Gaps for Future Experimental Program

Future Experimental Program

- Large scale experiments
  - MOLLER – Parity Violating Electron Scattering
  - SoLID – High luminosity open detector
- Other experiments
  - TDIS – Tagged Deep Inelastic Scattering – SAMPA readout
  - NPS – Neutral Particle Spectrometer

Simulation

- Gaps in geant4
- Collaboration/EIC

Advancing Readout and Analysis

- Grand Challenge, EIC, LDRD

Moller experiment

MOLLER experiment (currently CD0) – Hall A

Parity violating Moller electron scattering at 11 GeV.

Standard model test – weak charge of electron.

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$A_{PV} \sim 35\text{x}10^{-9}$ measure to ~2%

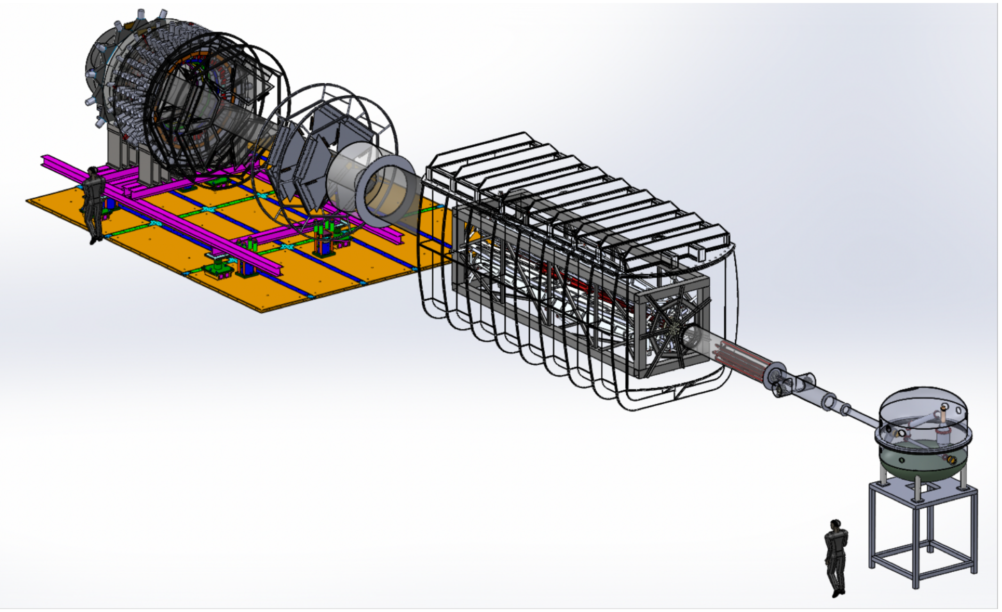
Need ~$3\text{x}10^{18}$ scattered electrons

~ 1 year of solid beam (~3 year run)

Beam helicity flips at ~ 2 kHz.

Detectors operate in integration mode,

readout at helicity flip rate.



Beam properties (energy, position, angle, size) can correlate with helicity -> false *A*

These properties deliberately tweaked (dithered) to measure correlations.

Highly segmented detector + beam instrumentation readout at helicity flip rate.

Moller experiment DAQ

DAQ:

500 channels – 250 detector, 250 beamline,

Integrating ADCs, @ 2 kHz

~118 Mbyte/sec – 425 GB/hour – 4PB total

Data rate predictable once experiment/DAQ design finalized.

Qweak was 50 channels
@ 1 kHz
225 process slots x 7 years

Rapid Online Analysis:

Feedback on beam quality and dithering

Continuous data quality checks

~50-100 CPUs

Q: Is that CPUs or cores?

Good question!
Analysis is simple, but IO intensive.

Analysis:

Builds on experience from Qweak, PREX and other parity experiments

ROOT file size ~ 5X raw data size – Live on disk or available on tape?

