

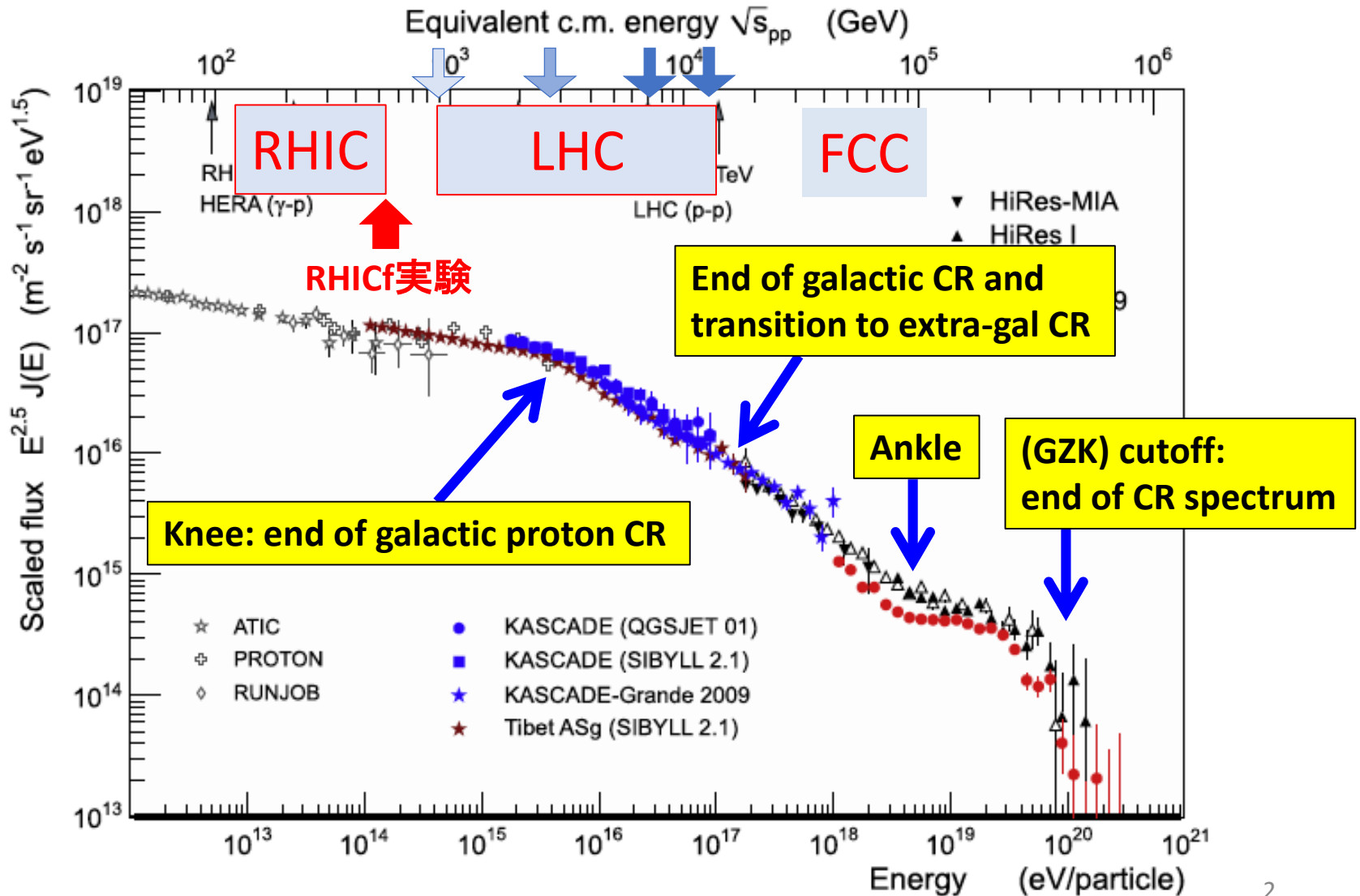
RHICf実験

さこ隆志

(名大 ISEE/KMI)

