RHICf: future plan

LHCf-RHICf joint meeting

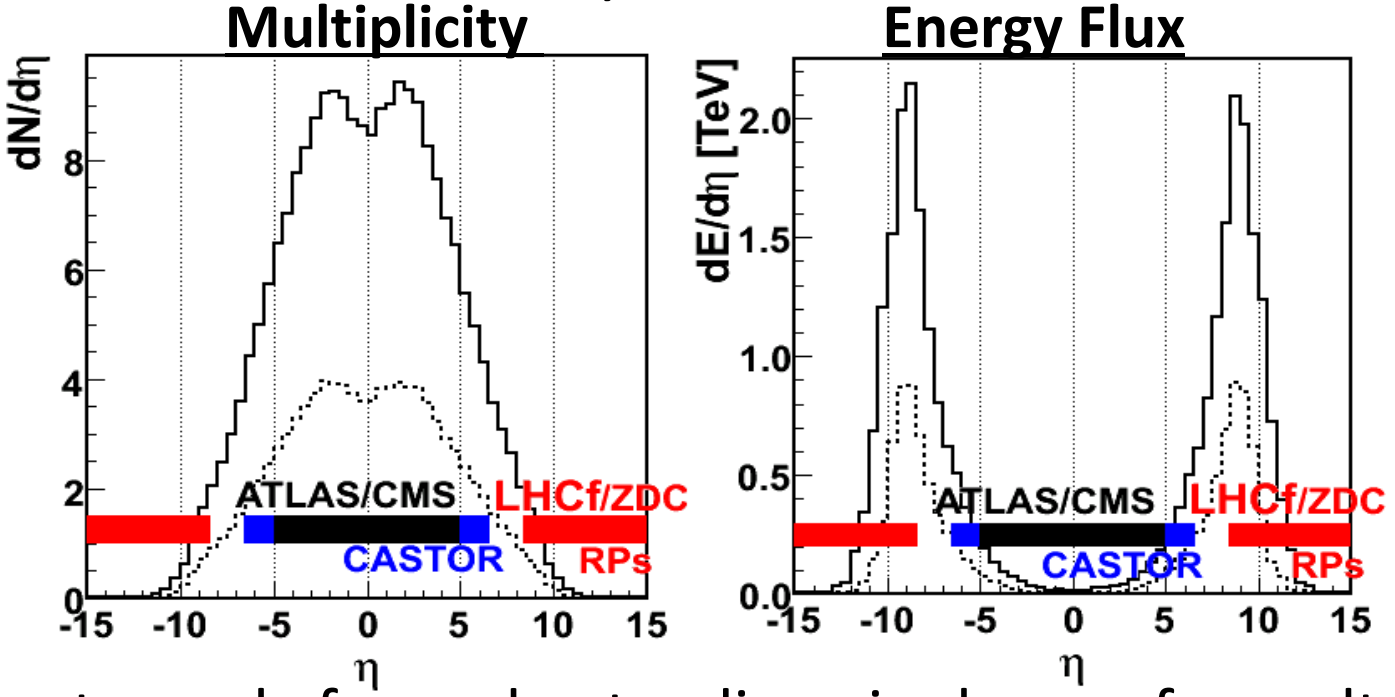
November 27th (Tue), 2018

Florence, Italy

Yuji Goto (RIKEN)

Physics at RHICf

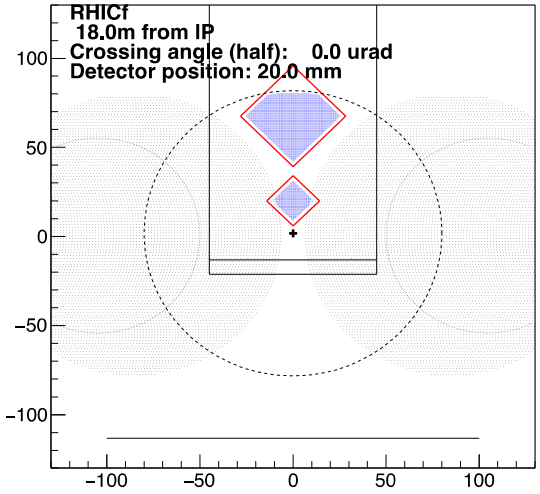
- Majority of energy flow from hadronic collisions concentrated in the very forward region, but reaction mechanism insufficiently understood there