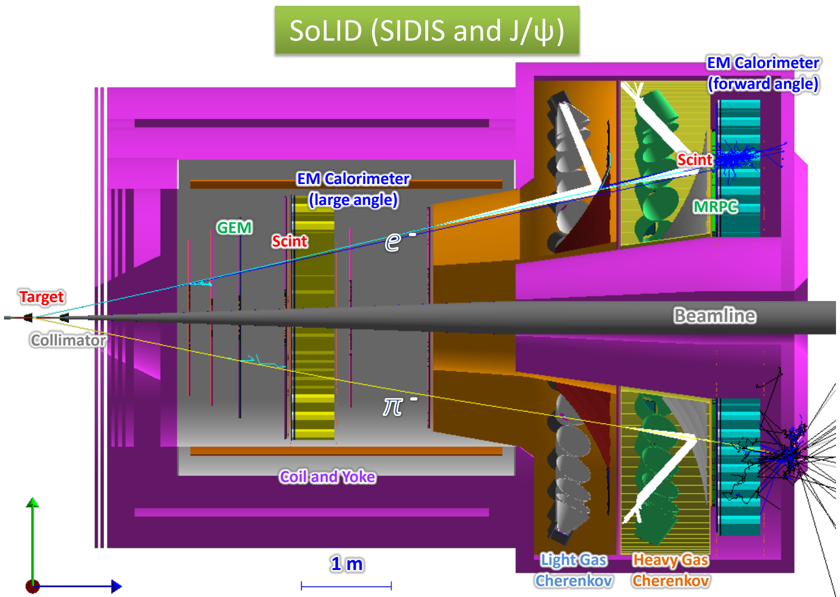
Collaboration looking at smarter ways to do analysis.

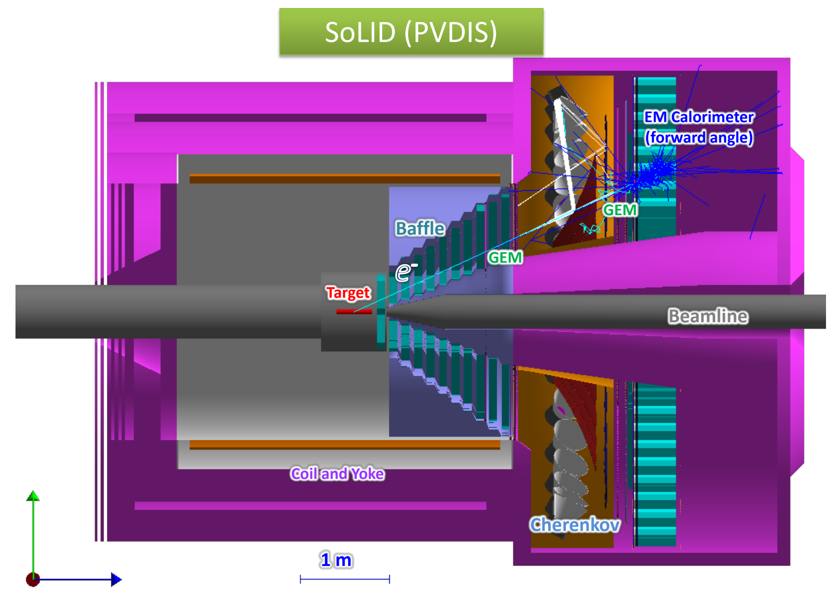
(Otherwise 2*(500/50)*(2000/1000) = 40 times more computing than Qweak)

SoLID – Solenoidal Large Intensity Device

SoLID – Multi configuration 2π forward detector (pre Pre-R&D)

CLEO Solenoid, GEM (165K channel), Gas Cherenkov, Shower, MRPC, Scintillator





Semi-Inclusive DIS - (e,e′π)

~ 100 kHz trigger

Parity Violating DIS - (e,e′)

~ 15 kHz trigger × 30

SoLID DAQ – PreCDR assumptions

Different physical configurations come with different DAQ configurations:

Parity Mode (PVDIS):

- Segment into 30 (almost) independent DAQ systems.
- 0.2 GB/segment, 6GB/s total, 175 PB for experiment

SoLID running time
>= 3 years

SIDIS J/ψ Mode:

