eRD17: BeAGLE

A Tool to Refine Detector Requirements for eA

M.D. Baker*
MDBPADS LLC

E.C. Aschenauer, J.H. Lee, Z. Tu*
Brookhaven National Laboratory

W. Chang.
Central China Normal University (+BNL)

L. Zheng
China University of Geosciences
(Wuhan)

31-January-2020

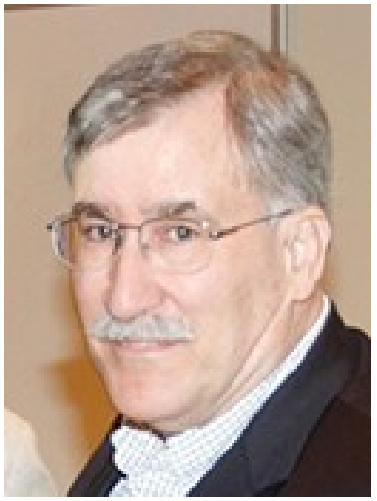
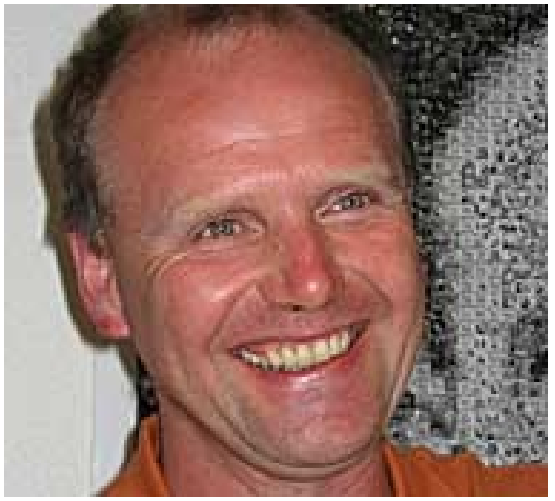
***-co-PIs**
contact person: mdbaker@mdbpads.com, mdbaker@bnl.gov, mdbaker@jlab.org

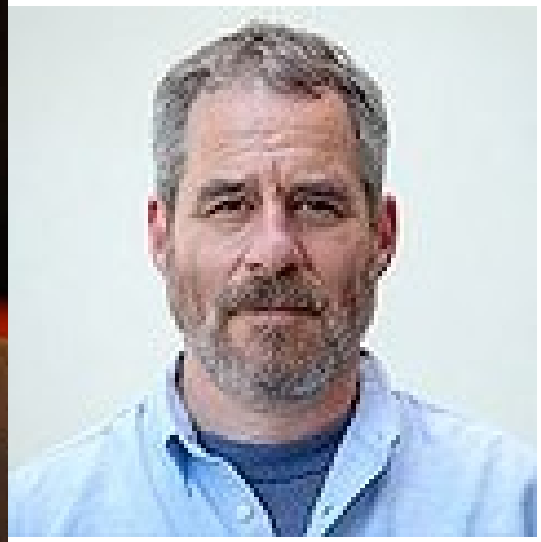
Outline

- The transition
  - BeAGLE's critical role during the next year or two
- "A week in the life"
  - Nimble and strategic support of key studies
- Project accomplishments and plans
- Conclusion

Thanks for all of the support since FY2015!



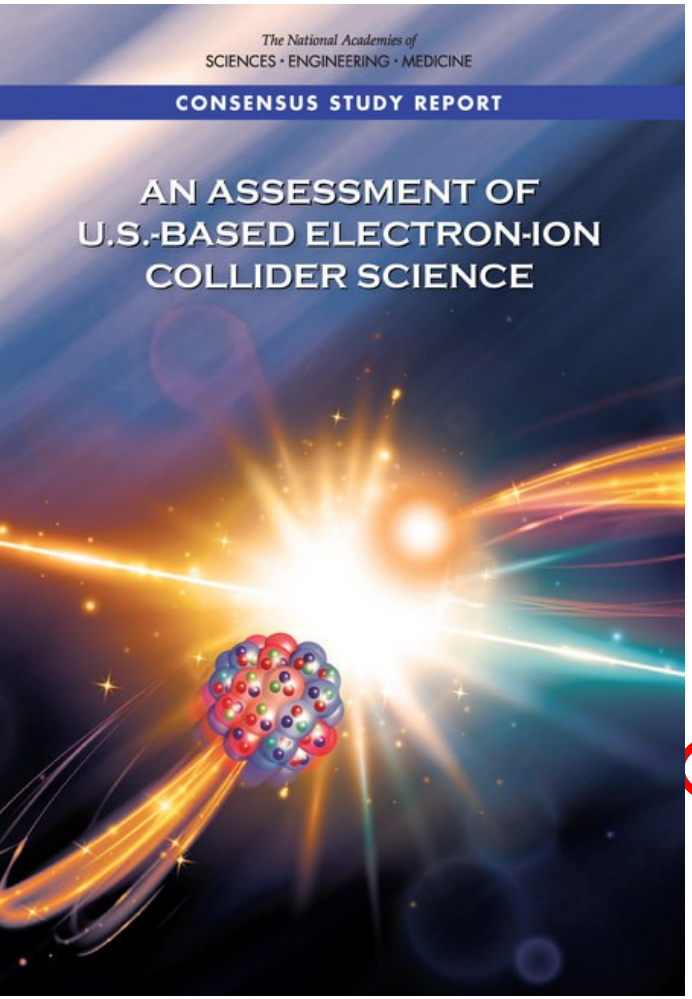





eRD17 has had a large impact on the detector/IR design especially for e+A.