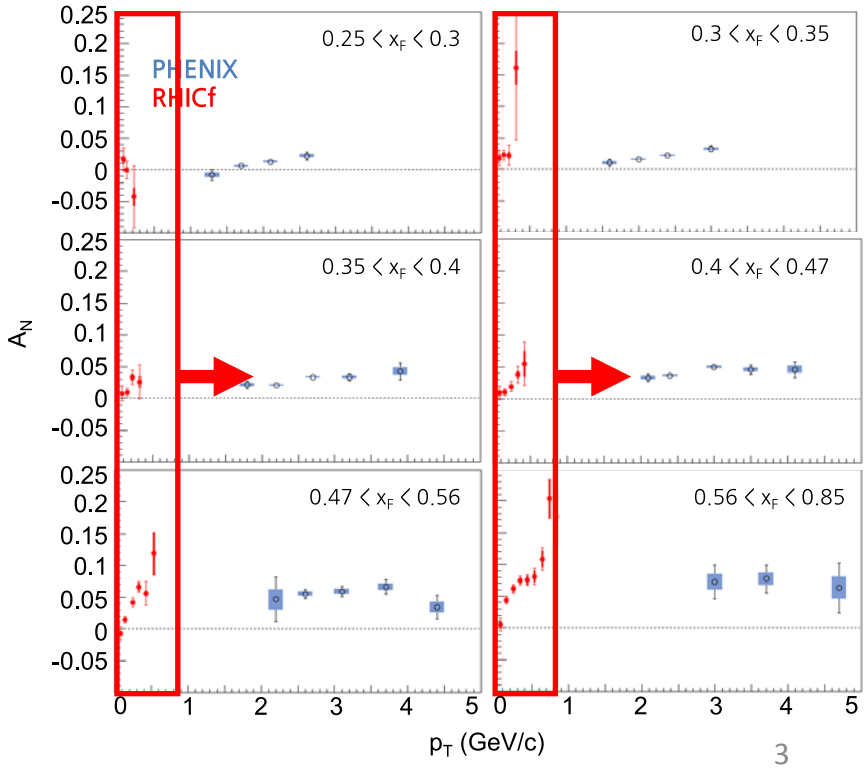


- How to apply for understanding air-shower from ultra-high energy cosmic rays
  - Phenomenological approach
- How to understand non-perturbative aspect in QCD
  - Asymmetry measurement in addition to cross section

Mid-term Physics at RHIC (and LHC)

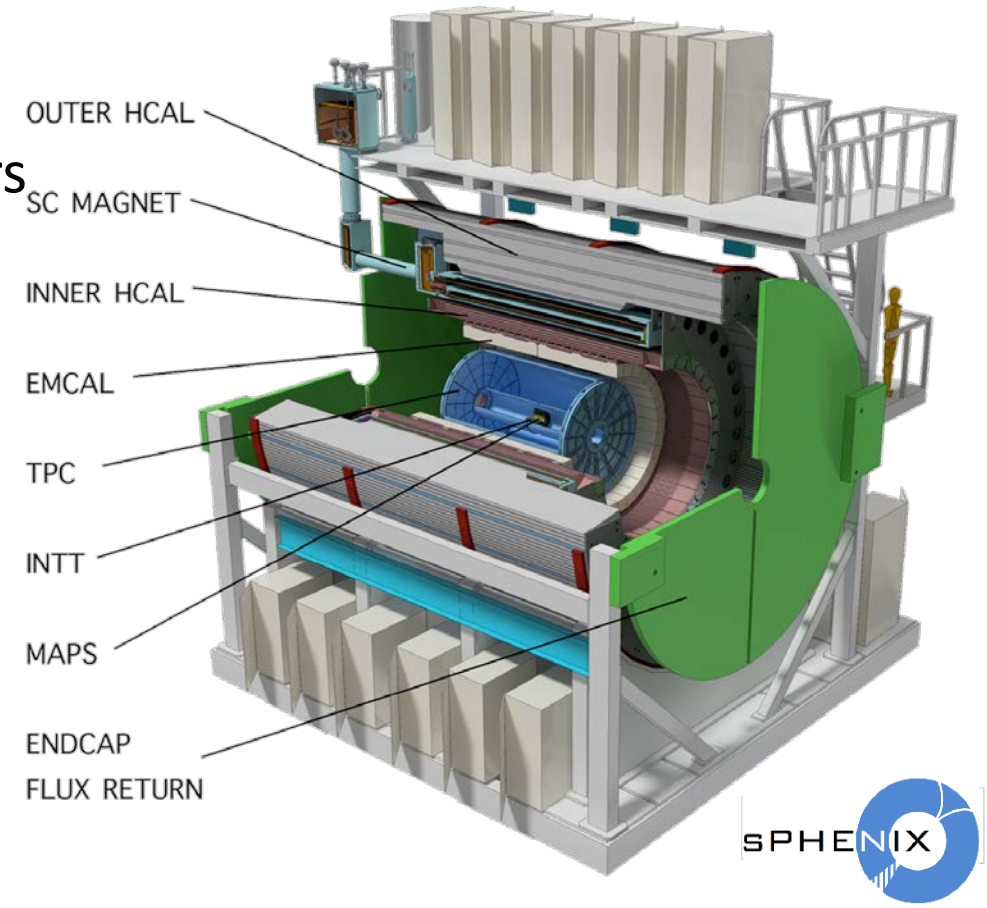
- RHICf @ z=18m from STAR IP
  - Downstream of the DX magnet
  - Acceptance limited by the DX magnet aperture
- For wide η & p_T coverage
  - To fill the gap
  - Large zero-degree detector
  - Upstream of the DX magnet?





