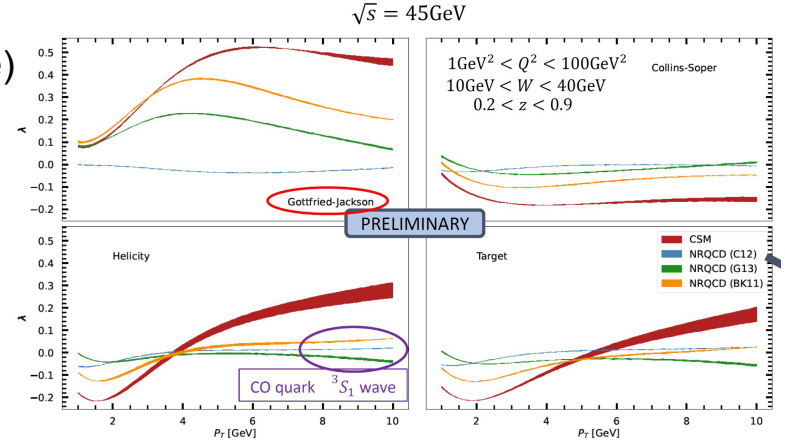
Experimental considerations on quarkonium measurements at EIC

Jin Huang (BNL), Xuan Li (LANL)
For the organizers

Inclusive Quarkonia Observables at EIC

- EIC is part of Part of global Quarkonia puzzle, ep/A, γp/A, pp/A/pbar, ee
- In addition to the quarkonia production in vacuum, the EIC will provide different e+A collision to explore the cold nuclear medium effects.

L. Maxia (Tue)



J. Lansberg (Mon)

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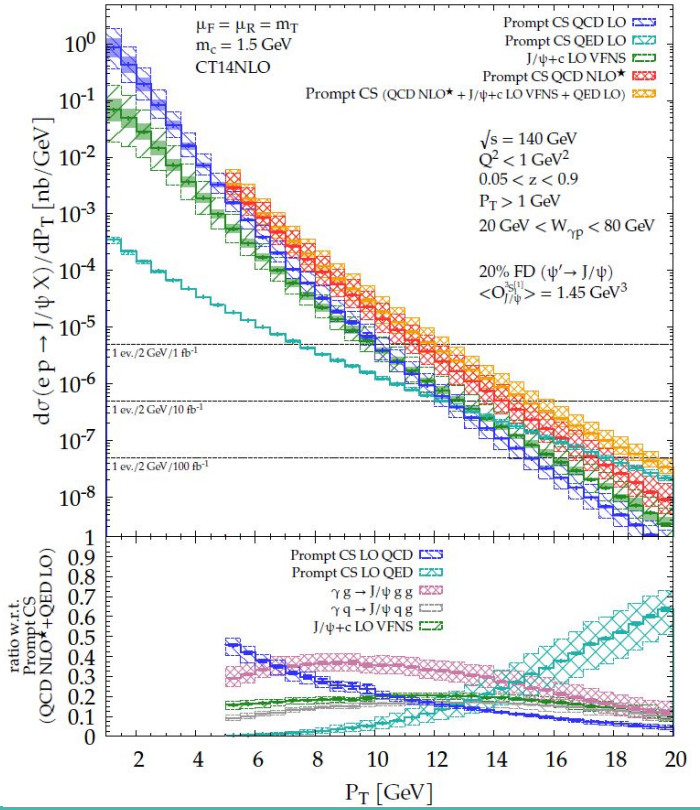
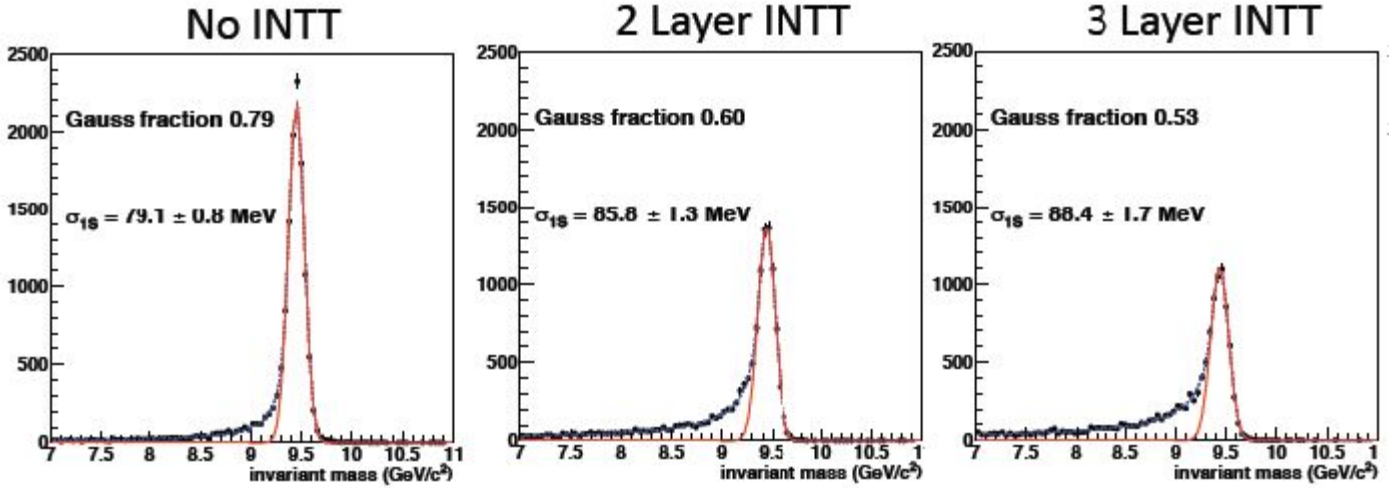