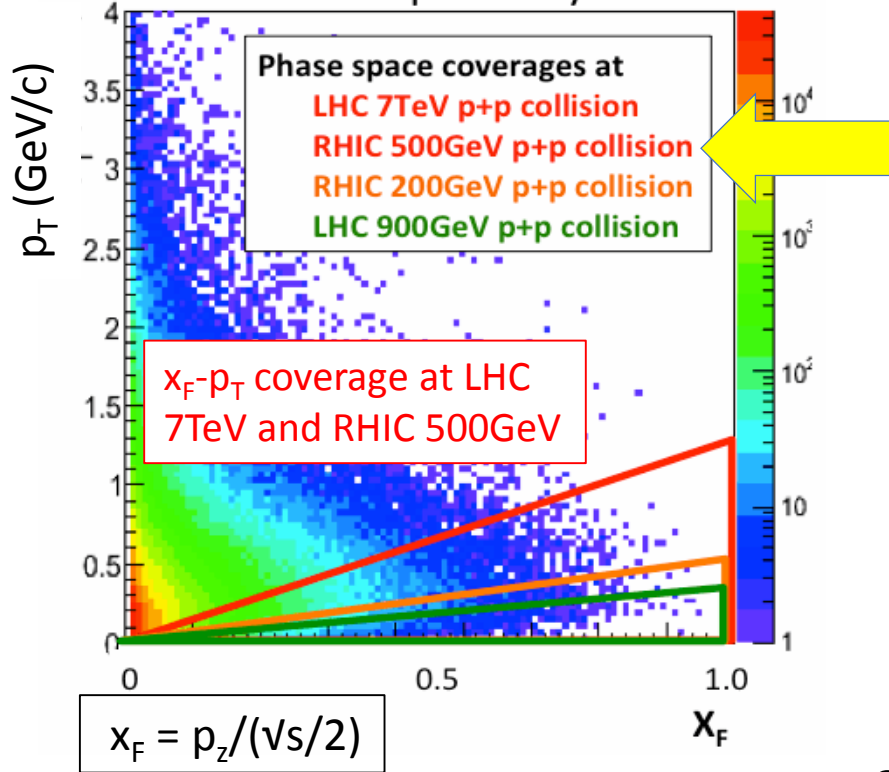
Cosmic-ray spectrum and collider energy

(D'Enterria et al., APP, 35,98-113, 2011)