NAS Report – R&D requirements chapter

Chapter 4: Accelerator Science, Technology, and Detectors Needed for a U.S.-Based Electron-Ion Collider

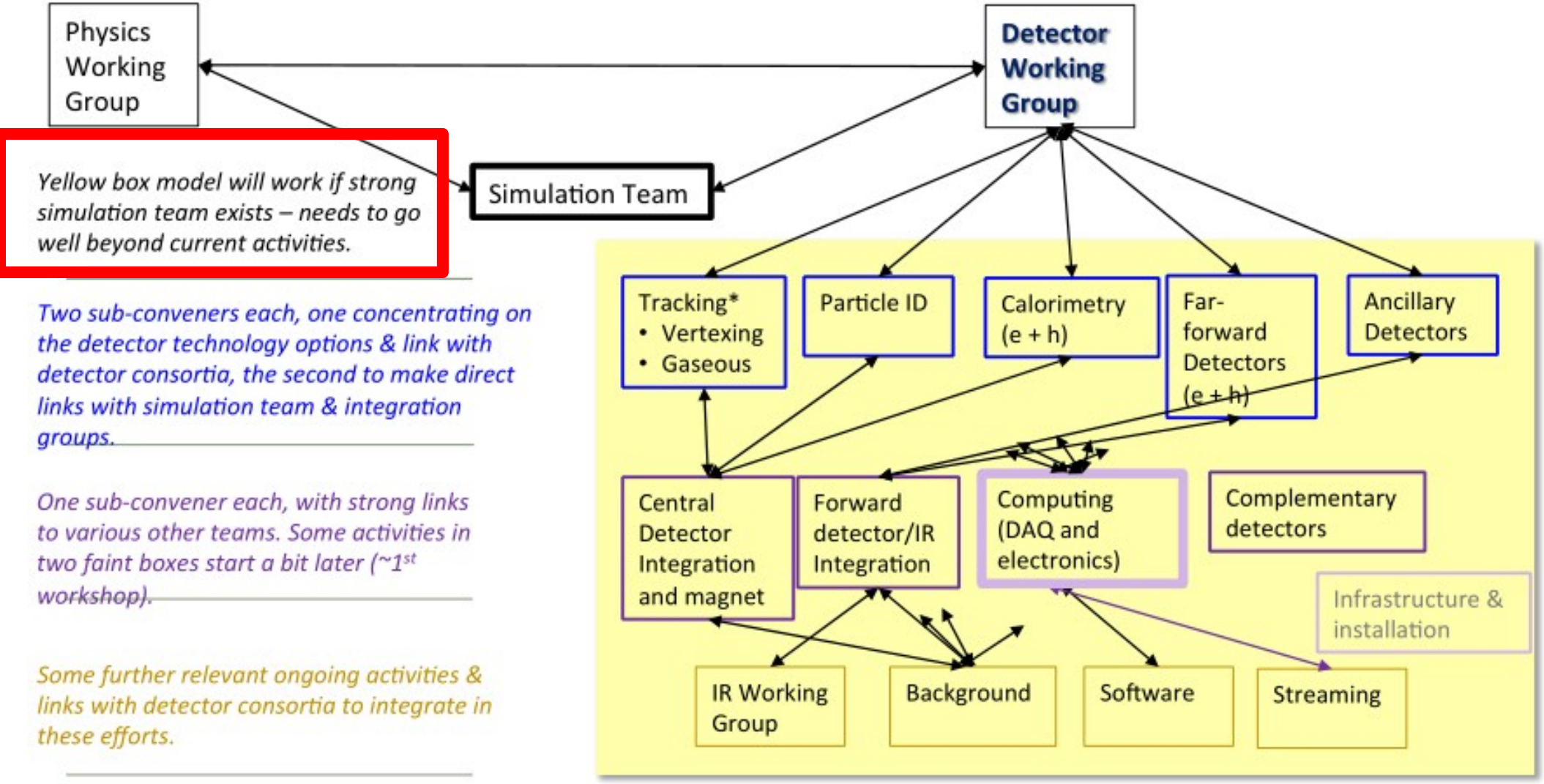


An EIC must enable the following:

- Extensive center-of-mass energy range, from ~20-~100 GeV, upgradable to ~140 GeV, to map the transition in nuclear properties from a dilute gas of quarks and gluons to saturated gluonic matter.
- Ion beams from deuterons to the heaviest stable nuclei.
- Luminosity on the order of 100 to 1,000 times higher than the earlierelectron-proton collider Hadron-Electron Ring Accelerator (HERA) at Deutsches Elektronen-Synchrotron (DESY), to allow unprecedented three-dimensional (3D) imaging of the gluon and sea quark distributions in nucleons and nuclei.
- Spin-polarized (~70 percent at a minimum) electron and proton/light-ion beams to explore the correlations of gluon and sea quark distributions with the overall nucleon spin. Polarized colliding beams have been achieved before only at HERA (with electrons and positrons only) and Relativistic Heavy Ion Collider (RHIC; with protons only).
- One or more interaction regions, which integrate the detectors into the collider and preserve the extensive kinematic coverage for measurements.

EIC Detector Working Group Organization Model

Slide from Ken Barish - yesterday



Mandatory Slide

* How much time do you envision to complete your ongoing project(s)
* What achievements are required for TDR readiness 2023

- It is a moving target as new and good questions keep being asked where improving BeAGLE is the quickest way to answer them.
  - Questions from BNL Detector/IR optimization team.
  - Anticipate questions from Yellow book process.
    - Plugged into Forward Detector/IR integration WG
    - Plugged into Diffractive/Tagging Physics WG.
- Could easily, productively fill all time between now and 2023 and then some...

The transition: You nailed it!