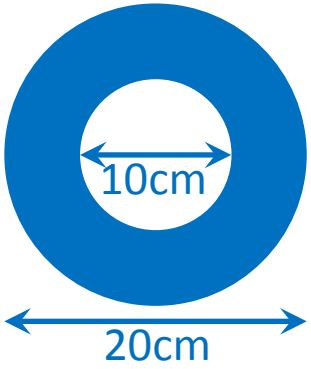
sPHENIX detector

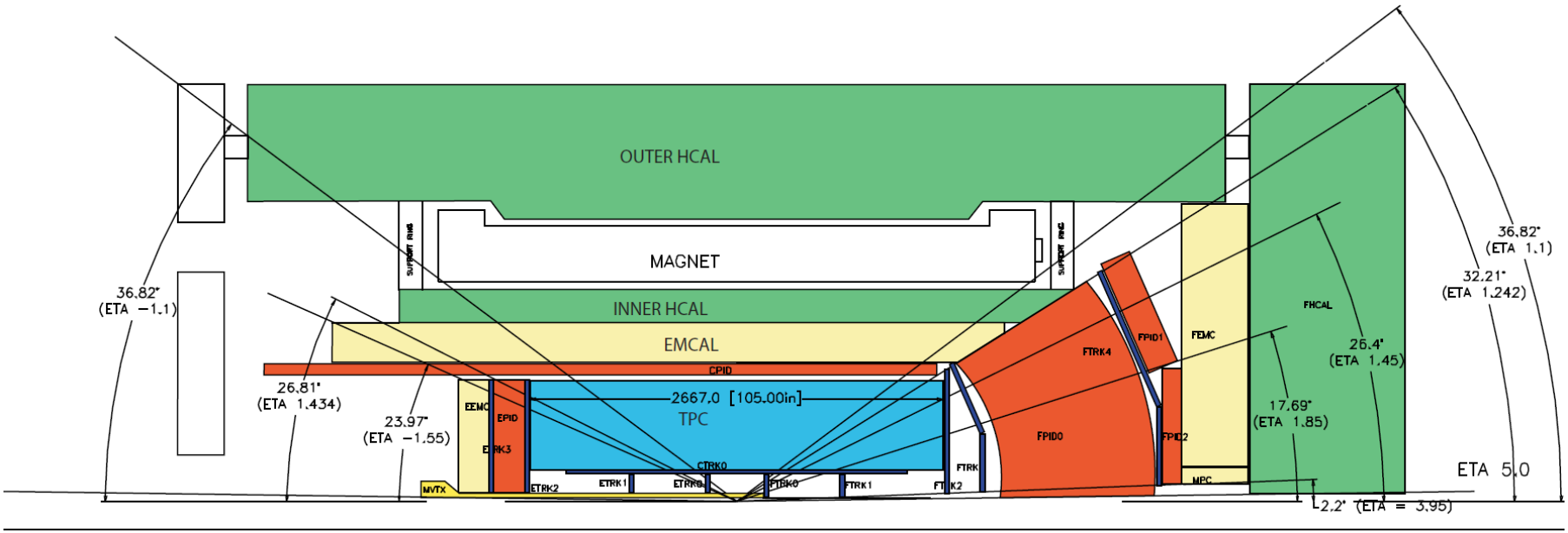
- Large-acceptance jet and upsilon detector around the BaBar superconducting solenoid
  - $|\eta| < 1.1$ and $0 < \phi < 2\pi$
  - EM & hadron calorimeters
  - TPC
  - Silicon detectors (MAPS)
- Under construction for 2023 operation



Mid-term Physics at RHIC (and LHC)

- Azimuthal detector around the beam pipe @ sPHENIX?
  - Upstream of the DX magnet
  - e.g. R = 5cm–10cm @ z = 5m
  - $0.01 < \theta < 0.02$
  - $4.6 < \eta < 5.3$