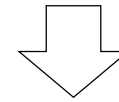


LHC 900GeVではダメなの？

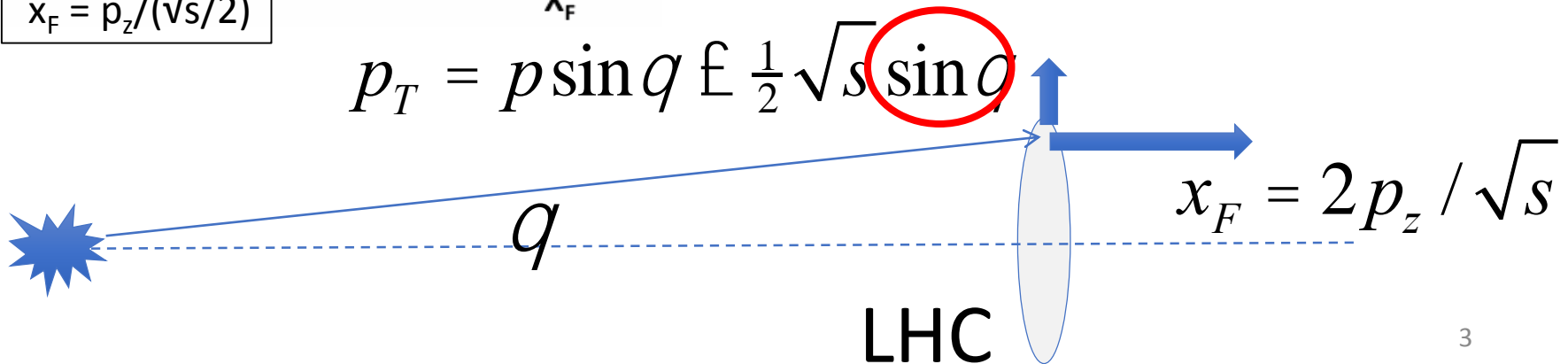
Forward photon yield



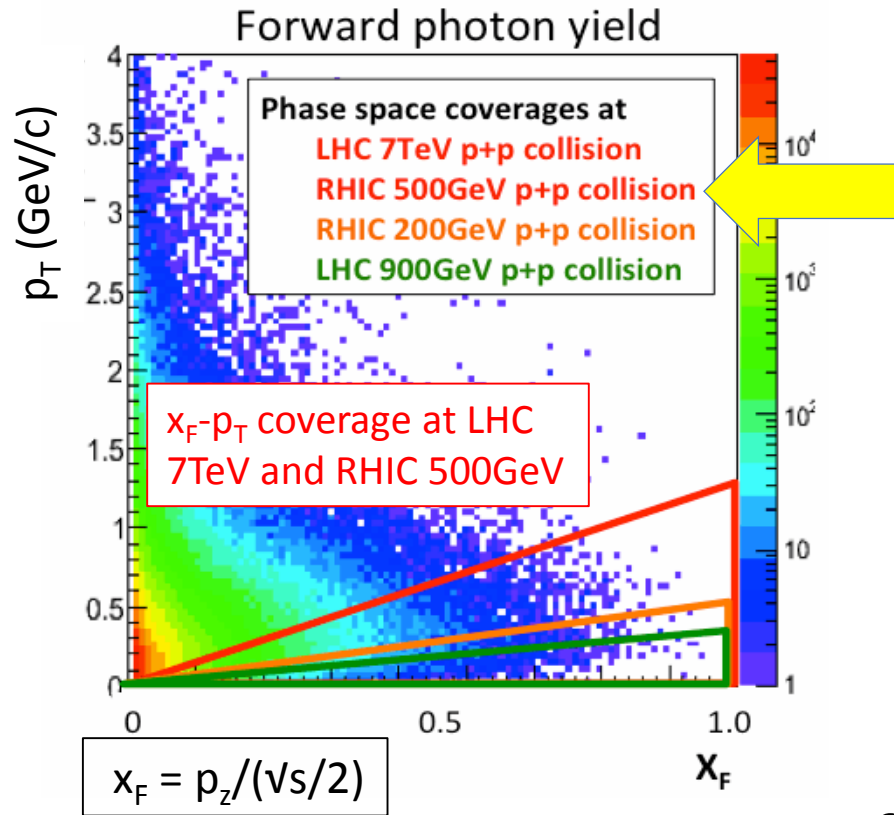
- ✓ Wide x_F - p_T coverage is desired
- ✓ Maximum p_T coverage is proportional to θv



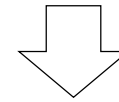
- ✓ RHIC allows larger θ with smaller v s



