Proposal:
Physics Simulations to Establish and Refine Detector Requirements and Detector Designs for the EIC

Thomas Ullrich (BNL)
EIC Detector R&D Advisory Committee Meeting
December 12, 2011
Brookhaven National Laboratory

BROOKHAVEN
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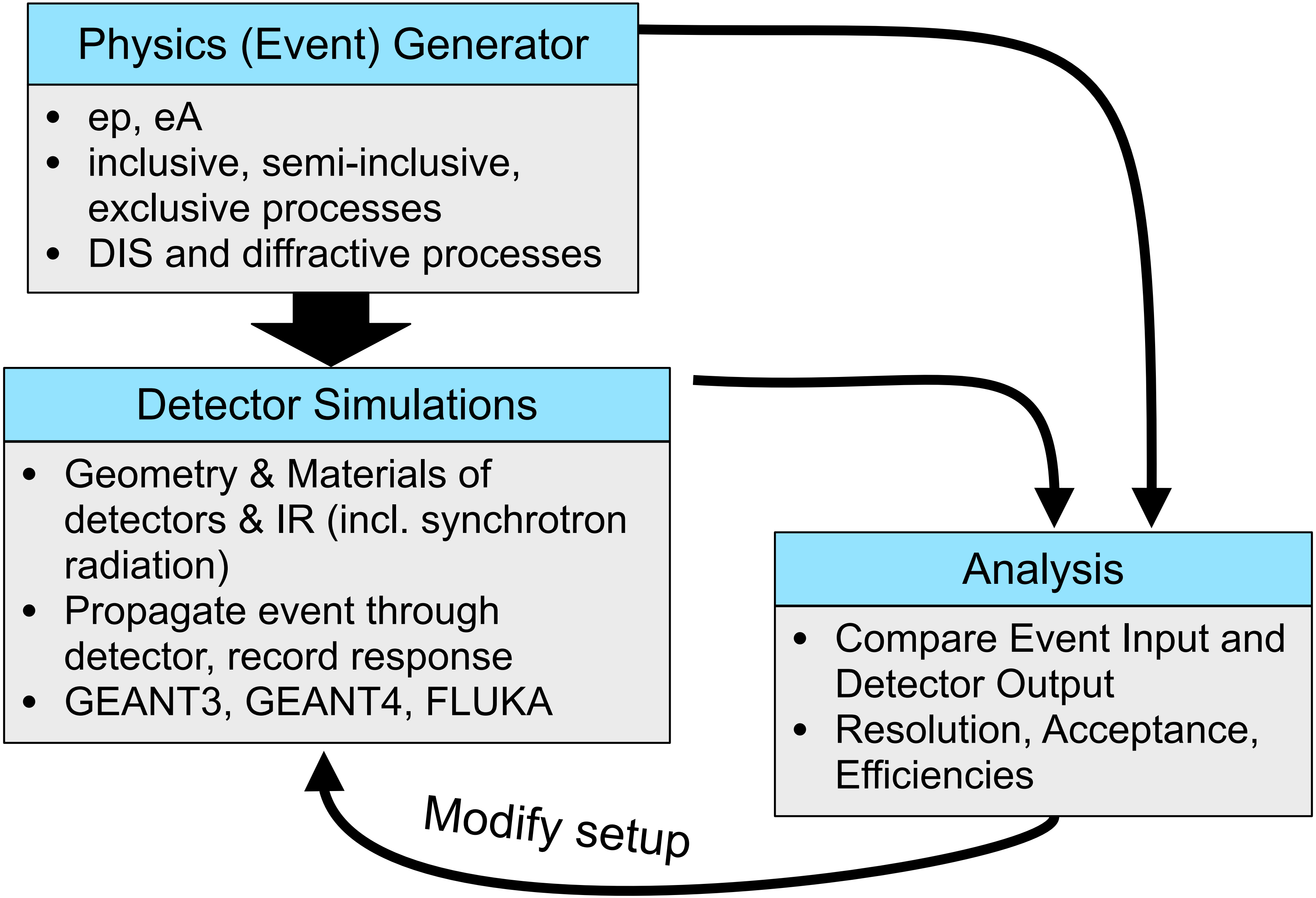
EIC Detector Advisory Committee

