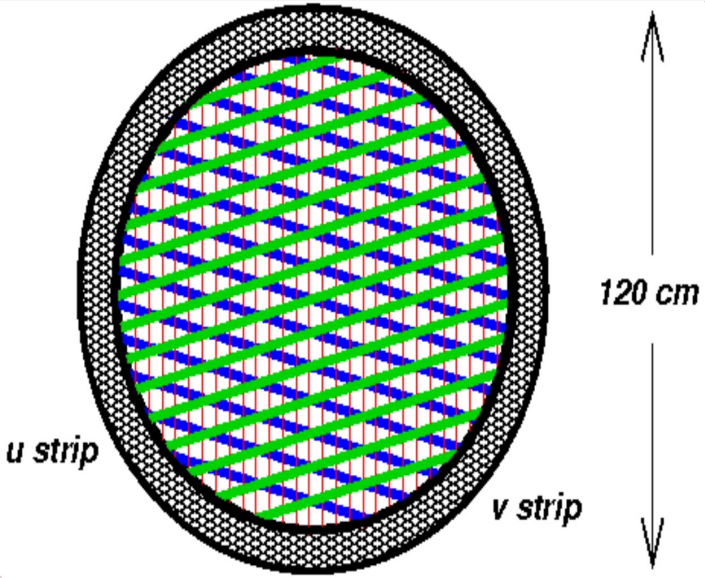
# The Central Drift Chambers

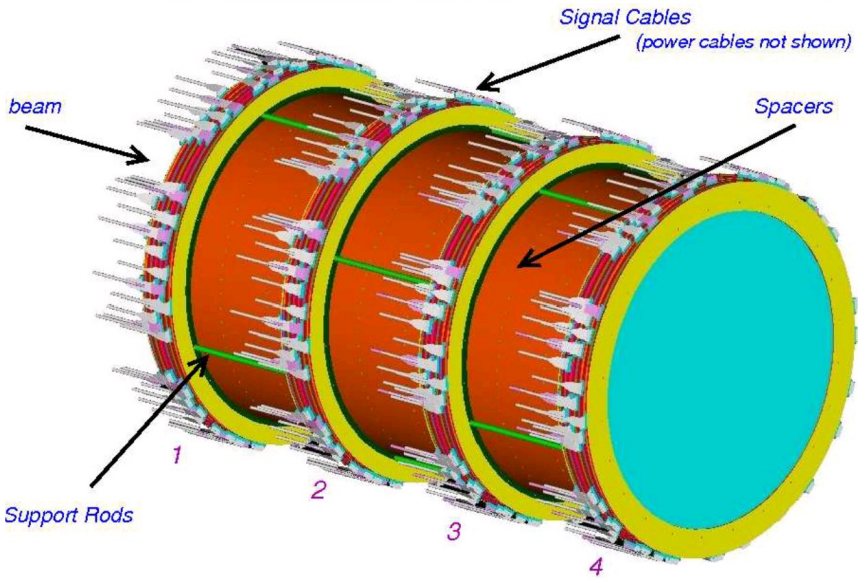



- 3522 straw tubes
- Straw diameter=1.6 cm
- Straw length=150 cm
- 28 Axial & stereo layers
- Resolution:
  - $\sigma_{drift}$ = 150 μm, $\sigma_z$ = 1.5 mm
- dE/dx for π, p identification