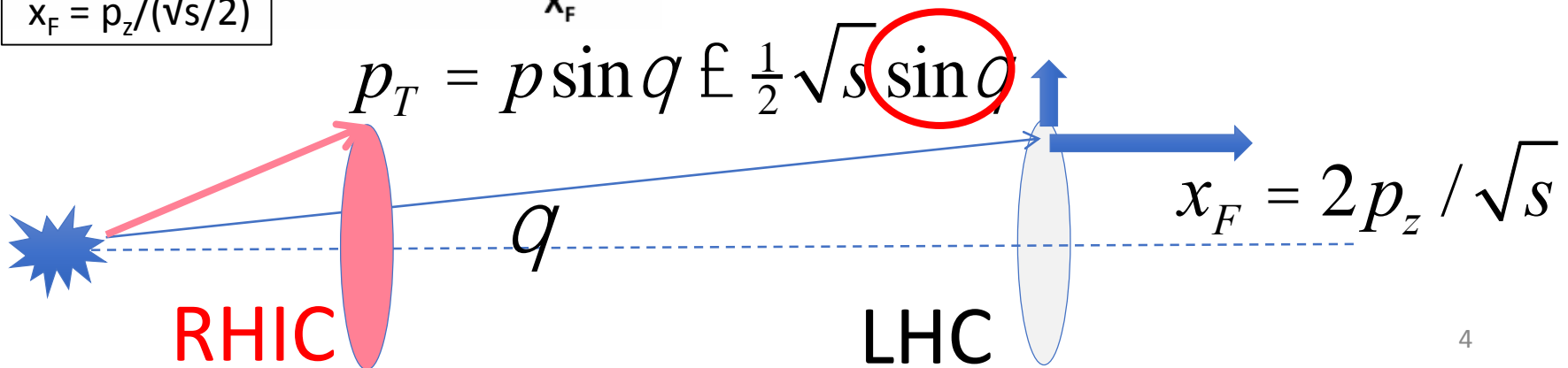
LHC 900GeVではダメなの？



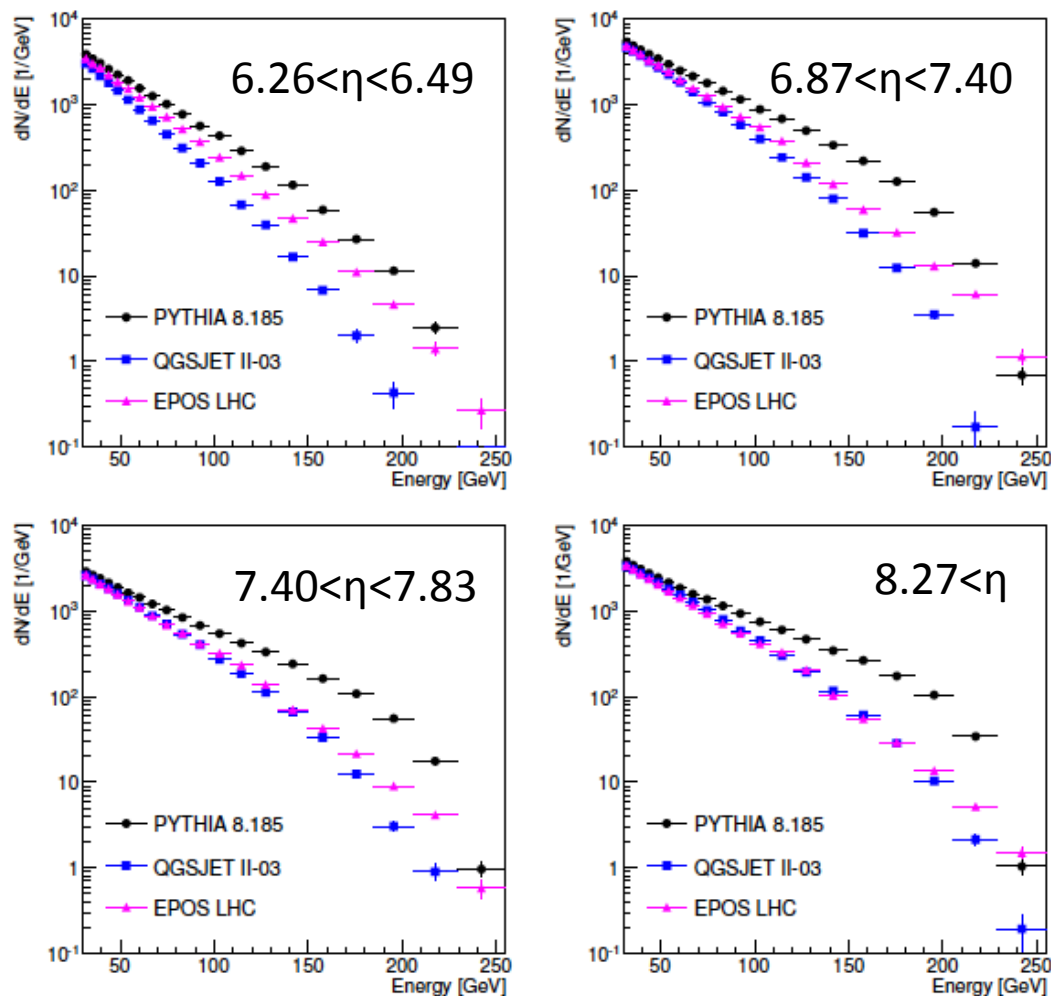
- ✓ Wide x_F - p_T coverage is desired
- ✓ Maximum p_T coverage is proportional to θv



- ✓ RHIC allows larger θ with smaller v s
- ✓ x_F - p_T coverage at LHC 7TeV and RHIC 500GeV are almost identical!!