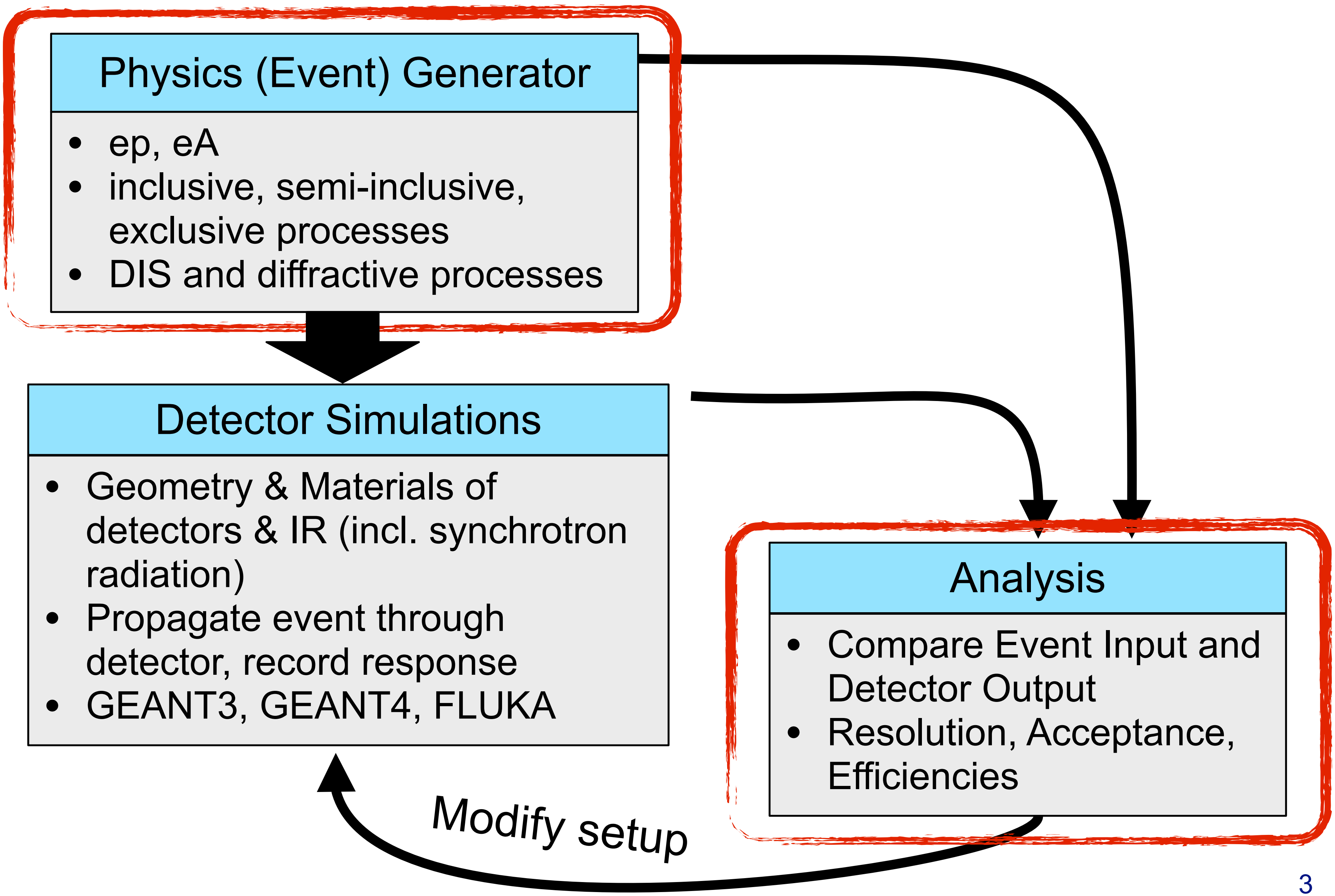
Report of the EIC Detector Advisory Committee Inaugural meeting, May 9-10 2011

"*The one concern that the committee had was that while the letter of intent stated the strong need for simulations, there was actually very little discussion or identification of resources that would be devoted to this important activity. The plans for hardware R&D were discussed and requests for associated funds were made. But, there were no similar plans outlined for simulations other than a brief mention by LBNL. It was suggested that a funding request for postdocs in support of simulations would be reasonable. [...].*"

EIC Simulations



EIC Simulations



Event Simulators

Situation is different for *ep* and *e*A

- ep
  - Many specific and general purpose generators available
  - Development was driven/inspired by HERA program
  - PYTHIA6, Milou, PEPSI, gmc_trans, RAPGAP, DJANGO, MC@NLO, LEPTO, DPMJet, CASCADE, ...
  - After shutdown of HERA and start-up of LHC development and maintenance ceased for many (e.g. PYTHIA8 has ep capabilities removed)
  - F77 code that does not integrate too well with modern analysis packages

Event Simulators

- *e*A
  - EIC is first eA collider
  - No comprehensive eA generators exist
    - some capabilities: DPMJet-III (unsupported & bugs)
    - future plans (?): add eA to CASCADE (H. Jung/DESY)

*e*A makes EIC unique* and provides access to a regime where gluon densities saturate and nature deviated from our established understanding ⇒ terra incognita

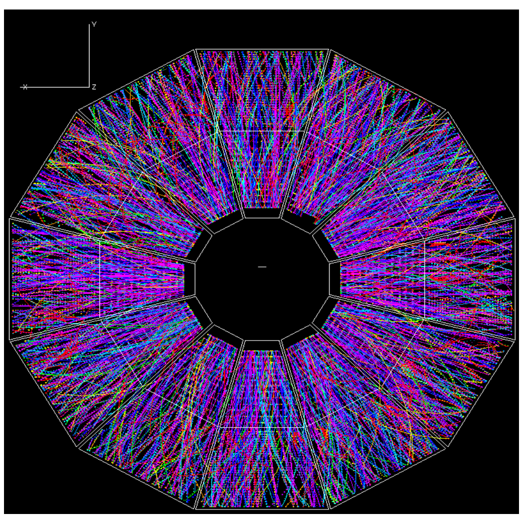
Mandatory: establishing that EIC (machine and detector) can detect and explore this new regime