July 2019 Report Recommendation:

The Committee looks forward to the completion of this demanding development cycle

and a transfer of the responsibility to a laboratory or university to maintain and support the software package.

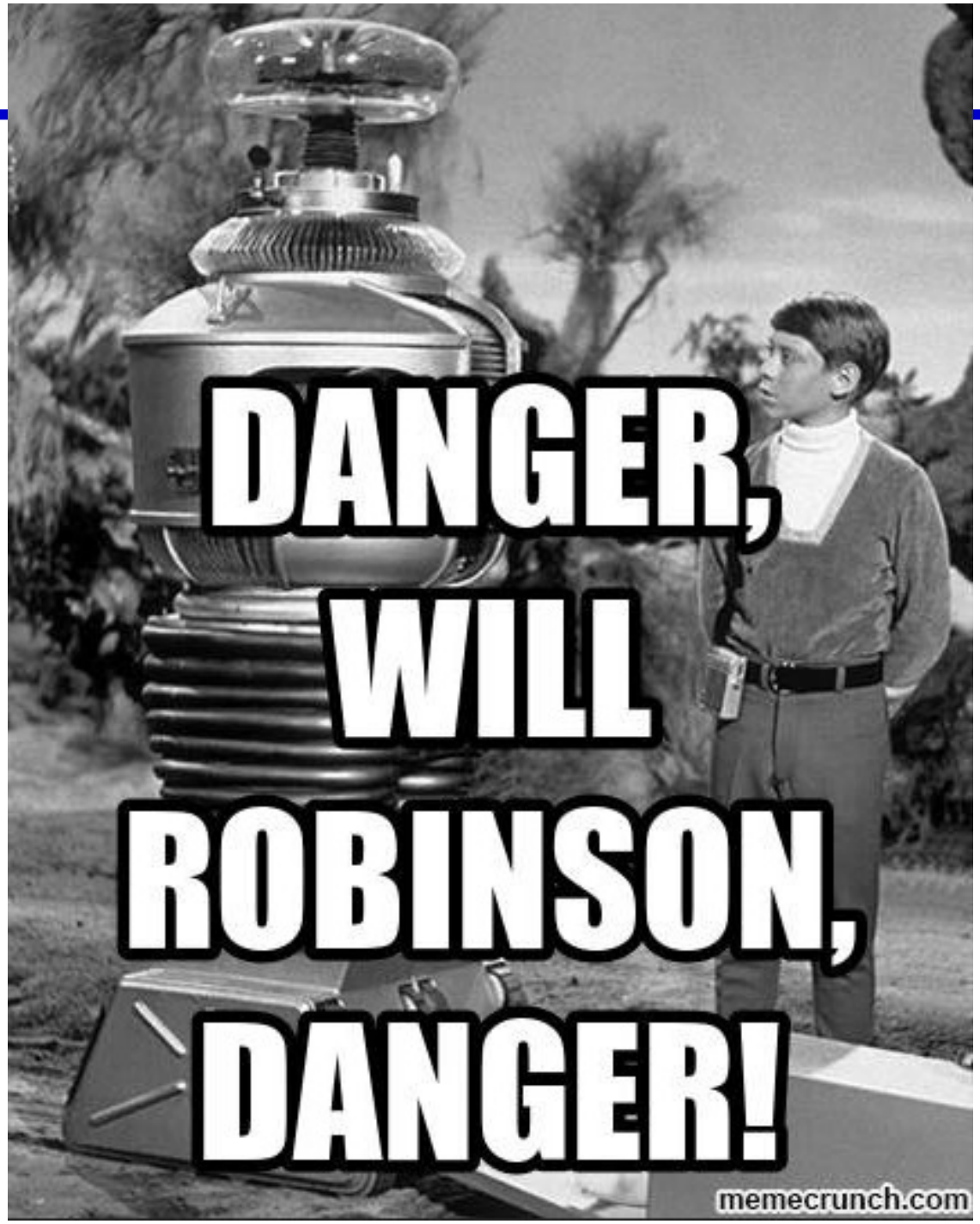
The Challenge:

The aggressive timetable for the TDR(s) and the Yellow Book process means that BeAGLE must be actively supported without a gap during the next 2-3 years (and probably for more like 5-7 years.)

In fact, it must even be further developed!

JLAB supported BeAGLE EIC work directly during FY2017-2019 @ 0.2FTE.
For FY2020 – reduced to part-year and indirect (BeAGLE for JLAB12).

BNL is in a state of … um … reorganization.


DANGER,
WILL
ROBINSON,
DANGER!
memecrunch.com

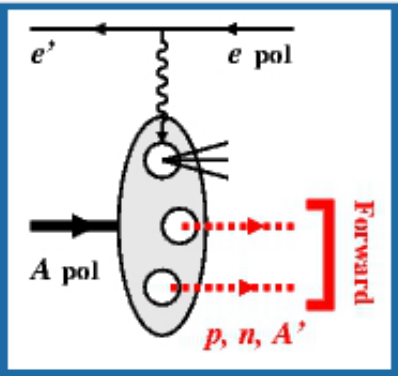
Without a fully supported BeAGLE...

...we would be flying blind.

Critical for the EIC forward detector / IR design for e+A

You are the QB! The handoff is critical!

A week in the life...