Low energyならモデルはあってるんじゃない？

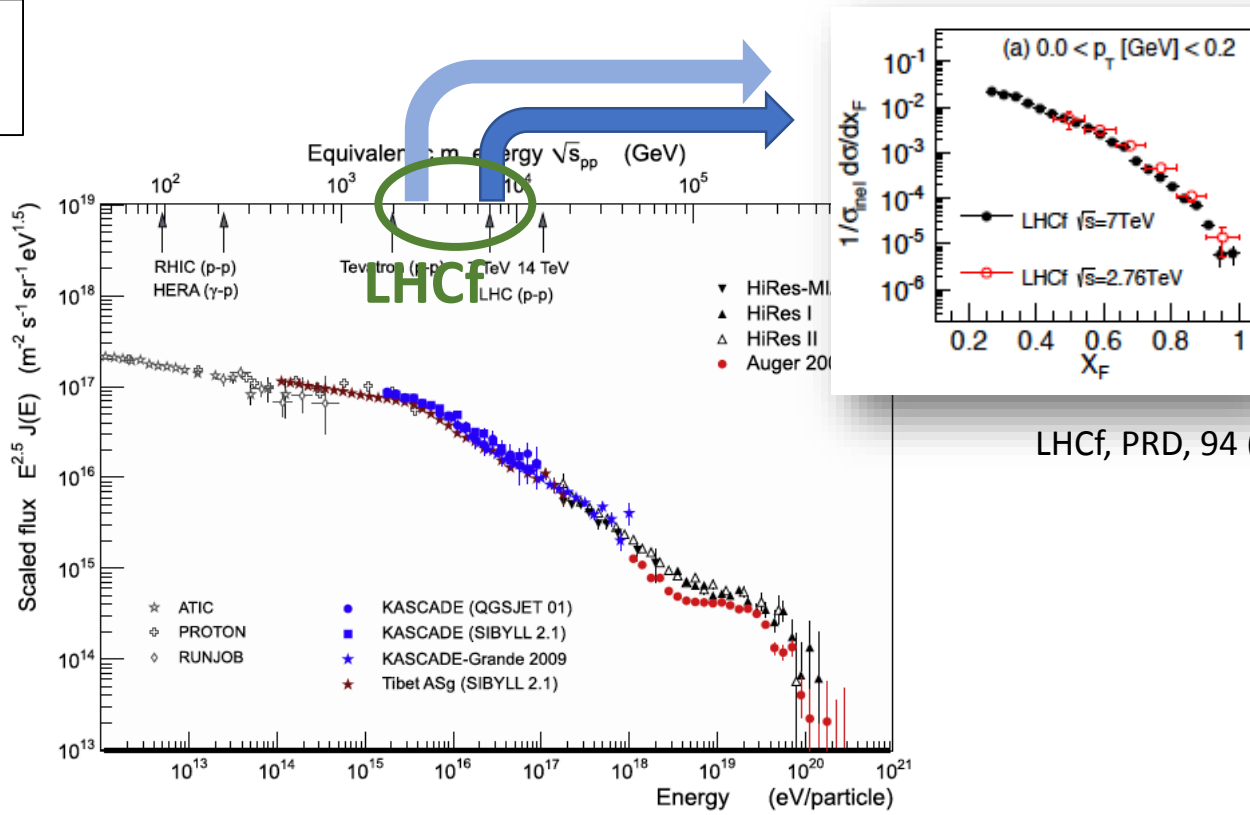


- ✓ Expected Results or Model Uncertainty ($\sqrt{s}=510\text{GeV}$, single photons)
- ✓ 4 rapidity (角度に対応)での光子スペクトル
- ✓ RHICf 12時間の測定に相当 (12 nb^{-1} effective luminosity; 360 nb^{-1} delivered)