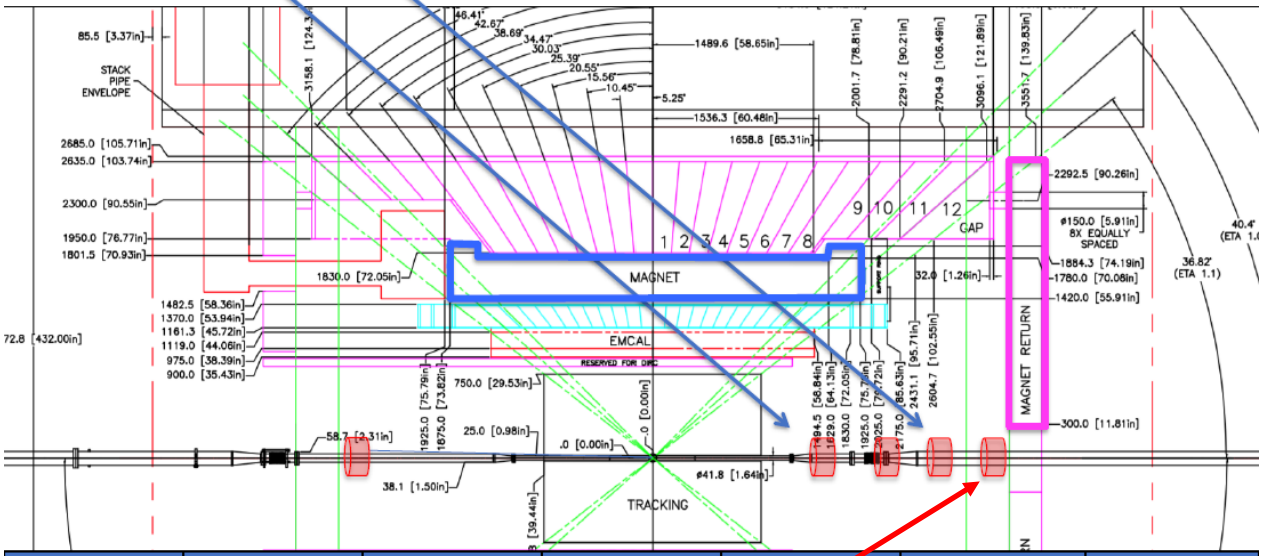


Mid-term Physics at RHIC (and LHC)

- sPHENIX BBC location

Placement in sPHENIX

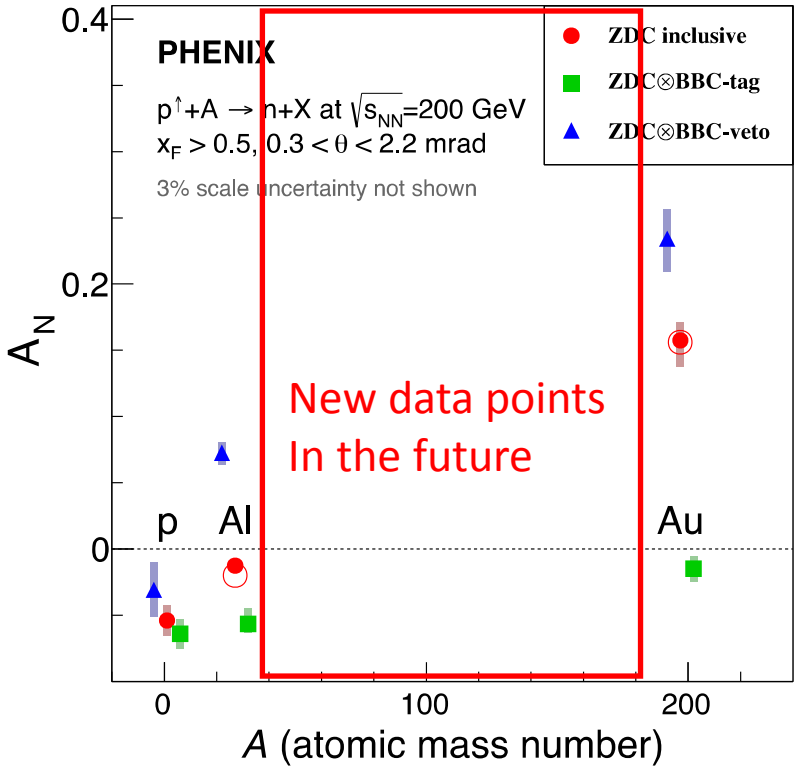
Considering z = 144, 200, 250, and 300 cm, ie, from original PHENIX location to near flux return



z (cm)	η_{min}	η_{max}	B_z (T)	Rel. Gain	AuAu MB Eff (%)	pp MB Eff (%)
144	3.0	3.9	1.11	0.01	90	39
200	3.33	4.23	0.75	0.15	89	36
250	3.56	4.45	0.50	0.5	88	34
300	3.74	4.63	0.32	0.9	87	32