Exploring QCD with light nuclei at EIC

(and short range correlations)

21-24 January 2020
SBU Physics Building C-120
US/Eastern timezone

- Overview
- Timetable
- Contribution List
- Registration
- Participant List
- Remote Connection (via BlueJeans)
- Hotel Information
- Parking Information

The EIC will enable a novel program of high-energy electron scattering on light nuclei (deuteron D, 3He, 4He, ...) using unpolarized and polarized beams. Such measurements address fundamental questions of nuclear physics and QCD such as the short-range structure of nuclei (short-range correlations, origin of nuclear core, nonnucleonic DoF), the partonic structure of the neutron (PDFs, GPDs, TMDs), nuclear modifications of quark/gluon densities (EMC effect, antishadowing, shadowing), and coherent phenomena at small x. Detection of the nuclear breakup state with the EIC forward detectors substantially extends the physics reach (spectator tagging, coherent processes) and poses new challenges for theory and experiment. The meeting is intended to discuss the physics concepts and objectives, assess the feasibility and potential of such measurements with EIC, and plan next steps in physics and detector simulations. It brings together researchers in spin physics, nuclear QCD at large and small x, and accelerator and detector development.

Light ions (and nucleon correlations)

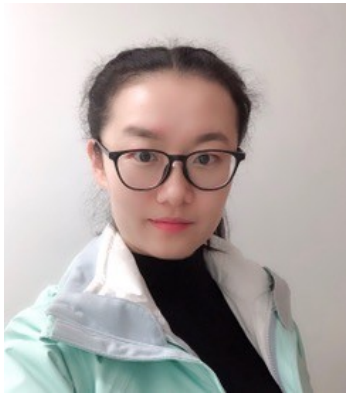
Day 2 of meeting (last Tuesday)

- 1 email from a BNL postdoc:
  - Requesting e+D & e+^{3}He in BeAGLE for IR/detector acceptance studies at BNL.
- 1 email from an ODU/JLAB postdoc:
  - Requesting access/instructions for the latest quasielastic simulations with SRCs (short-range correlations) on JLAB computers.
- Responded immediately, getting these studies underway before the meeting even ended.

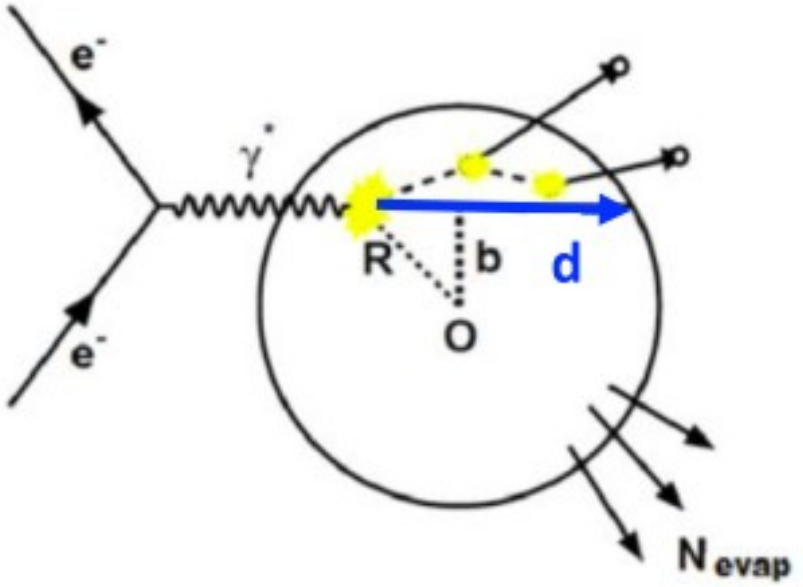
And acquired a new ToDo...

- Discovered that e+^{3}He in BeAGLE, while useful immediately, needs investigation.
- The DPMJET-F code (independent program also used by BeAGLE) has some odd behavior.
  - The program gets confused and has to start over about 80% of the time when a neutron is struck in ^{3}He, leaving a "diproton" remnant.

Geometry tagging beyond the ideal ZDC



An example –
from Wan Chang et al.,
Joint CFNS & RBRC Workshop on Physic Detector Requirements at Zero-Degree of Colliders
September 24-26, 2019