Considerations 1: tracking efficiency and radiative loss

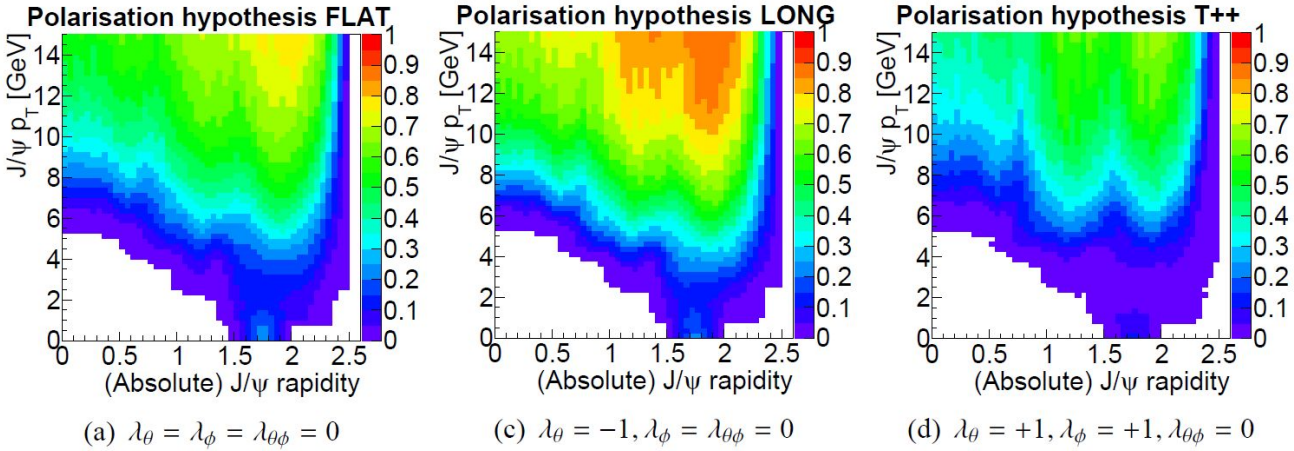
- Quarkonia detection require multiple final states (e.g dielectron), usually tracks.
- Tracking efficiency contribute in quadrature
  - Decay could be asymmetric and require tracking reach to both low and high momentum region
- In the popular electron channel, low radiation length tracker is critical
  - Impact from service and support of inner detectors, study with full detector simulation
  - Reconstruction optimization helps, e.g. Gaussian sum filter