実験では \sqrt{s} 依存はどんななの？

LHCf 2.76TeV and 7TeV data shows scaling of forward π^0

Feynman x;
 $x_F = p_z / (\sqrt{s}/2)$



π^0

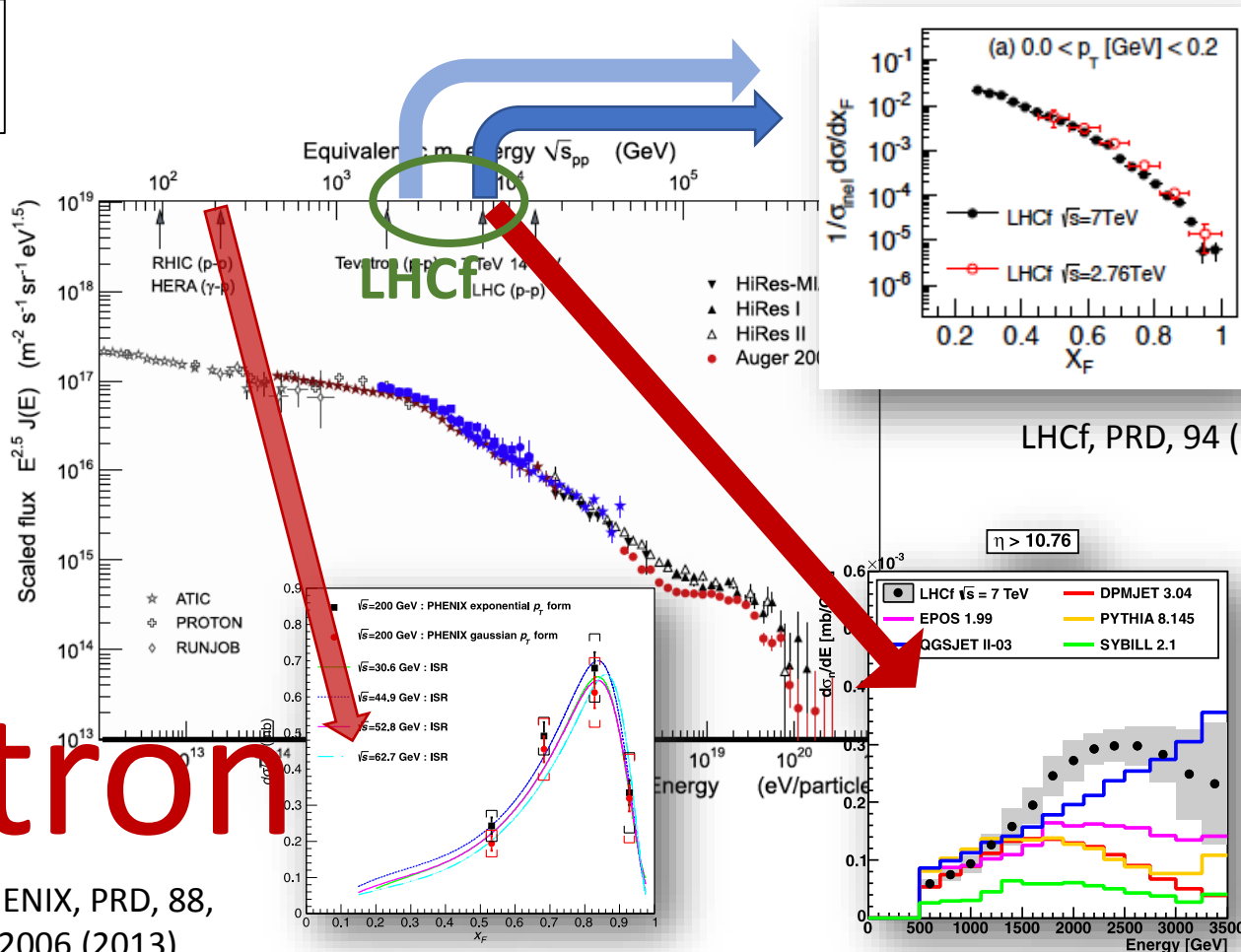
LHCf, PRD, 94 (2016) 032007

実験では \sqrt{s} 依存はどんななの？

LHCf 2.76TeV and 7TeV data shows scaling of forward π^0

Feynman x;
 $x_F = 2p_z/\sqrt{s}$

π^0



neutron

PHENIX, PRD, 88,
032006 (2013)

LHCf, PRD, 94 (2016) 032007

LHCf, PLB 750
(2015) 360-366

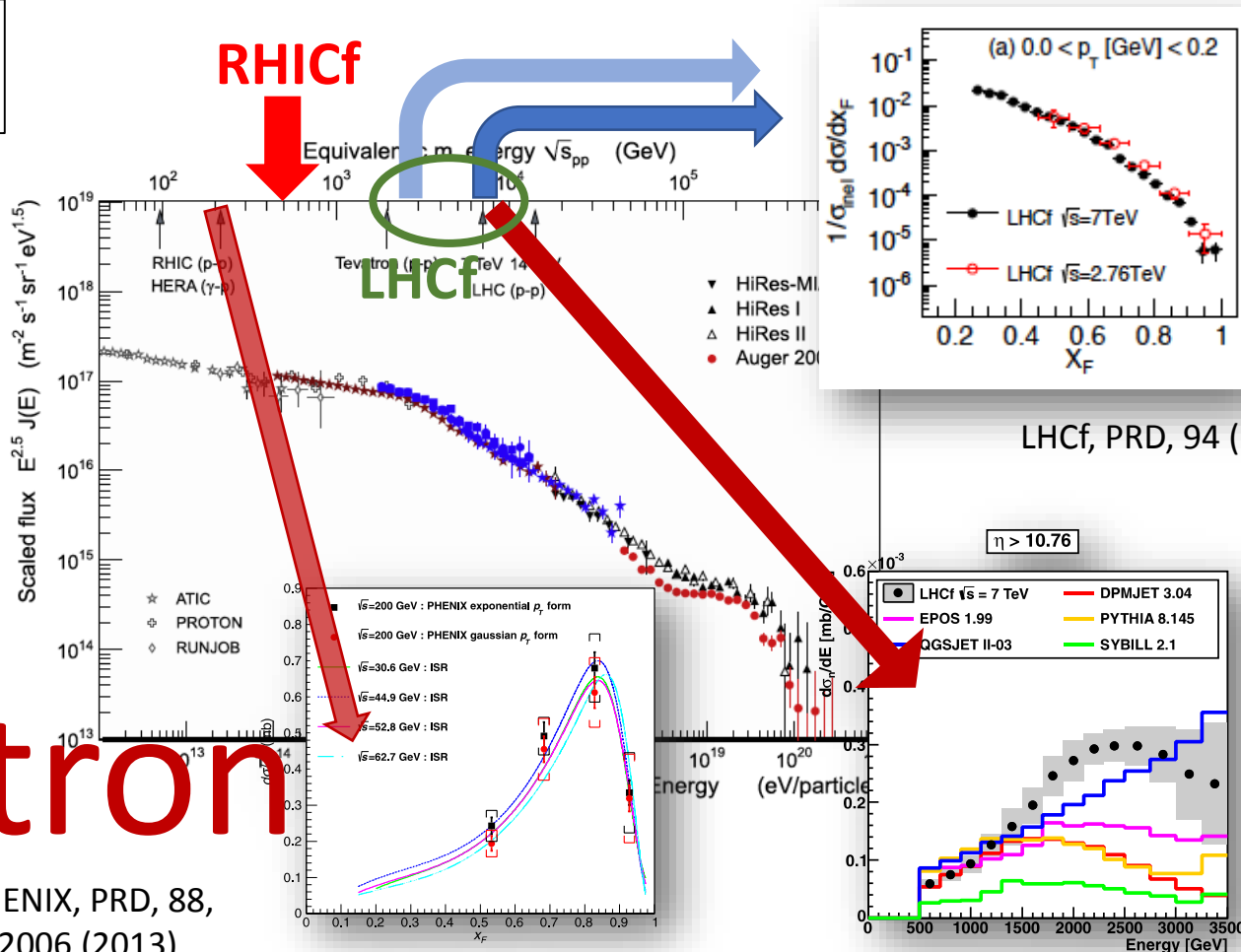
ISR (30-60GeV), PHENIX (200GeV) and LHCf (7TeV) data indicate scaling **braking** of forward neutrons