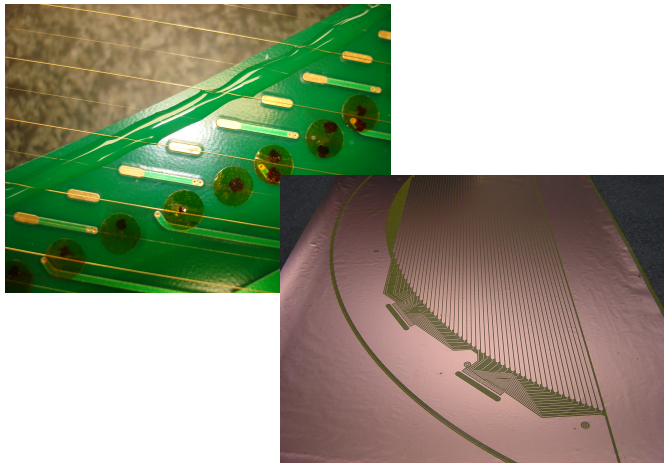


# The Forward Drift Chambers



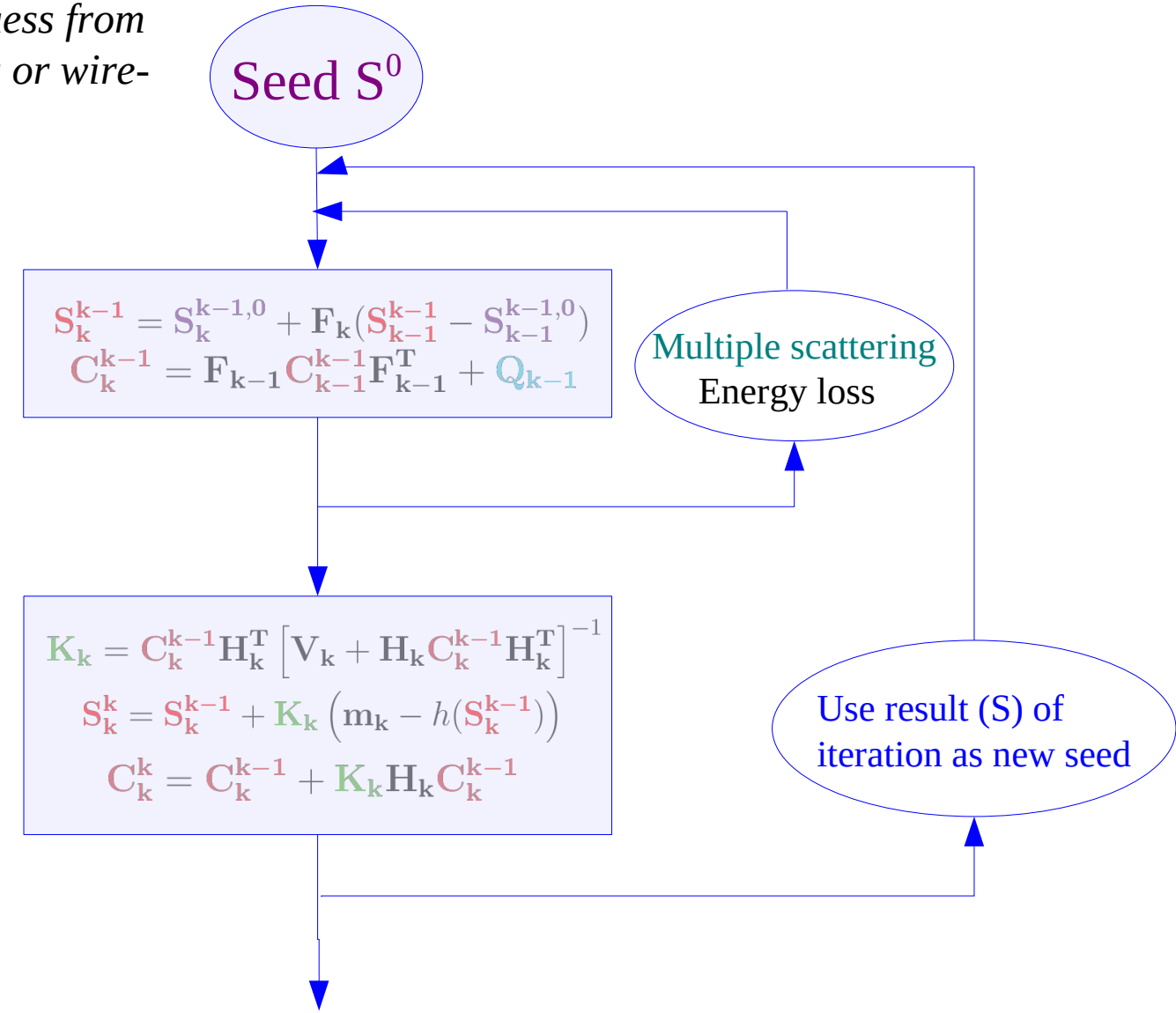




- Cathode strip chambers: 4 packages of six cathode-anode-cathode sandwiches
  - 2304 anode wires, 10 mm wire pitch
  - 10368 cathode strips, 5 mm strip pitch
  - Measure coordinate along wire + transverse to wire (drift time)
    - Resolution: $\sigma_{x,y} \sim 200\mu m$



# Kalman Filter Algorithm

*Start with guess from track finding or wire-based stages*




*Propagate state S and covariance C through magnetic field*

*Use measurements to update state vector*

# Parallelization

- Large event rates → need to find ways to speed up reconstruction
  - *Reconstruction code is fully multi-threaded*

- Modern CPUs have special registers that support Single Instruction, Multiple Data operations ("vectorization")
  - Operations on 4 ints, 4 floats, or 2 doubles at a time can be done in parallel
  - "Streaming SIMD Extensions"
- SSE2 instructions
  - ADDPD | A1 | A0 | + | B1 | B0 | → | A1+B1 | A0+B0 |
  - SUBPD | A1 | A0 | − | B1 | B0 | → | A1−B1 | A0−B0 |
  - MULPD | A1 | A0 | * | B1 | B0 | → | A1*B1 | A0*B0 |
- SSE3 instructions
  - HADDPD = horizontal add | A1 | A0 | ⊕ | B1 | B0 | → | B0+B1 | A0+A1 |

*Matrix and 3-vector operations have been "SIMD-ized" in code...*

# Reconstruction Rates

- Generated 50000 events → simulation → smearing → reconstruction
  - Track fitting with mass hypotheses:
    - $\{\pi^-\}$ for negative particles,
    - $\{\pi^+, \text{proton}\}$ for positive particles
- 4 threads on 2.8 GHz Nehalem, 64-bit OS

| Topology | Kalman(Hz) | KalmanSIMD(Hz) |
|---|---|---|
| $\pi^-$ (0.1-3.1 GeV/c, 1-121°) | 127.4 | 174.2 |
| $\pi^+$ (0.1-3.1 GeV/c, 1-121°) | 81.8 | 113.9 |
| p (0.1-3.1 GeV/c, 1-121°) | 93.2 | 128.5 |
| $p\rho$ | 47.9 | 62.5 |
| $n\pi^+\pi^+\pi^-$ | 35.5 | 46.3 |
| $pb_1{}^+\pi^-$ | 18.5 | 24.6 |

*A speed-up of 30-40% is possible, depending on event topology...*

# Summary

- GlueX: new apparatus under construction at JLab
  - Solenoidal field
  - Tracking in central region (CDC) and forward region (FDC)
- Reconstruction code designed to take advantage of parallel computation
  - Multiple threads
  - Vectorization of matrix and 3-vector operations with SIMD can speed up code significantly