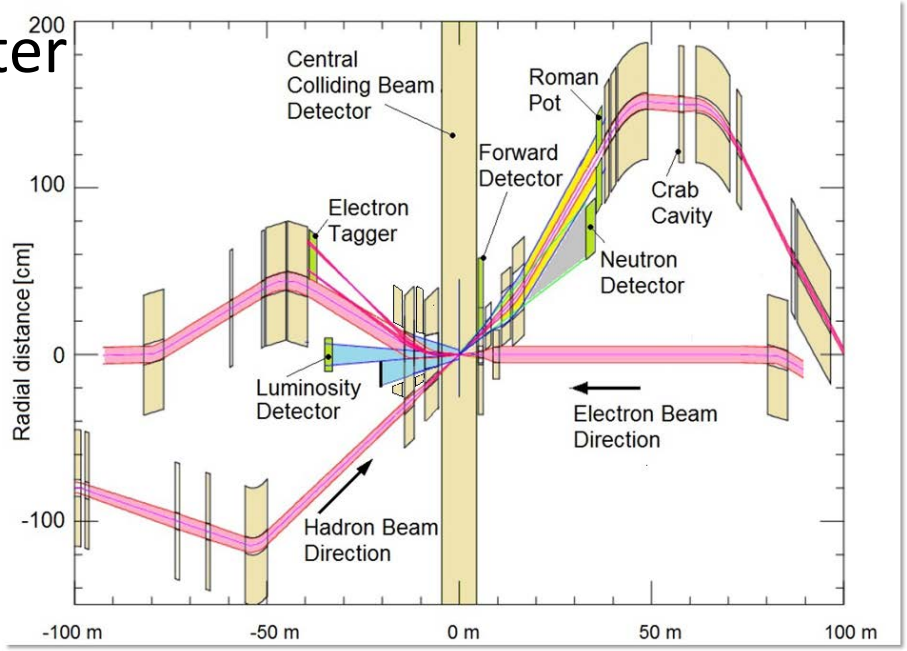
Mid-term Physics at RHIC (and LHC)

- (pol-)p + A collision
  - Neutron / π^0 / photon
  - Cross section & asymmetry
  - UPC vs hadronic component
- More particles (K^0_S, Λ,…)
  - With wide acceptance



Long-term physics at EIC (and LHeC)

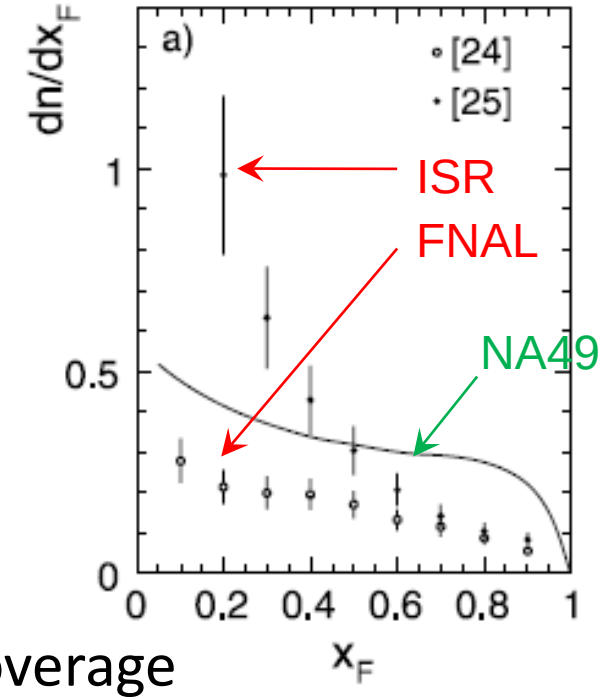
- Wide η & p_T coverage
- Cross section p+p vs e+p
  - RHIC & EIC
- Gluon saturation at EIC zero degree?
  - Diffractive cross section measurement
- EIC IR design: ZDC + spectrometer
  - Breakup neutrons for exclusive & diffractive reactions in e+A collisions
  - e+p $\rightarrow$ e'+n+π^+
  - Scattered protons
    - Roman pot
  - Spectator protons & neutrons in e+^{3}He / e+d