Impact from material to Upsilon (ee) measurement [early sPHENIX optimization]

Considerations 2: acceptance, efficiency and uncertainty

- Acceptance, efficiency and uncertainty of them impact Quarkonia measurement with complication of
  - Polarization dependent acceptance
  - Constraint feed-down contributions



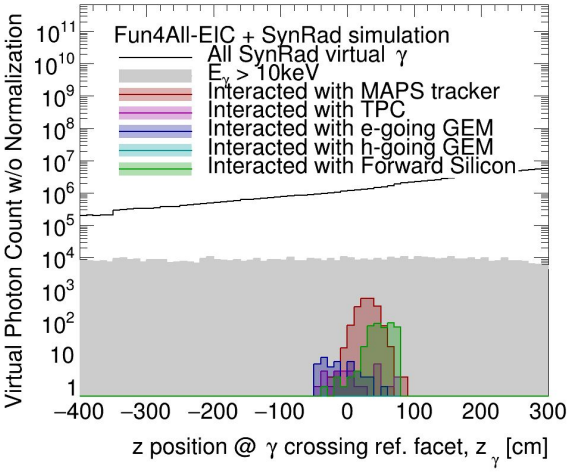
(a) $\lambda_\theta = \lambda_\phi = \lambda_{\theta\phi} = 0$ (c) $\lambda_\theta = -1, \lambda_\phi = \lambda_{\theta\phi} = 0$ (d) $\lambda_\theta = +1, \lambda_\phi = +1, \lambda_{\theta\phi} = 0$

ATLAS, DOI:
10.1016/j.nuclphysb.2011.05.015
See also talk
V. Cheung Day-1

Considerations 2: acceptance, efficiency and uncertainty

- Acceptance, efficiency and uncertainty of acceptance due to polarization and feed-down
- Uncertainty of acceptance*efficiency → systematic uncertainty and physics reach
  - Low pT reach
  - At the presence of local multiplicity: in-jet and eA
  - At the presence of the background

EIC SynRad background with a generic detector model [Ref]



Consideration 3: background rejection

- Electron ID with calorimetry and PID: 3 sigma electron/pion separation enough?
- Tracking momentum resolution requirements
- HF continuous rejection with vertex tracker
- Conversion photonic electron rejection