- Single DAQ – 3.2 GB/sec, 100 PB for experiment

Data Rates assume APV25 GEM readout

- APV25 likely no longer available – alternatives are higher rates
- SoLID a good candidate for full streaming
- Real time data reduction/filtering likely required

TDIS - meson structure

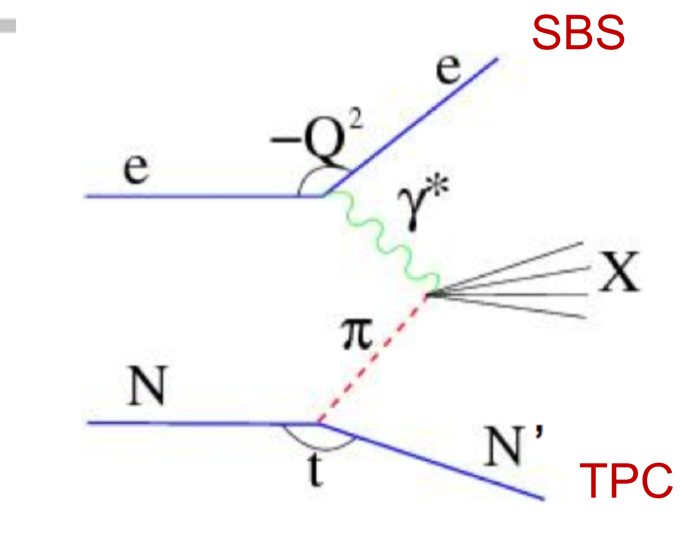
Tagged Deep Inelastic Scattering

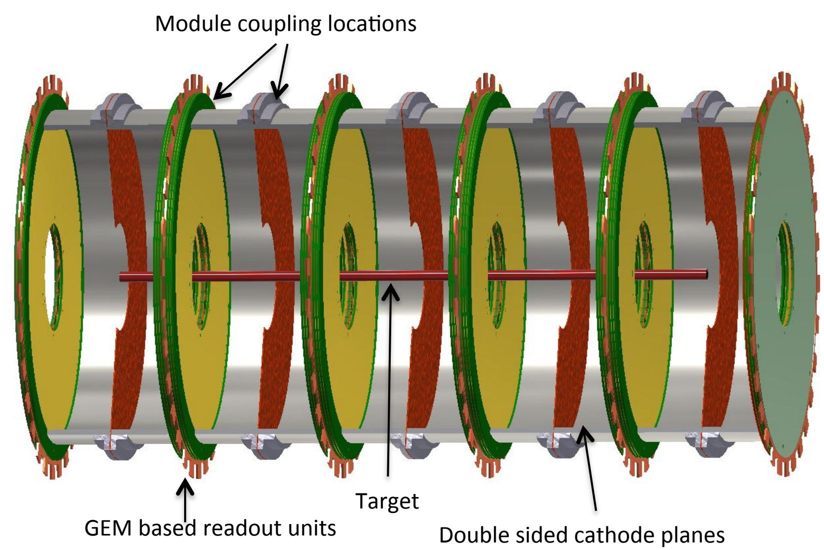
- 6 kHz SBS trigger

Proton detecting 10 cell Time Projection Chamber. Length 55cm, diameter 30cm.

Rate in TPC: ~ 1GHz, 100 MHz/cell

25000 pads – 80% occupancy in 1 μsec drift time. Tracking challenging.





TDIS – TDC with SAMPA chip

JLab creating test stand to evaluate
SAMPA chip system.

Mixed streaming/conventional DAQ

High rates from chip, but with front end
FPGA peak fitting -> 8bytes/hit

Final rate 1GB/sec (+SBS)