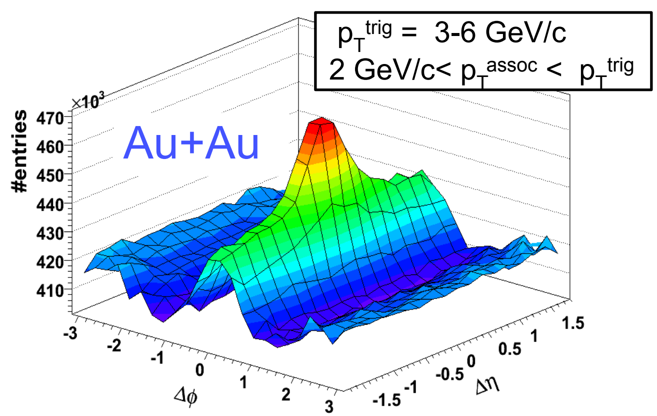
*together with polarized ep

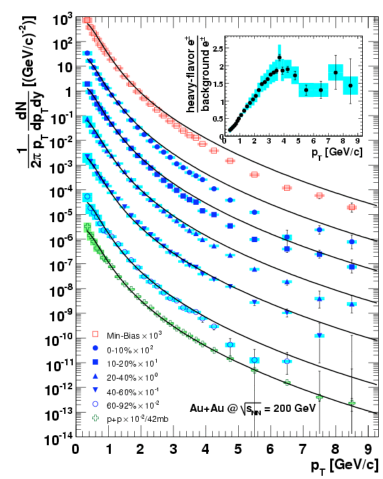
Why are Event Generators so Important?

Situation is different to RHIC R&D era:

- Established generators were available (ongoing AGS, SPS HI program)
- Key issues:
  - Can the detectors handle the multiplicity?
  - Can e.m. probes be extracted from the “bulk”?
  - Early physics focus was on discovery not precision
    - changing now ⇒ RHIC detector upgrades







Why are Event Generators so Important?

EIC:

- Key observables are not: multiplicity, rapidity or momentum spectra
- Key observables are: complex, derived variables: structure function, form factors, correlation functions, ...
- Lack of kinematic reach and PID in a small region can have negative impact on a specific measurement as a whole

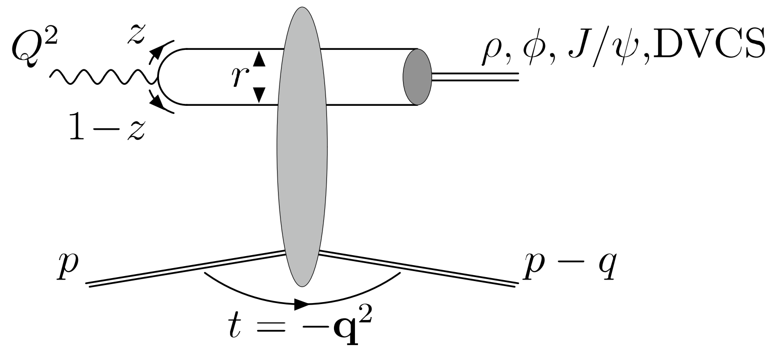
RHIC was and is data driven,

EIC physics is theory driven

One Example (1)

Diffractive Vector Meson Production: e + A → e' + *V* + A'

V = J/ψ, φ, ρ, γ

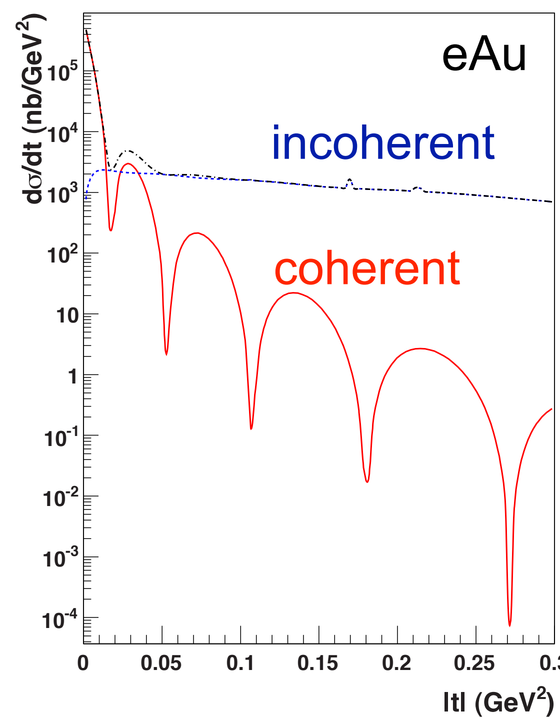


- Sensitive to spatial gluon distribution

$$\frac{d\sigma}{dt} \equiv$$ Fourier Transformation of Source Density $\rho_g(b)$