実験では \sqrt{s} 依存はどうなってるの？

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π^0



neutron

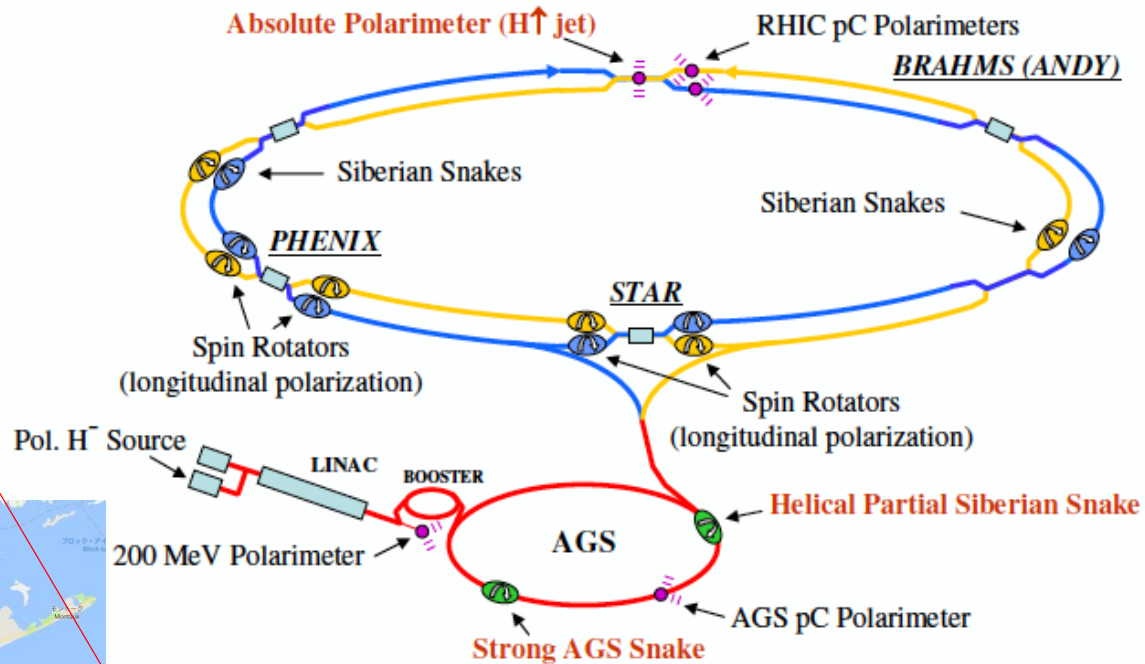
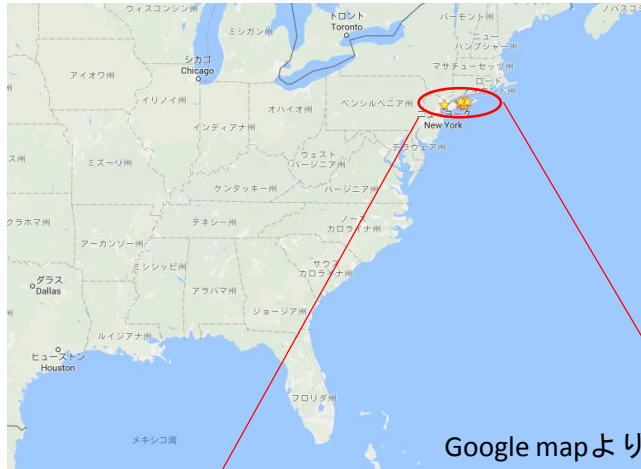
PHENIX, PRD, 88,
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ISR (30-60GeV), PHENIX (200GeV) and LHCf (7TeV) data indicate scaling **braking** of forward neutrons