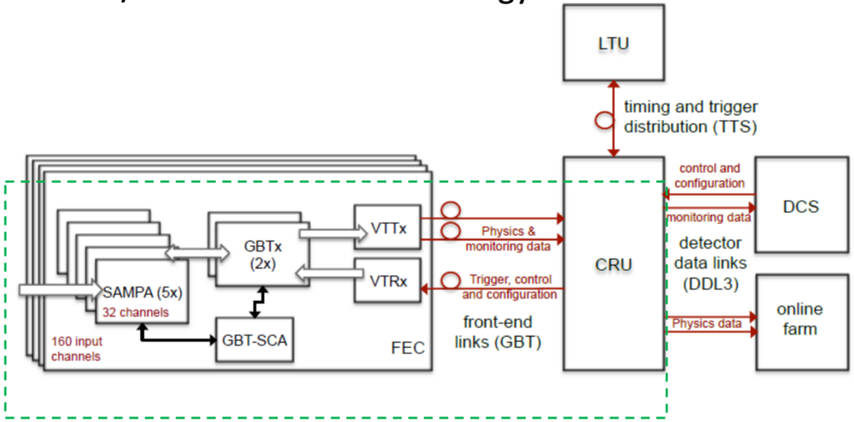
Experiment -> 1 PB

Don't need further filtering before tape,

(unless rates underestimated)

but near online reconstruction
important. (To show data is good.)

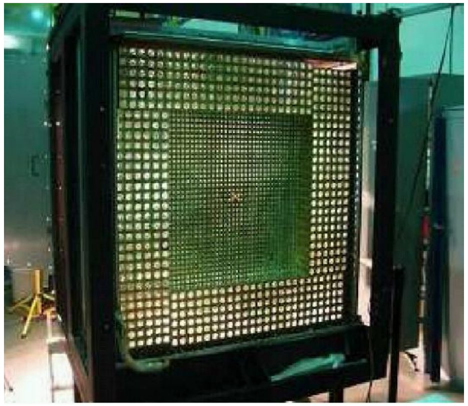
- **Fast Track test stand**– start with components of the ALICE TPC readout/control chain as technology demo.



FEC – Front End Card
CRU – Common Readout Unit
DCS – Detector Control System
LTU – Local Trigger Unit

NPS – Neutral Particle Spectrometer

New 1324 $PbWO_4/PbF_2$ block calorimeter with FADC250 readout. Used with and triggered existing Hall C magnetic spectrometer for >= 6 experiments.



Trigger rates usually < 1 kHz.

Data rate << 1GB/sec, even if full 200ns uncompressed waveform read for each block.

Calorimeter streaming readout a part of lab's "Grand Challenge".

(needed if calorimeter is the electron detector.)

Future experiments – summary

Very Approximate timeline:

NPS - 2022, TDIS – 2023

Moller – 2025, SoLID – 2028 (could be sooner interleaved with Moller)

SoLID:

Dominated by GEM readout

Tracking under high backgrounds

Partial or full streaming DAQ

TDIS:

Tracking under high backgrounds and occupancies

Similar issues as SoLID, but runs much sooner

Geant4 - Gaps

Electromagnetic production processes not well supported/validated

- RadCon prefers FLUKA or Geant3 for radiation estimates.

Event biasing

- Event biasing insufficient for shielding calculations

Polarization/spin transport

- Simulations with polarized targets or beam need to add ad-hoc spin transport
- Important for TMD program, JLab investigating how to add spin physics to LUND model as follow-up of LDRD work - not an easy problem

Geant4 – Collaboration

JLab historically has not played much role in geant4 collaboration

JLab community now collaborating on description of low E photoproduction – both 6-GeV data and phenomenological models (like MAID)

Meson Photo-Production in GEANT4 for $E_\gamma = 0.225 - 3.0$ GeV Using the $\gamma + p \rightarrow p + \pi^0$ reaction