Only diffractive process where *t* can be extracted in eA

e + Au → e' + J/ψ + Au'



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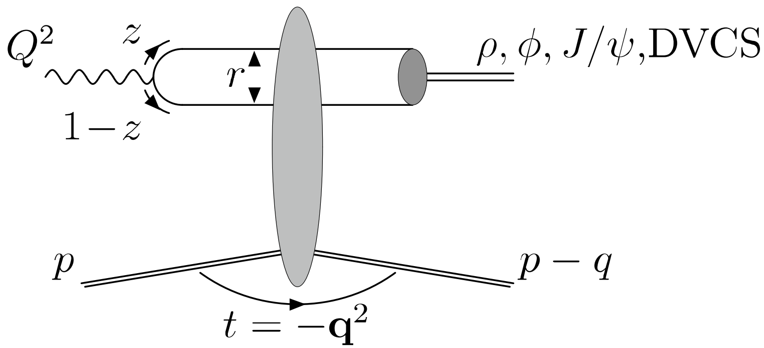
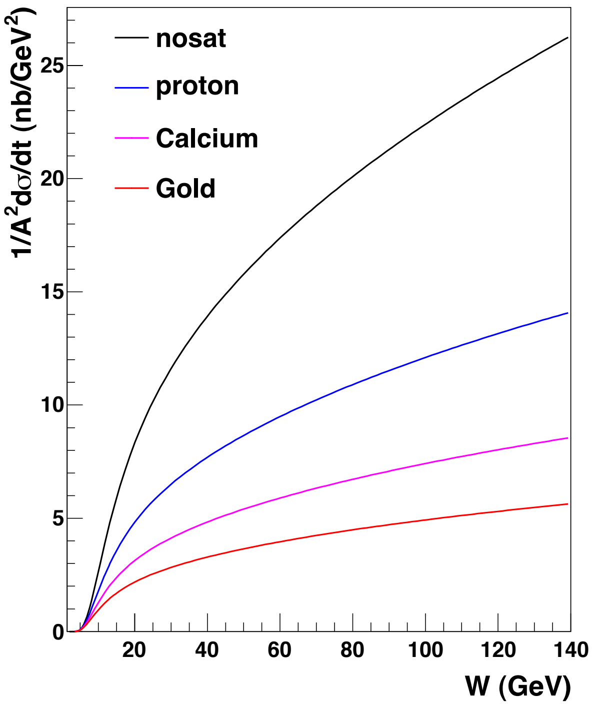


e + Au → e' + φ + Au'

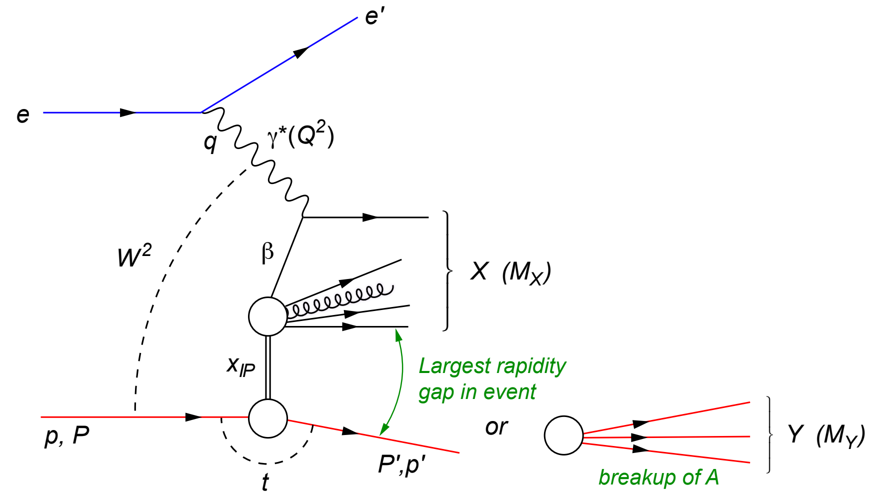


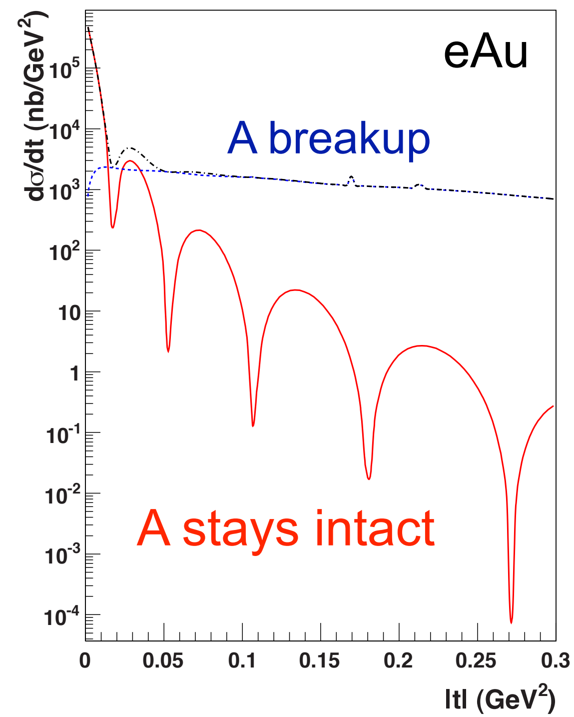
- Extremely sensitive to saturation
  - light mesons better
  - no need to measure t