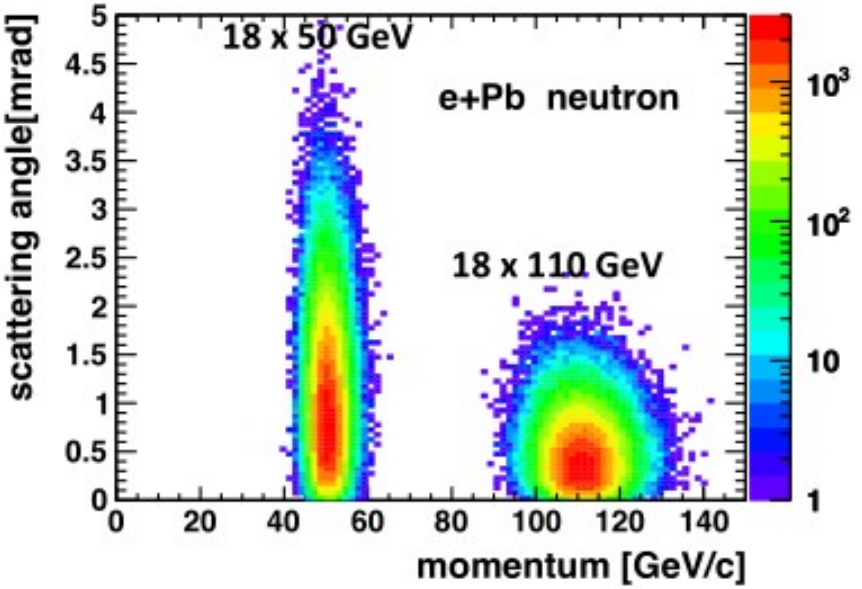
b = impact parameter

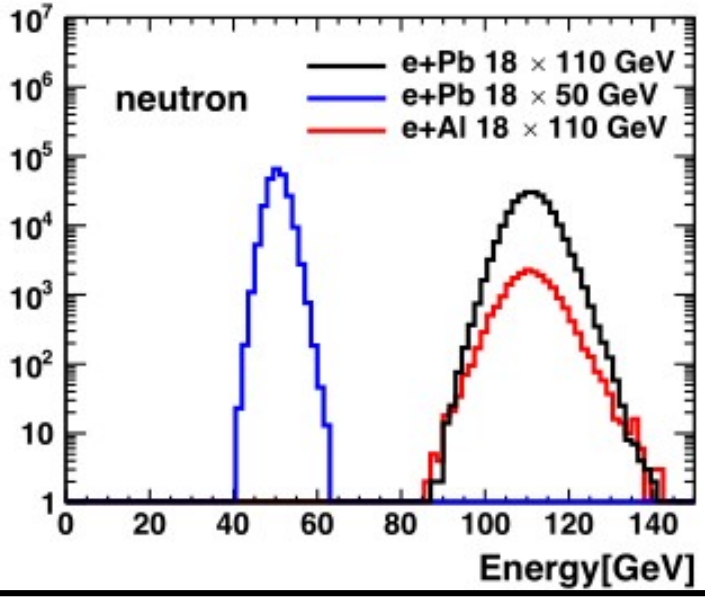
d = effective distance traveled in nucleus by the reaction products = $\int_z^{+\infty} dz\, \rho(b,z)/\rho_0$ in fm

T(b) = full nuclear thickness (normalized):
= $\int_{-\infty}^{+\infty} dz\, \rho(b,z)/\rho_0$ in fm

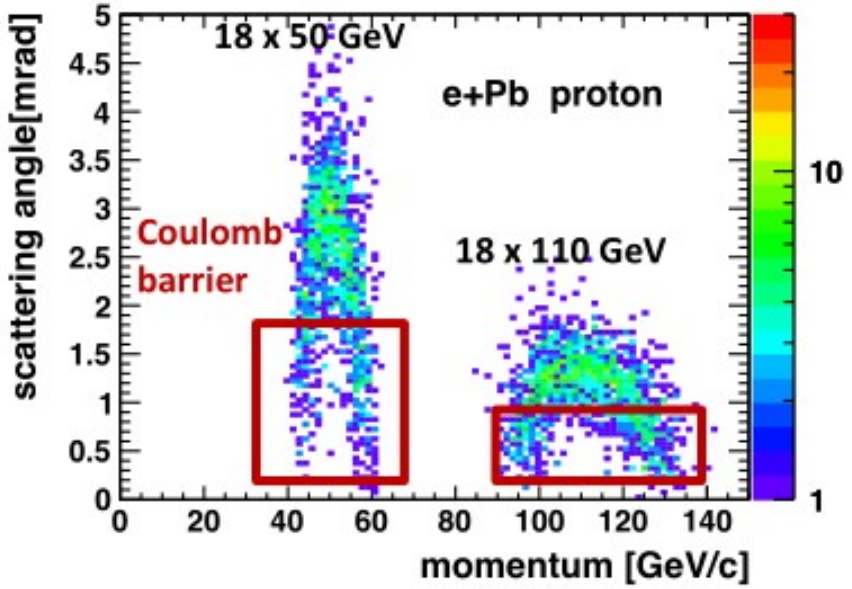
Kinematics of evaporation neutrons and protons

neutron





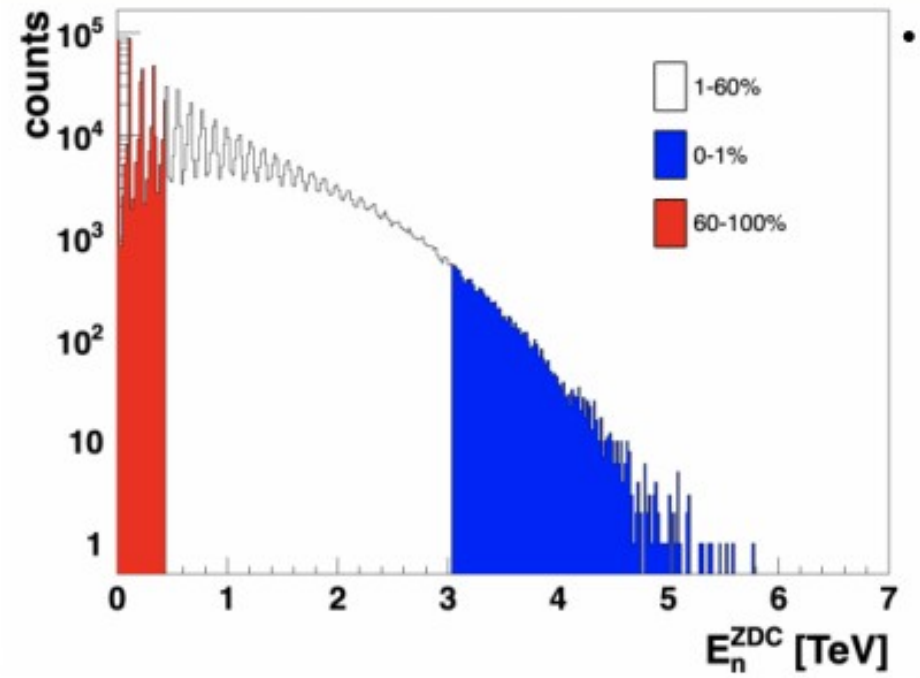
proton



- Evaporation neutrons and protons:
  → momentum (energy) is close to beam energy, scattering angle is small.
- Decreasing Beam Energy:
  → lower momentum, scattering angle is larger.
- Proton emission during evaporation process is greatly suppressed compared to that of neutrons.