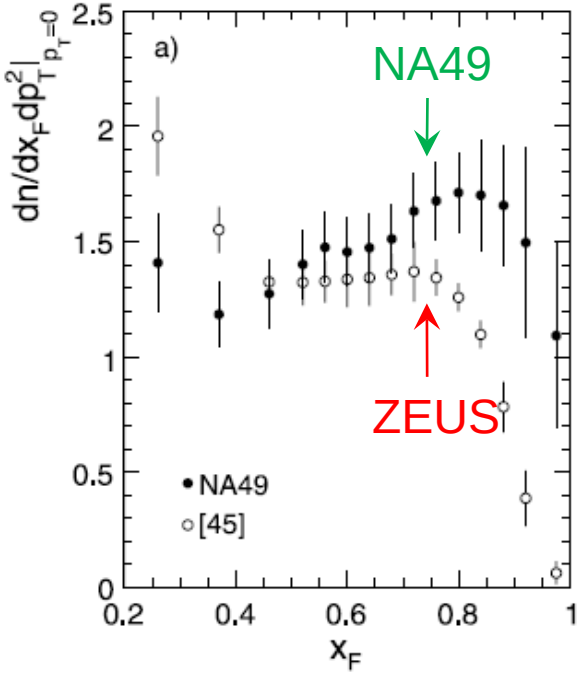


Forward neutron production

- Cross section measurement at HERA(e+p)/NA49(p+p)
  - High resolution p_T distribution
    - $\sigma \propto a(x_F)\cdot\exp(-b(x_F)\cdot p_T^2)$, $b \sim 8$ GeV^{-2} for $0.3 < x_F < 0.85$
  - x_F distribution
    - Suppression of the forward peak at high $\sqrt{s}$?
- More data necessary to understand the production mechanism
  - Asymmetry measurement as a new independent input

NA49 Collaboration,
Eur. Phys. J.
C65 (2010) 9.





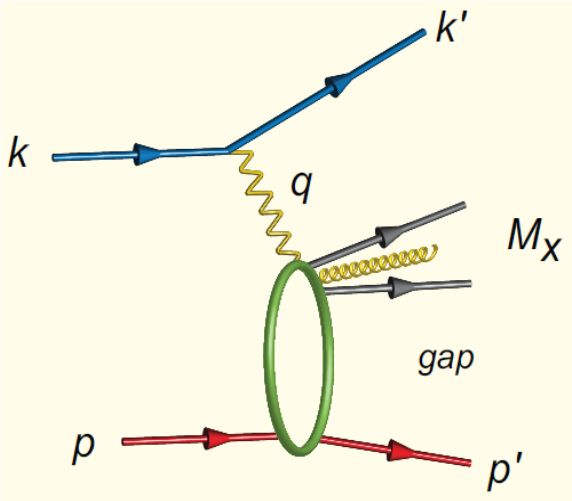
➡ Wide η & p_T coverage

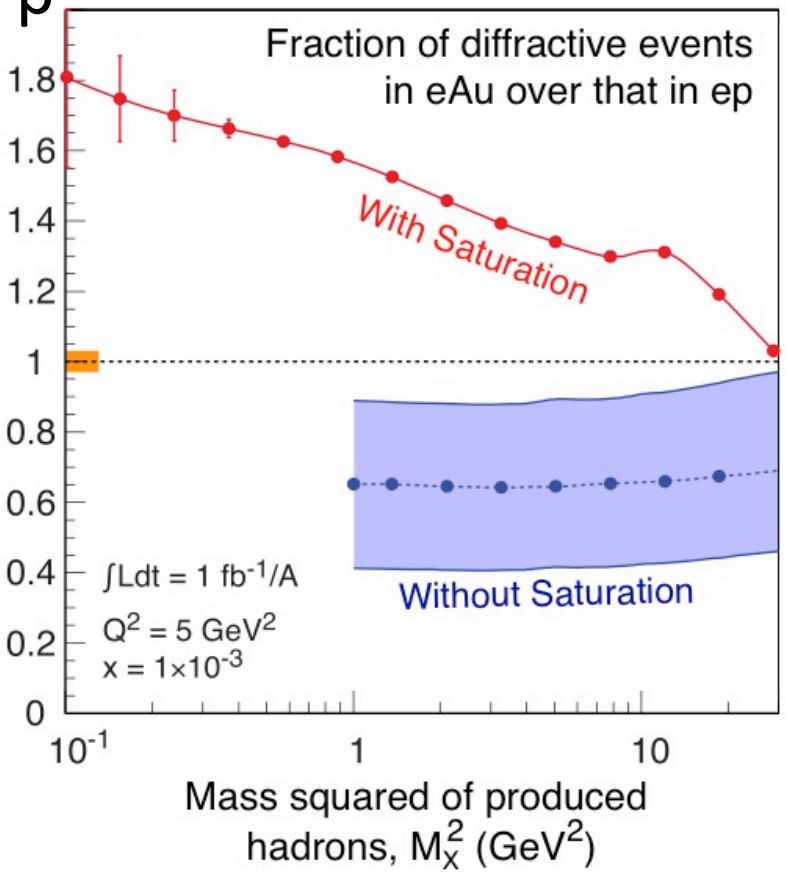
Gluon saturation

- Diffractive cross section
  - Most sensitive way to study the gluon saturation

$$\sigma_{\mathrm{diff}} \propto [g(x, Q^2)]^2$$

- 10-15% diffractive at HERA e+p
- 25-30% diffractive predicted by CGC at EIC e+A