One Typical Example (2)

Complex and demanding, especially in eA

- Rapidity gap
  - hermetic detector
- Coherent/incoherent
  - detect nuclear breakup
  - detector & IR design
- $Q^2 \sim 0$: $t \approx p_T^2$ of J/ψ
  - t is small: need high resolution for e^+e^- ($\mu^+\mu^-$) or $\pi^+\pi^-$ (ρ)
  - ensure electron in beampipe
- small Q^2:
  - need p_T of scattered e at small angle to calculate t
  - J/ψ decay dilepton go forward





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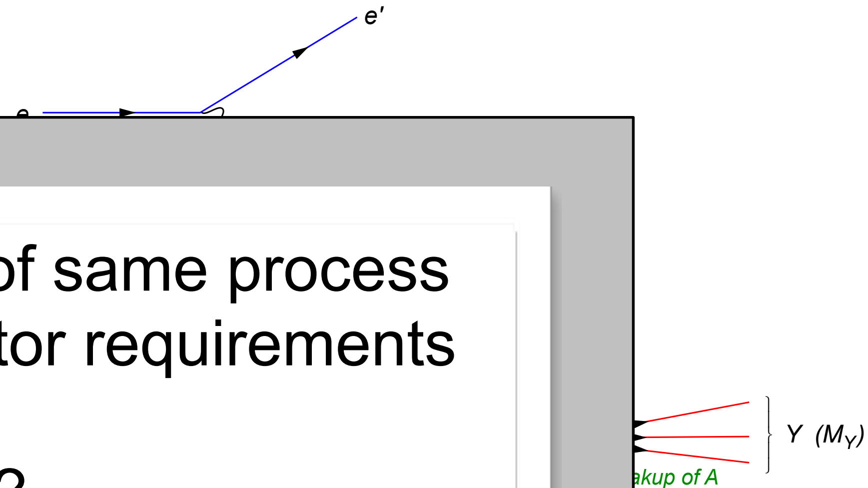
Complex and demanding,

espe

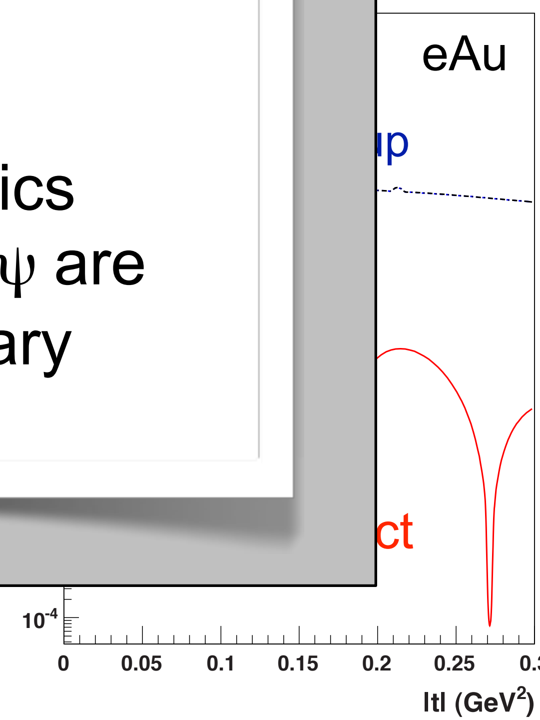
- R
- C
- Q
- sr



Every kinematic range of same process imposes different detector requirements

Which can be achieved?
Where is the “golden” middle?

Need to simulate the whole physics process in great detail: e’, Au’, J/ψ are intricately related and all necessary



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New Challenge: Detecting Nuclear Breakup

- Detecting **all** fragments $p_{A'} = \sum p_n + \sum p_p + \sum p_d + \sum p_\alpha$ ... not possible
- Focus on n emission
  - Zero-Degree Calorimeter
  - Requires careful design of IR
- Additional measurements:
  - Fragments via Roman Pots
  - γ via EMC