- Energy doesn't depend on A.

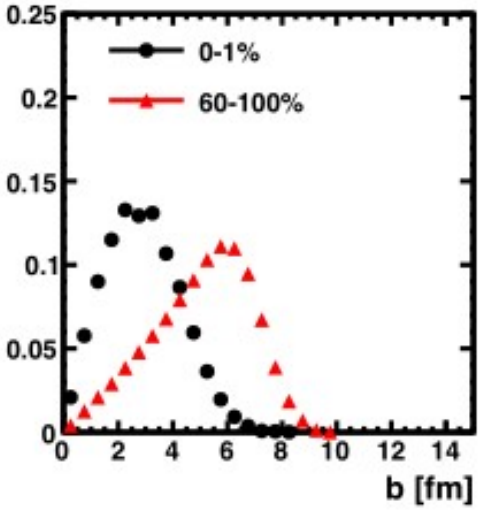
Selection of centrality for 18x110 GeV e+Pb

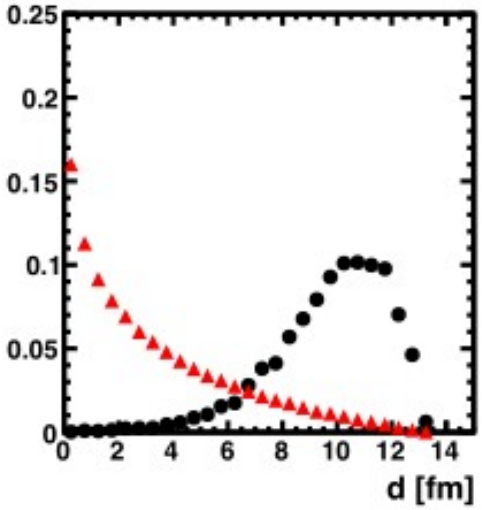


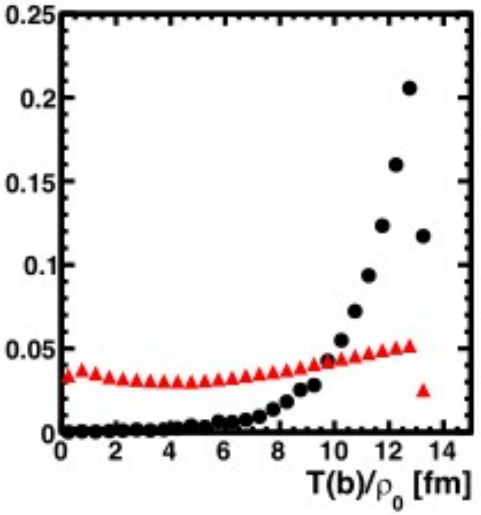
- Centrality is selected by the energy deposition. 0-1% represents top 1% highest energy deposition.

	0-1%	60-100%
E_n^{ZDC}[TeV]	>3.04	<0.42

b, d, $T(b)/\rho_0$ can be used as the probe of centrality in BeAGLE framework.