➡ Impact on saturation from forward production of hadrons

Long-term physics at EIC (and LHeC)

- EIC detector requirements

EIC Detector Requirements

η	Nomenclature			Tracking			Electrons		π/K/p PID		HCAL	Muons
				Resolution	Allowed X/X_0	Si-Vertex	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Resolution σ_E/E	
-6.9 — -5.8	↓ p/A	Auxiliary Detectors	low-Q^2 tagger	$\delta\theta/\theta < 1.5\%$; $10^{-6} < Q^2 < 10^{-2}$ GeV^2								
…												
-4.5 — -4.0			Instrumentation to separate charged particles from photons									
-4.0 — -3.5												
-3.5 — -3.0		Central Detector	Backwards Detectors	$\sigma_p/p \sim 0.1\%xp+2.0\%$	~5% or less	TBD	2%/√E	π suppression up to $1{:}10^4$	≤ 7 GeV/c	≥ 3σ	~50%/√E	
-3.0 — -2.5												
-2.5 — -2.0				$\sigma_p/p \sim 0.05\%xp+1.0\%$								
-2.0 — -1.5							7%/√E					
-1.5 — -1.0												
-1.0 — -0.5			Barrel	$\sigma_p/p \sim 0.05\%xp+0.5\%$		$\sigma_{xyz} \sim 20$ μm, $d_0(z) \sim d_0(r\phi) \sim 20/p_T$ GeV μm + 5 μm	(10-12)%/√E		≤ 5 GeV/c		TBD	TBD
-0.5 — 0.0												
0.0 — 0.5												
0.5 — 1.0												
1.0 — 1.5			Forward Detectors	$\sigma_p/p \sim 0.05\%xp+1.0\%$		TBD			≤ 8 GeV/c		~50%/√E	
1.5 — 2.0												
2.0 — 2.5									≤ 20 GeV/c			
2.5 — 3.0				$\sigma_p/p \sim 0.1\%xp+2.0\%$								
3.0 — 3.5									≤ 45 GeV/c			
3.5 — 4.0	↑e	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 — 4.5												
…												
> 6.2			Proton Spectrometer	$\sigma_{intrinsic}(\|f\|)/\|f\| < 1\%$; Acceptance: $0.2 < p_T < 1.2$ GeV/c								

+ ZDC (EM+Hadron)

RHIC schedule

- Under discussion & review
- 2021-2022 @ STAR p+p $\sqrt{s}$ = 510 GeV
  - pol-p + A possible by proposing
- 2023-2025 @ sPHENIX p+p $\sqrt{s}$ = 200 GeV & p+A

Baseline

2023

2024

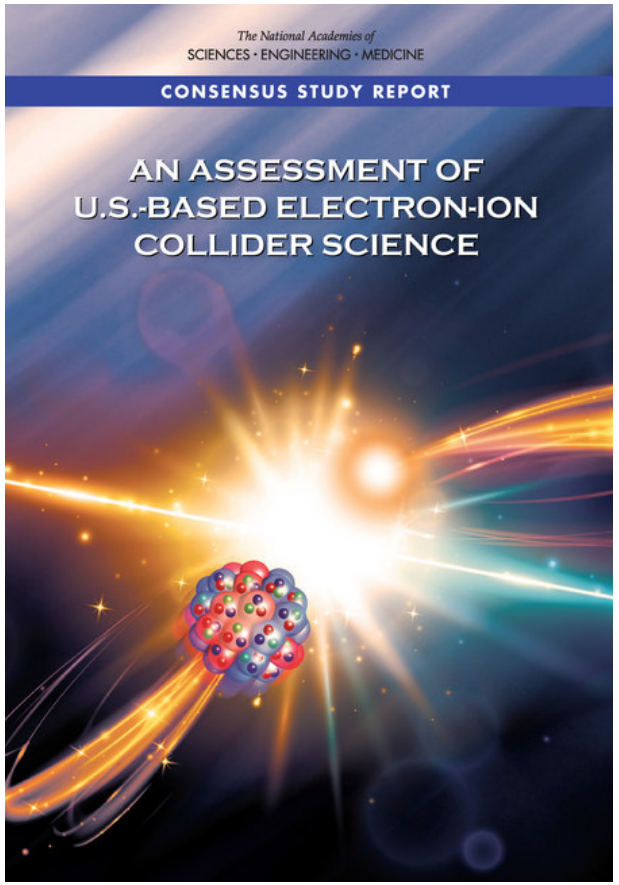
2025

Extension depending on EIC construction

Year	Species	Energy [GeV]	Wks	Rec. L	Samp. L	Samp. L (all-z)
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	$p+p$	200	11.5	—	48 pb^{-1}	267 pb^{-1}
	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	$p+p$	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