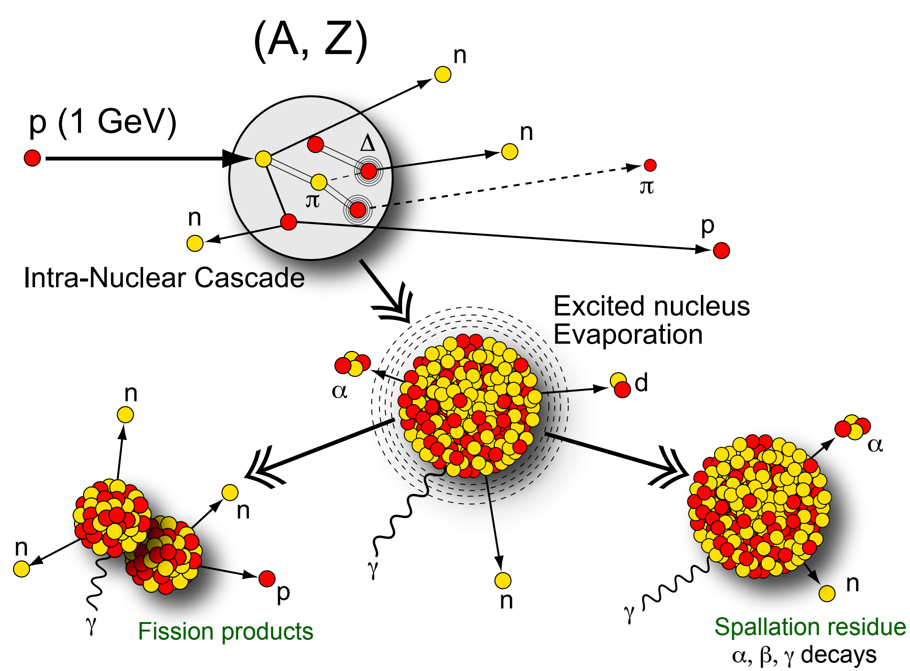
Traditional modeling done in pA:

Intra-Nuclear Cascade

- Particle production
- Remnant Nucleus (A, Z, E*, ...)
- ISABEL, INCL4

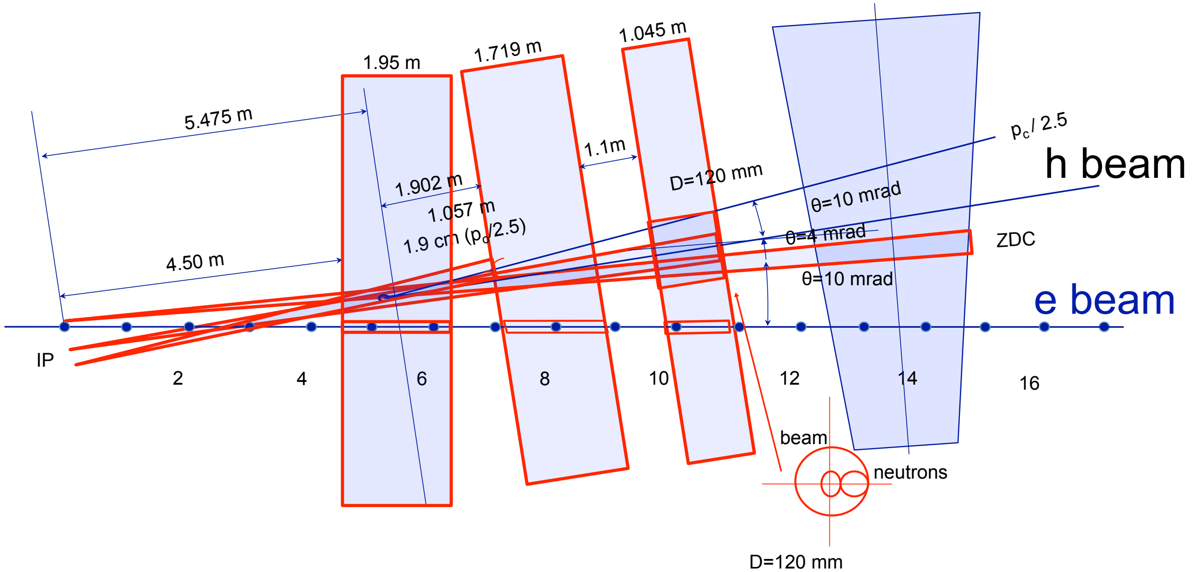
De-Excitation

- Evaporation
- Fission
- Residual Nuclei
- Gemini++, SMM, ABLA (all no γ)



Challenging also for IR Design

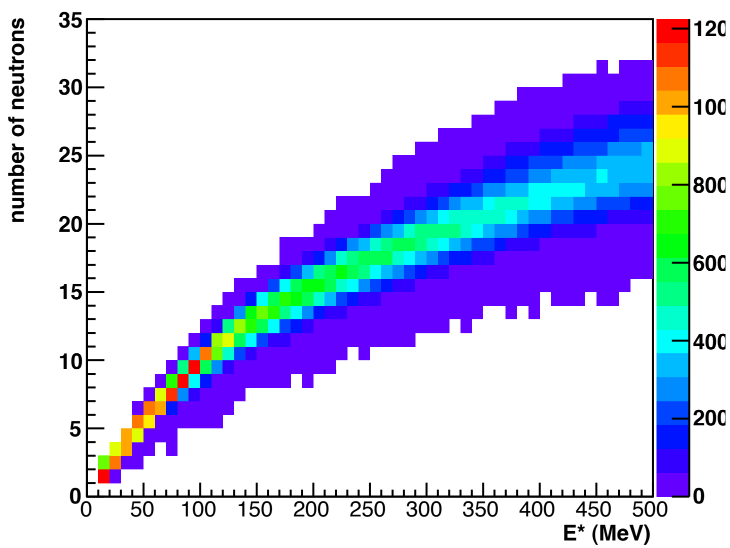
Here eRHIC IR layout:

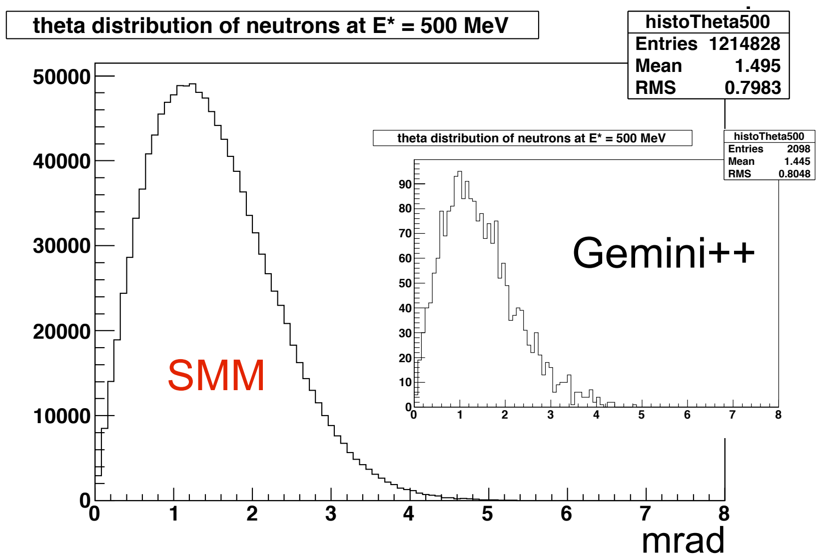


Need ±X mrad opening through triplet for *n* and room for ZDC

Big questions:

- Excitation energy E*?
- ep: $d\sigma/M_Y \sim 1/M_Y^2$
- eA? Assume ep and use $E^* = M_Y - m_p$ as lower limit





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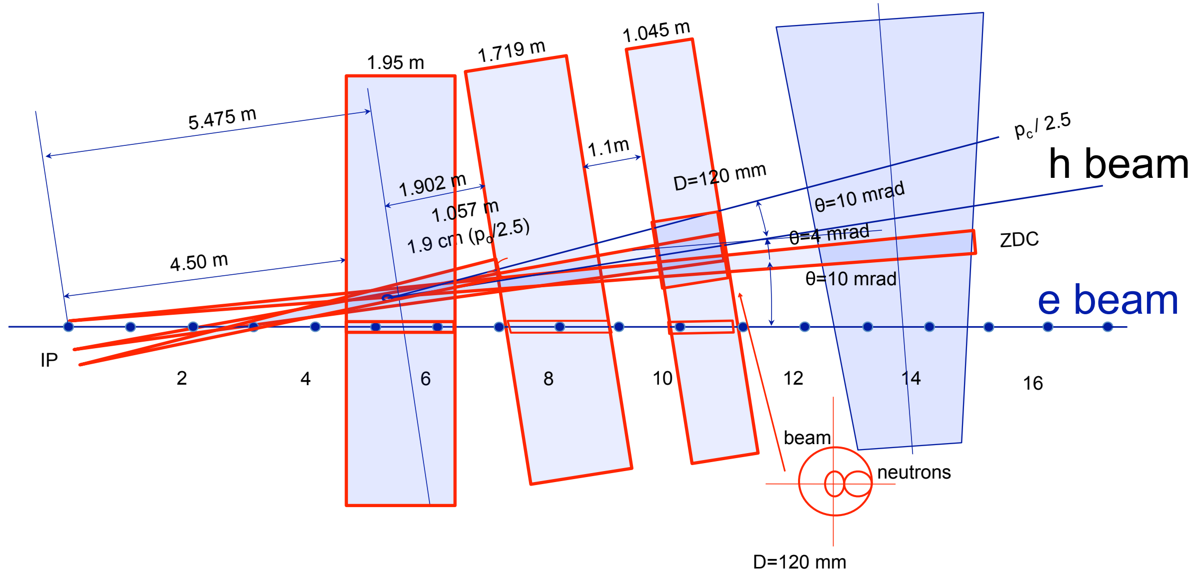

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First simulations using Gemini++ & SMM show it works:

- For $E^*_{tot} \geq 10$ MeV and 2.5 mrad *n* acceptance we have rejection power of at least 10^5.
- Separating incoherent from coherent diffractive events is possible at a collider with *n*-detection via ZDCs alone BUT more studies are needed

Status of eA Event Generators

- DIS
  - DPMJet-III is candidate
    - not maintained
    - has problems and needs improvements
    - needs to be adopted by “someone” to fix, improve, and maintain