Detector requirements from the EIC Yellow Report

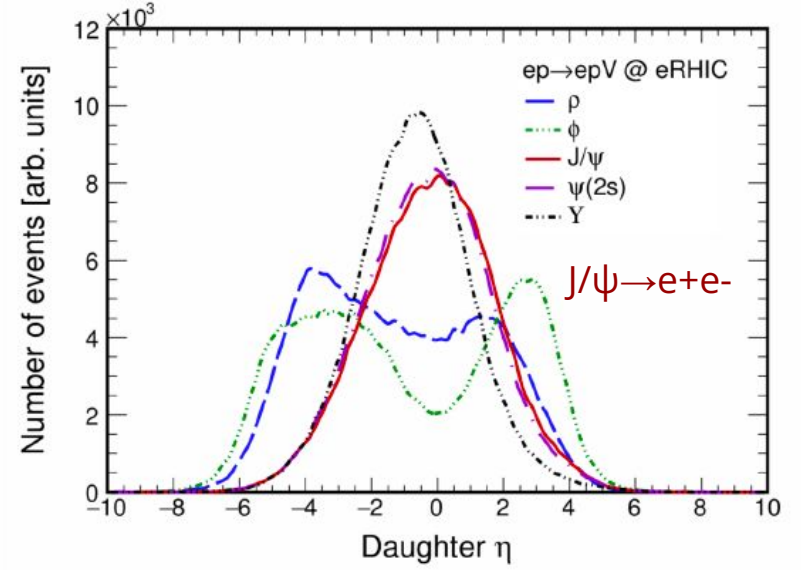
η	Nomenclature			Tracking				Electrons and Photons			π/K/p PID		HCAL		Muons
				Min p_T	Resolution	Allowed X/X_0	Si-Vertex	Min E	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Min E	Resolution σ_E/E	
-6.9 — -5.8		Auxiliary Detectors	low-Q^2 tagger		$\delta\theta/\theta < 1.5\%$; $10^{-6} < Q^2 < 10^{-2}$ GeV^2										
...	↓ p/A														
-4.5 — -4.0			Instrumentation to separate charged particles from γ												
-4.0 — -3.5														~50%/√E+6%	
-3.5 — -3.0									2%/√E+(1-3)%						
-3.0 — -2.5					σ_p/p ~ 0.1%×p+2.0%		σ_{xy}~30μm/p_T+40μm								
-2.5 — -2.0			Backwards Detectors											~45%/√E+6%	
-2.0 — -1.5					σ_p/p ~ 0.05%×p+1.0%		σ_{xy}~30μm/p_T+20μm				≤ 7 GeV/c				
-1.5 — -1.0									7%/√E+(1-3)%	π suppression up to 1:10^4					
-1.0 — -0.5															
-0.5 — 0.0		Central Detector	Barrel	100 MeV π	σ_p/p ~ 0.05%×p+0.5%	~5% or less	σ_{xyz} ~ 20 μm, $d_0(z)$ ~ $d_0(r\varphi)$ ~ 20/p_T GeV μm + 5 μm	50 MeV				≥ 3σ	~500 MeV	~85%/√E+7%	Useful for bkg, improve resolution
0.0 — 0.5				135 MeV K							≤ 10 GeV/c				
0.5 — 1.0											≤ 15 GeV/c				
1.0 — 1.5									(10-12)%/√E+(1-3)%		≤ 30 GeV/c				
1.5 — 2.0					σ_p/p ~ 0.05%×p+1.0%		σ_{xy}~30μm/p_T+20μm								
2.0 — 2.5			Forward Detectors							3σ e/π	≤ 50 GeV/c			~35%/√E	
2.5 — 3.0							σ_{xy}~30μm/p_T+40μm				≤ 30 GeV/c				
3.0 — 3.5					σ_p/p ~ 0.1%×p+2.0%		σ_{xy}~30μm/p_T+60μm				≤ 45 GeV/c				
3.5 — 4.0			Instrumentation to separate charged particles from γ												
4.0 — 4.5															
...	↑e	Auxiliary Detectors													
> 6.2			Proton Spectrometer		$\sigma_{intrinsic}(\|t\|)/\|t\|$ < 1%; Acceptance: 0.2< p_T <1.2 GeV/c										

Table 8.20: Summary of the Physics Working Group detector requirements

Consideration 4: extended reconstruction channels

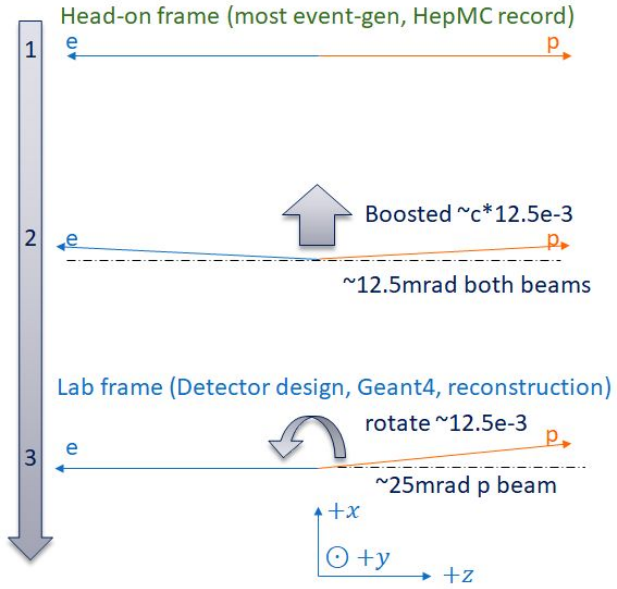
- Muon ID to be implemented in the EIC?
  - Detector technology? R&D and cost evaluation? Space limitations?
- Far-forward and far-backward reconstruction?
  - Detector performance?
  - Physics signature, e.g., exclusive J/ψ cross section, see details in Spencer's talk.