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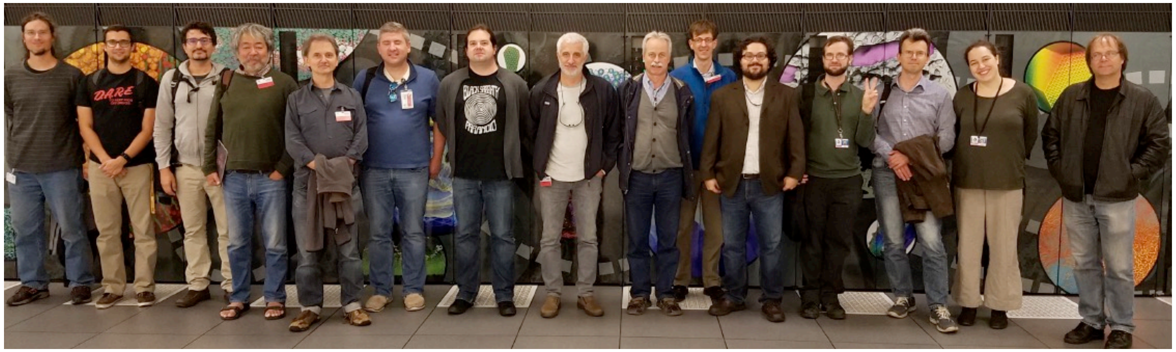
(Dated: November 24, 2018)

Background: The study of nuclear resonances in the intermediate energy regime requires accurate modeling of the experimental physics background. A systematic study of the cross sections implemented in the Geant4 toolkit is still lacking to adequately assess the treatment of meson photo-production.

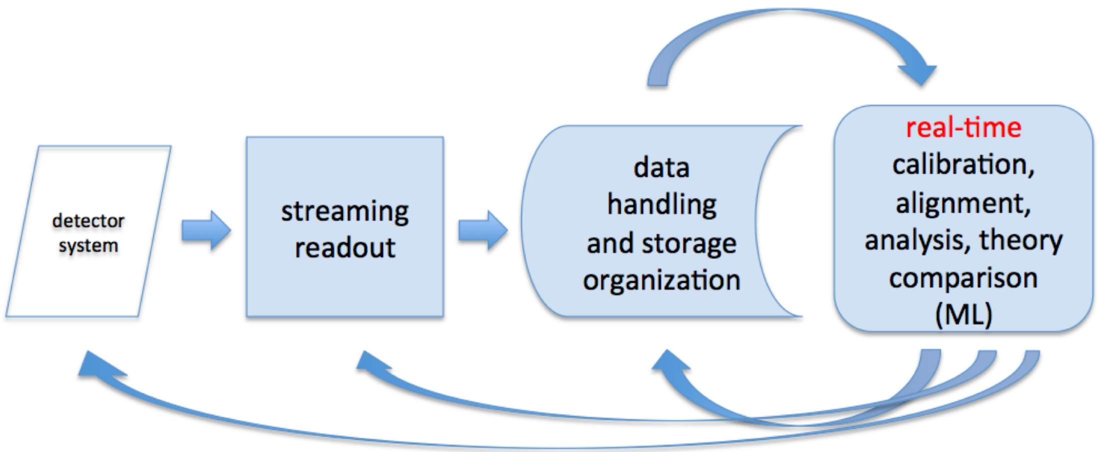
Purpose: The purpose of this study is to compare experimental data and theoretical models implemented in version 9.6.p02 of the GEANT4 Monte Carlo simulation toolkit for the total and differential cross sections of pion photo-production.

Likely to much increase with EIC effort ramp-up. JLab part of the EIC Software Consortium



"Grand Challenge"

Develop proof of concept integrated whole-experiment model of data handling and analysis for late state 12-GeV analysis and EIC.



Organize existing efforts and LDRD proposals under this idea.

EIC/Late stage 12 GeV activities

SAMPA test stand for TDIS (DAQ Group)

Calorimeter streaming readout (with INFN-Genova & CUA)

Crateless readout, advance FPGA use to integrate diverse front ends (Fast Electronics Group)

Lab Directed R&D

- Modernize JANA framework – software trigger, use with JLEIC (2019-LDRD-8)
- Algorithms and techniques for streaming readout (2019-LDRD-10)
- Universal Monte Carlo Event Generator via Machine Learning (2019-LDRD-13)

EIC activities

- Lab plays major role in EIC Software Consortium (ESC)
  - (ANL, BNL, FNAL, INFN Trieste, JLab, LUND, SLAC, W&M)
  - See Diefenthaler HEP Software Foundation talk for more on ESC
- Lab scientist co-convenor of EIC User Group Software Working Group
- JLab Common Environment (GEMC/geant4, JLEIC geometry) packaged into containers