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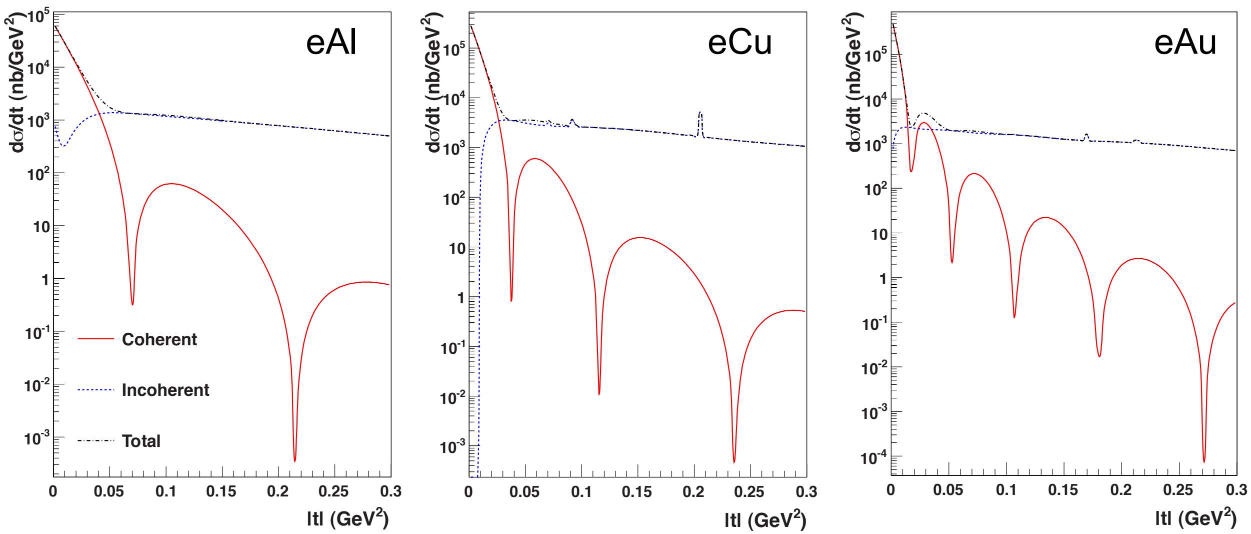
- Diffractive Events
  - No generator exists encapsulating all aspects (incl/ saturation)
  - BNL/LDRD #10-042 May 2010: "Realization of eA event generators"
    - Postdoc & visitors
    - Development of diffractive event generator SARTRE

Status of eA Event Generators



- Sartre
  - work on exclusive vector meson production completed
  - includes “draft” simulation of nuclear breakup
  - testing still going on, required tables are generated on OSG
  - inclusive processes missing
    - needed to test measurements of diffractive structure functions
- LDRD ends April/May 2012
  - lose only postdoc working on eA event generators

Description of R&D Project

Project:

- Realization of a set of eA event generators
- Conduct physics simulations with focus on eA

Goal:

- Provide & support event generators for EIC community
- Improve and refine detector requirements and detector designs

Approach:

- To conduct this work we propose to hire a postoctoral fellow for 2 years including some moderate funds for travel and visitors to help in the project

Goals: eA Generator(s)

- Cover DIS as well diffractive physics
- Include nuclear geometry of various ions from *d* up to U
- Simulation of hadronic initial state (e.g. shadowing) and final state (E-loss, color-transparency, medium modified hadronization) nuclear effects
- Simulation of nuclear breakup of the nucleus
- Allowance for the implementation of different models of high energy QCD to study the sensitivity to new physics
- Implementation of the relevant QED effects like radiative corrections that may be very significant for large nuclei
- Provision of an event record compatible with current standards
- Integration with EIC detector simulation packages (see R&D proposal by K. Dehmelt et al.)
- Documentation

Goals: Simulations

DIS

- Study the feasibility of jet measurements
- Optimize detector design for dihadron measurements
- Optimize design for measurement of the structure functions F_2 and F_L
- Investigate the possibilities of measuring the charm structure functions
- Study the impact of cold matter energy loss on the reconstruction of x, Q^2 using the hadronic final state

Diffractive Collisions

- Optimize detector design for measurement of the diffractive structure functions F_2^D and F_L^D
- Optimize detector design to measure $d\sigma/dt$ for exclusive diffractive events
- Study in detail how the nuclear breakup can be detected and which detectors are required

Obviously studies are conducted in collaboration with all R&D efforts and the EIC community

Necessary Resources & Budget

- Postdoctoral Fellow for 2 years
- Travel
  - EIC related conferences
  - Visiting experts
- Visitors
  - Short & long term
  - Most efficient and cost-effective way to tap into a knowledge database otherwise not available (affordable) locally

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- Budget

(detailed budget in proposal, here assume extend appointment of postdoc hired through LDRD)

Budget Plan Dept Code: PO

Revision Id: CURRENT REVISION 1

Budget Plan Id: EIC ULLRICH R AND D

Description	***FY 2012***	***FY 2013***	***FY 2014***	***TOTAL***
NEW FUNDING	74,500	143,000	101,500	319,000
COST PLAN	74,493	143,000	101,500	318,993