EIC schedule

- Long-term physics at EIC (and LHeC)
- NAS webinar and NAS report release 7/24/2018
- CD-0 (US mission need statement) could be awarded after the completion of the NAS study ~2018/2019
- Site selection may occur around 2019/2020
- EIC facility construction has to start after FRIB completion, with anticipated FRIB construction to ramp down around 2020
- Optimistic scenario would have EIC funds start in FY20, more realistically begin of construction funds in FY22/FY23 time frame
- Completion of EIC facility construction would be around 2025-2030 timeframe

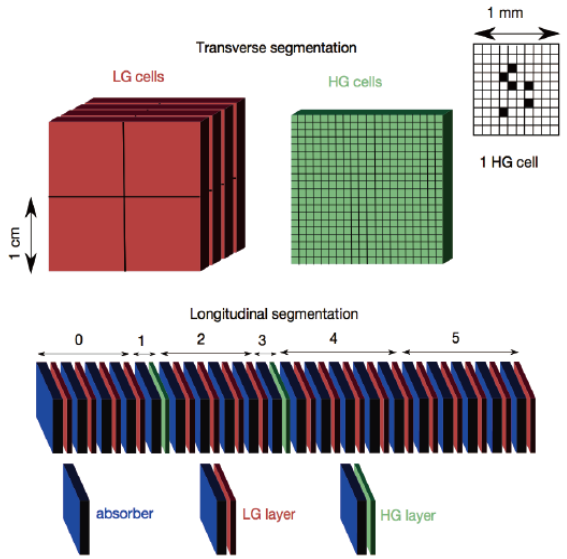


Detector development

- Collaboration with people having common interest in position-sensitive calorimeter
- Tsukuba Univ. ALICE FoCal

Slide by
Prof. Chujo

FoCal-E prototypes



- **Si/W** sandwich calorimeter layer structure:
  - W absorbers (thickness $1X_0$)+ Si sensors
- Longitudinal segmentation:
  - 4 segments low granularity (LG)
  - 2 segments high granularity (HG)

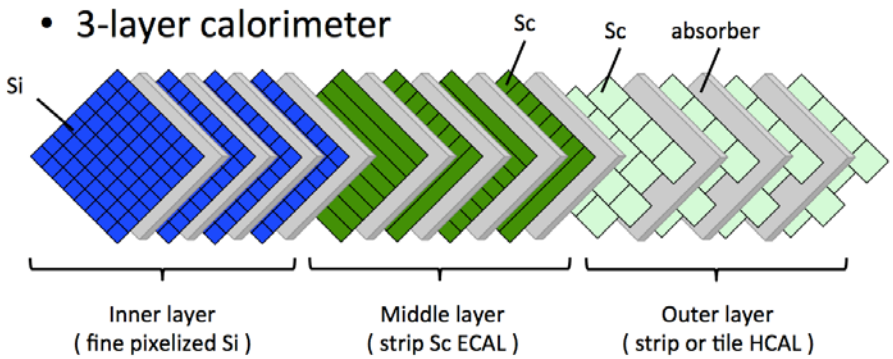
- **LG segments**
  - 4 (or 5) layers
  - Si-pad with analog readout
  - cell size 1 x 1 cm^2
  - longitudinally summed

- **HG segments**
  - single layer
  - CMOS-pixel (MAPS*)
  - pixel size ≈ 25 x 25 μm^2
  - digitally summed in 1mm^2 cells

*MAPS = Monolithic Active Pixel Sensor (cm)

Detector development

- Kobe U. LHeC&EIC ZDC
  - (internal information from Prof. Yamazaki)
  - Radiation-hard scintillator
- EIC IR design: ZDC + spectrometer
  - Proposal for EIC detector R&D program?
    - operated by BNL with ~$1M / year
- ILC calorimeter group?
  - ILD SiECAL & ScECAL
  - Kyushu U., Shinshu U.,…?



- sPHENIX / STAR / EIC forward hadron calorimeter
  - Collaboration with UCLA group
- SeaQuest EMCal for dark photon

Calorimeter workshop

- Position-sensitive calorimeter
- Organized by RIKEN / Nagoya U. / Kobe U.?
  - To be held sometime in Jan-Mar, 2019
- Proposal for EIC detector R&D program
  - To be submitted in June, 2019
- Budget, organizers, program to be discussed…