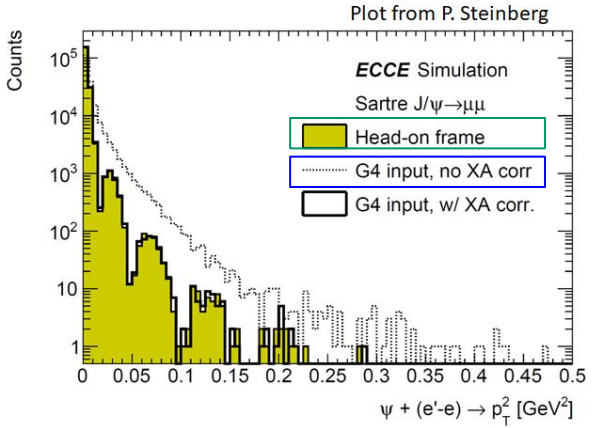
EIC vector meson daughter pseudorapidity in e+p simulation (EIC Yellow Report)



Consideration 5: beam crossing effect

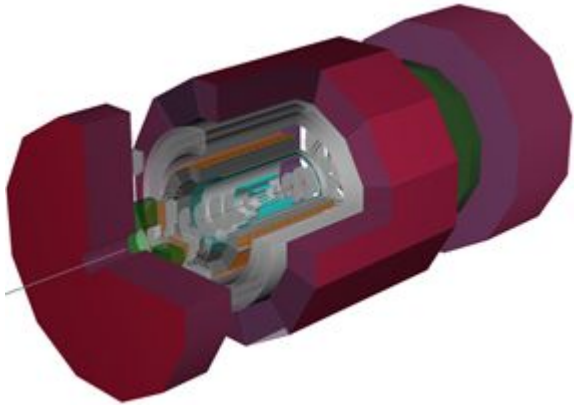
- EIC collision comes with sizable crossing angle (25-35 mrad), among many other beam effects (e.g. divergence)
- Important to differentiate observables expressed in head-on frame as used in many theory work and those measured with lab frame
- Reference:
  - Tech note [link]
  - EICUG x-ing taskforce [link]

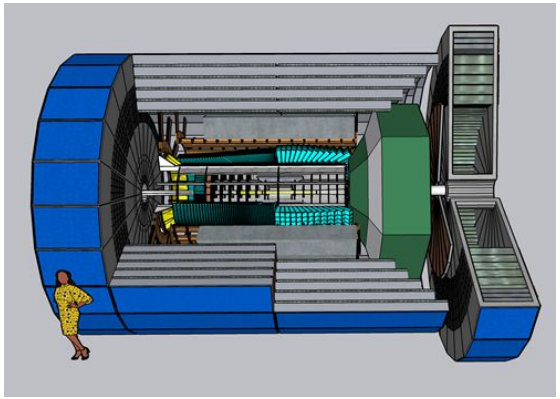


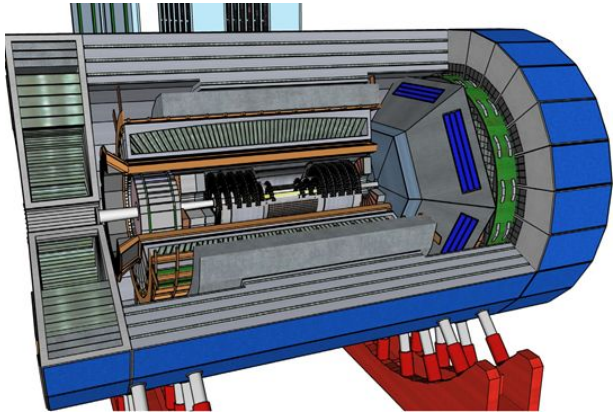


Next session: studies for EIC experiment proposals

ATHENA: athena-eic.org • CORE: eic.jlab.org/core • ECCE: ecce-eic.org







Discussion Session

- Tracking efficiency and radiative loss
- Acceptance, efficiency and uncertainty
- Background rejection
- Extended reconstruction channels
- Beam crossing effect
- More...