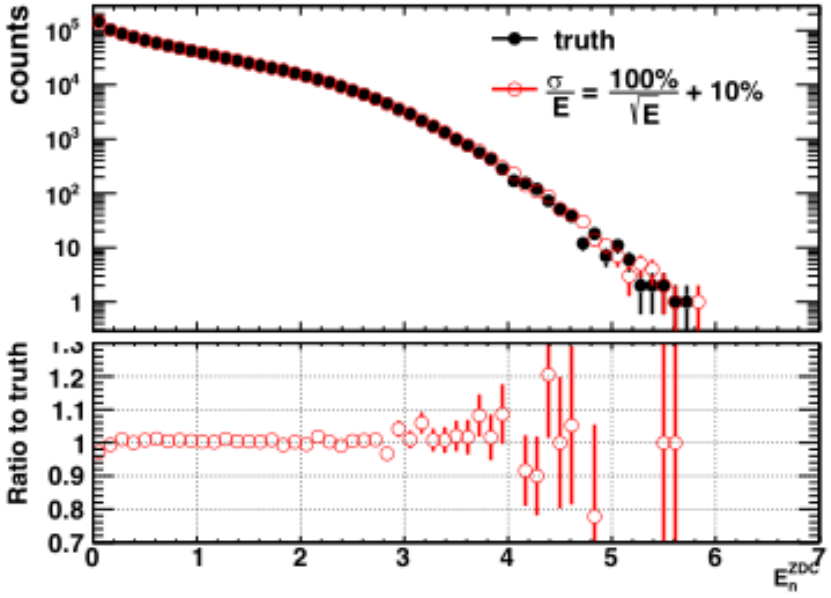


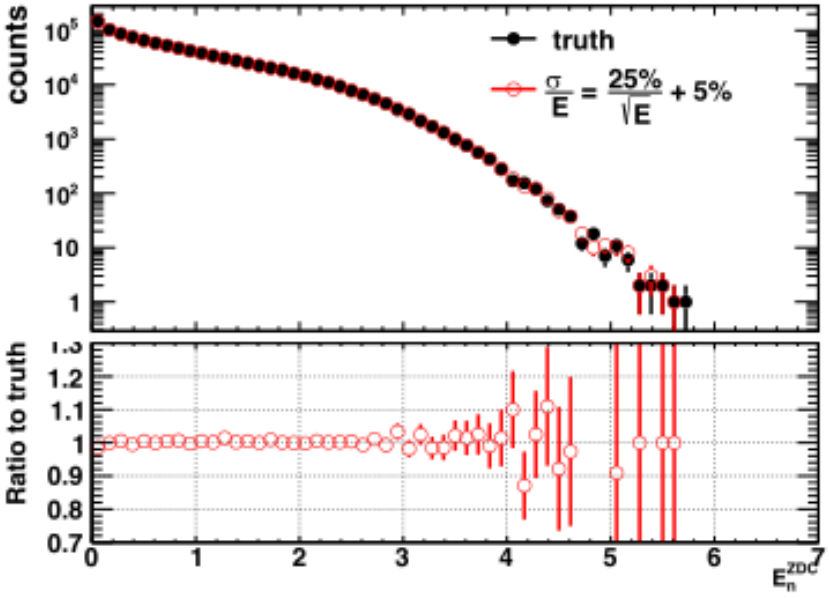


Detector smearing

Energy resolution: 1. $\frac{\sigma}{E} = \frac{100\%}{\sqrt{E}} + 10\%$ 2. $\frac{\sigma}{E} = \frac{25\%}{\sqrt{E}} + 5\%$

Smear each individual neutron by a Gaussian representing the resolution.

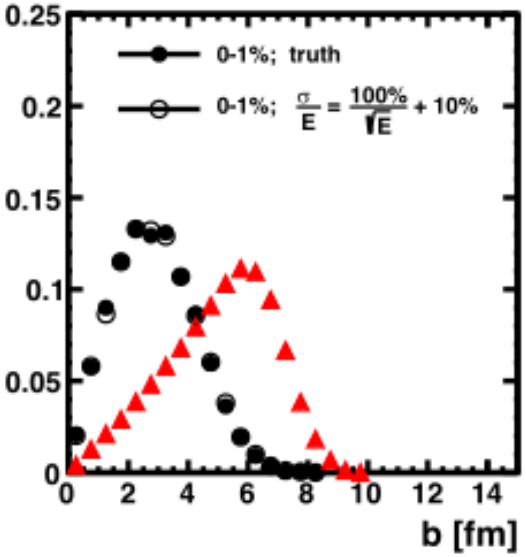


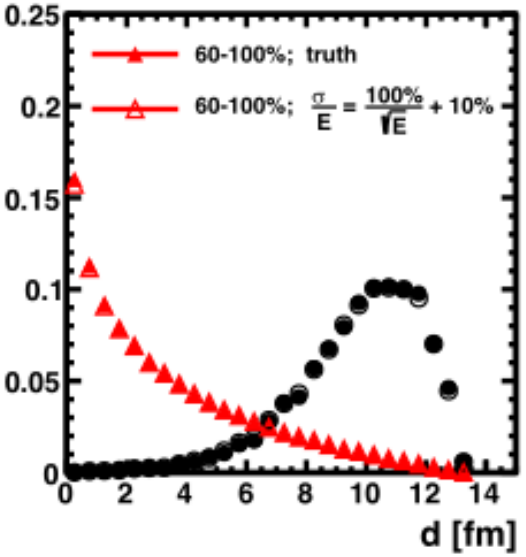


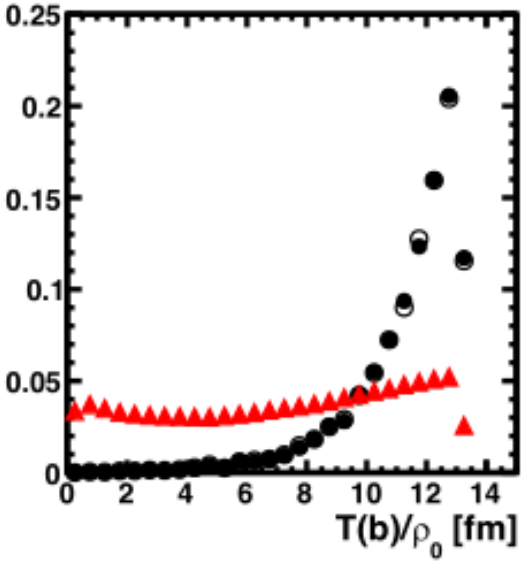
- The true distribution and the smeared one are almost identical.
- A higher resolution calorimeter is not required for this analysis.

Detector smearing

The b, d, $T(b)/\rho_0$ comparison between generated and smeared distributions in **central** and peripheral collisions.

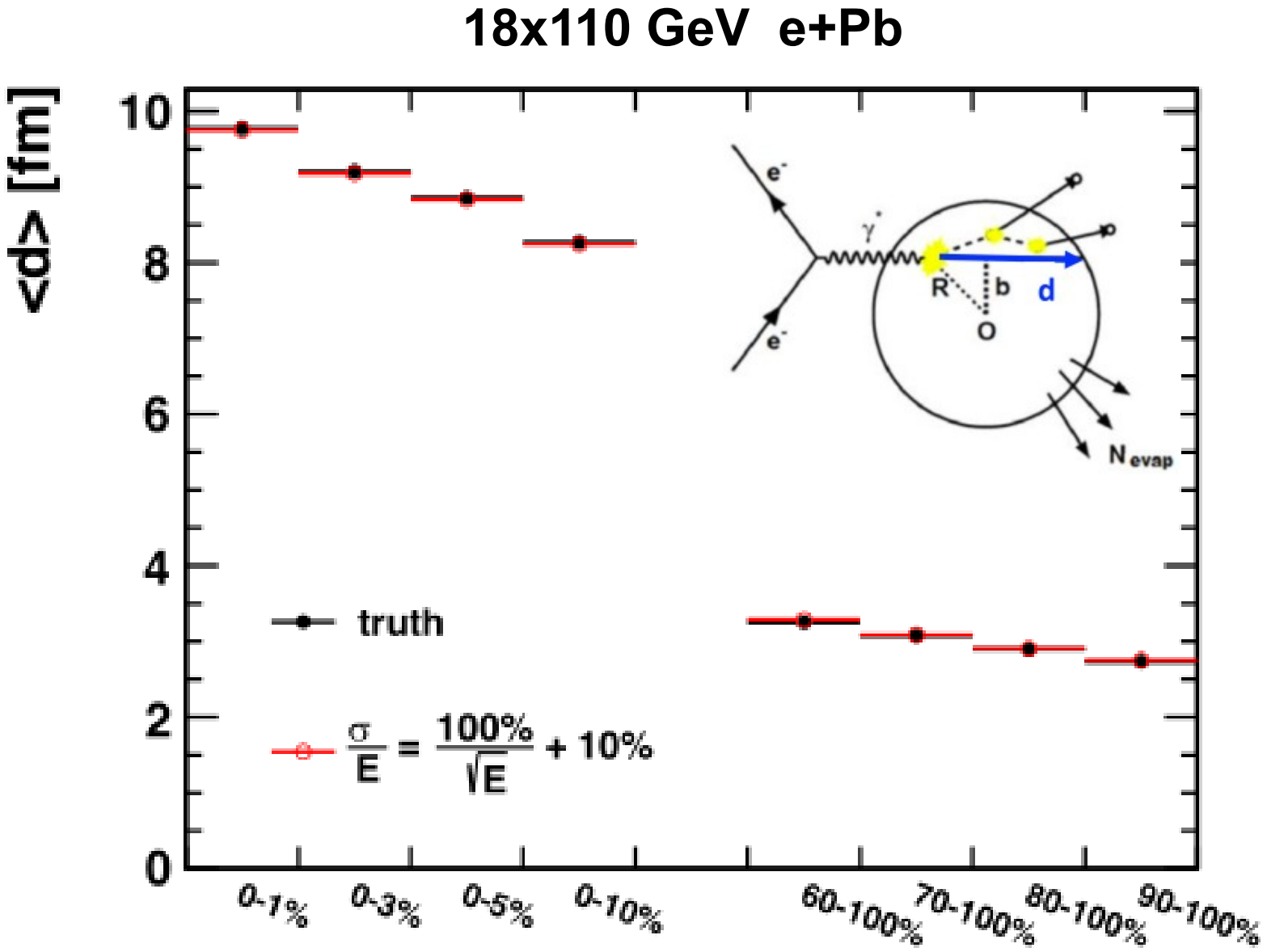






- The true distribution and the smeared one are almost identical.
- A higher resolution calorimeter is not required for this analysis.

Tight geometry cuts are meaningful!



FY2020 Milestones (from July 2019)

- January 2020
  - BeAGLE cleanup — **YES**
  - Full RAPGAP installation — **Progress (e+p DIS)**
  - Submit a paper — **Internal draft**
- April 2020
  - Compare BeAGLE to E665 Data — **Progress**
- September 2020
  - Tuning complete — **Progress**

External Support

- Salaries from home institutions (for eRD17):
  E. Aschenauer, W. Chang, J.H. Lee, Z. Tu, L. Zheng
  Leverage: 1.15 FTE vs. 0.25 FTE funded
- Baker support at JLAB changed from BeAGLE for EIC to BeAGLE for JLAB/JLAB12
  & maybe reduced (previously 0.2 FTE year)
  R. Ent & D. Higinbotham
- Possible modest support from MIT 0.05 FTE year (O. Hen et al.)

Conclusions

- BeAGLE is being used at BNL and by users to understand detector acceptances and requirements for e+A.
- Nimble and active user support is essential.
- Stable funding is key, especially given the aggressive TDR + Yellow Book schedule.
- A fumble-free handoff to BNL is critical!

Extras

The Technical Table

Feature added or error corrected	07/2019	12/2019	Priority
1-8,10,13-17,20-22,24. Completed BeAGLE tasks.	YES	YES	
9. Shadowing coherence length	NO	NO	Low
11a. Effective σ_{dipole} for J/ψ averaged over x & Q^2	YES	YES	
11b. Effective σ_{dipole} for ϕ averaged over x & Q^2	YES	YES	
11c. Eff. $\sigma_{dipole}(x,Q^2)$ for V=ψ,ϕ,ρ,ω from Sartre (ePb)	NO	NO	Low
11d. Use correct $R_{diff}^{(A=208)}(x,Q^2)$ for V from Sartre	NO	NO	Low
11e. Improved σ_{dipole} for V, if necessary	NO	NO	Low
12a. Understand E665 Event Trigger (& Q^2 dist.)	NO	YES	
12b-?. Tune to E665 μA Streamer Chamber data	NO	NO	Medium
18. Tune the t distribution for multiple scattering.	NO	NO	Low
19a. Release α version BeAGLE/RAPGAP	YES	YES	
19b. Release β version BeAGLE/RAPGAP	YES	YES	
19c. Fix charge non-conservation bug (DPMJET-F)	YES	YES	
19d. Fix lost energy bug (DPMJET-F)	YES	YES	
19e. Fix excess energy bug (DPMJET-F?)	YES	YES	
19f. Release tested version BeAGLE/RAPGAP	NO	NO	High
19g. Extend RAPGAP to include e+n (w/ H. Jung)	NO	NO	High
23a. Put e+D on mass-shell (ad-hoc)	YES	YES	
23b. Put e+D on mass-shell, light-cone prescription	NO	NO	High
25. Fix smaller and/or rarer 4-momentum bugs	NO	NO	Medium

Released e+p for DIS

Soon!

Identified as a PYTHIA problem