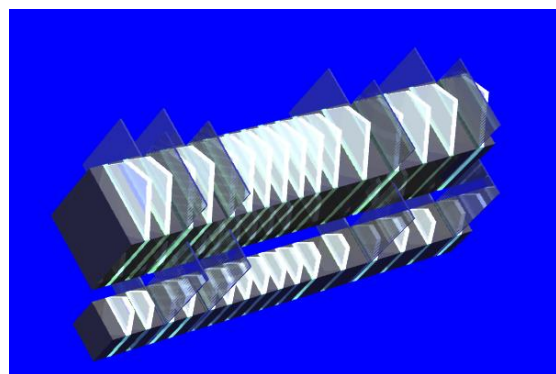
Relativistic Heavy Ion Collider



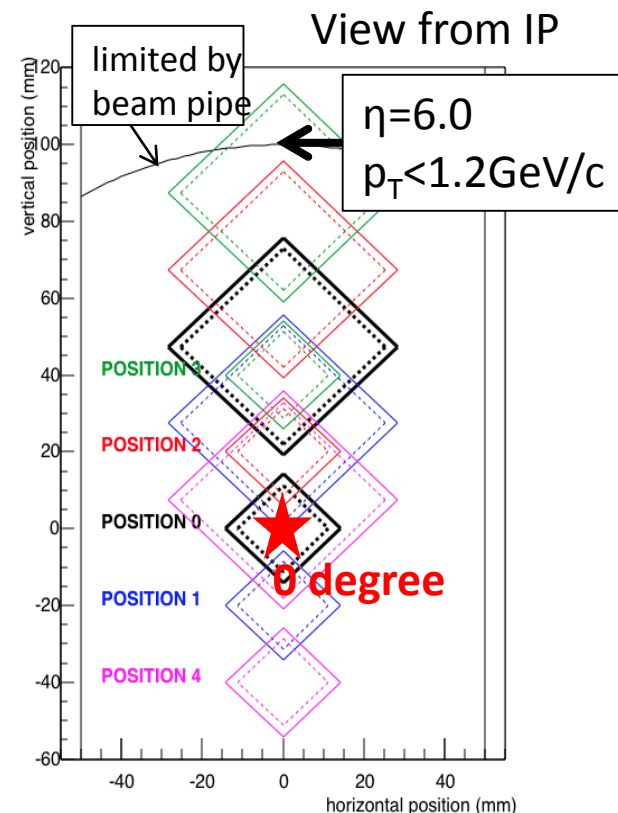
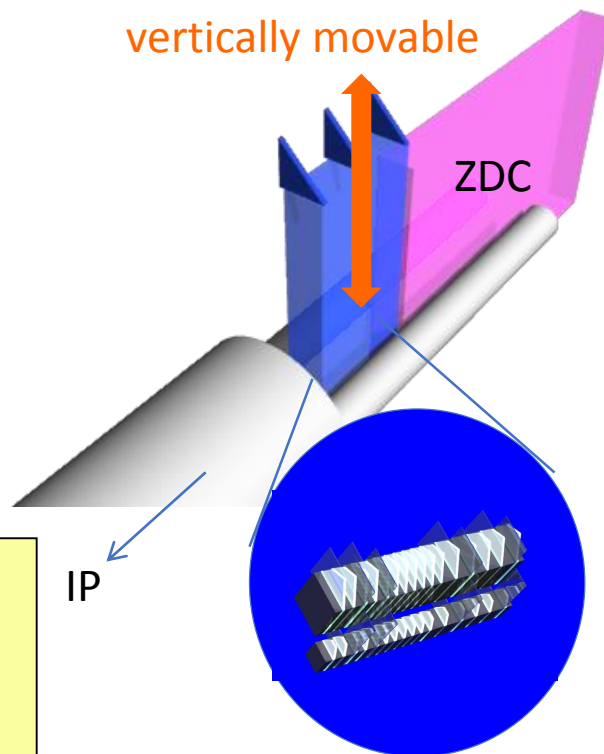
- 米国Brookhaven National Laboratoryのハドロンコライダー
- $<510\text{GeV}$ p+p衝突と、 $<200\text{GeV}/n$ 原子核衝突が可能
- スピン偏極衝突可能
- STAR実験が運転中(PHENIXが sPHENIXにアップグレード中)

LHCf Arm1 Detector => RHICf Detector

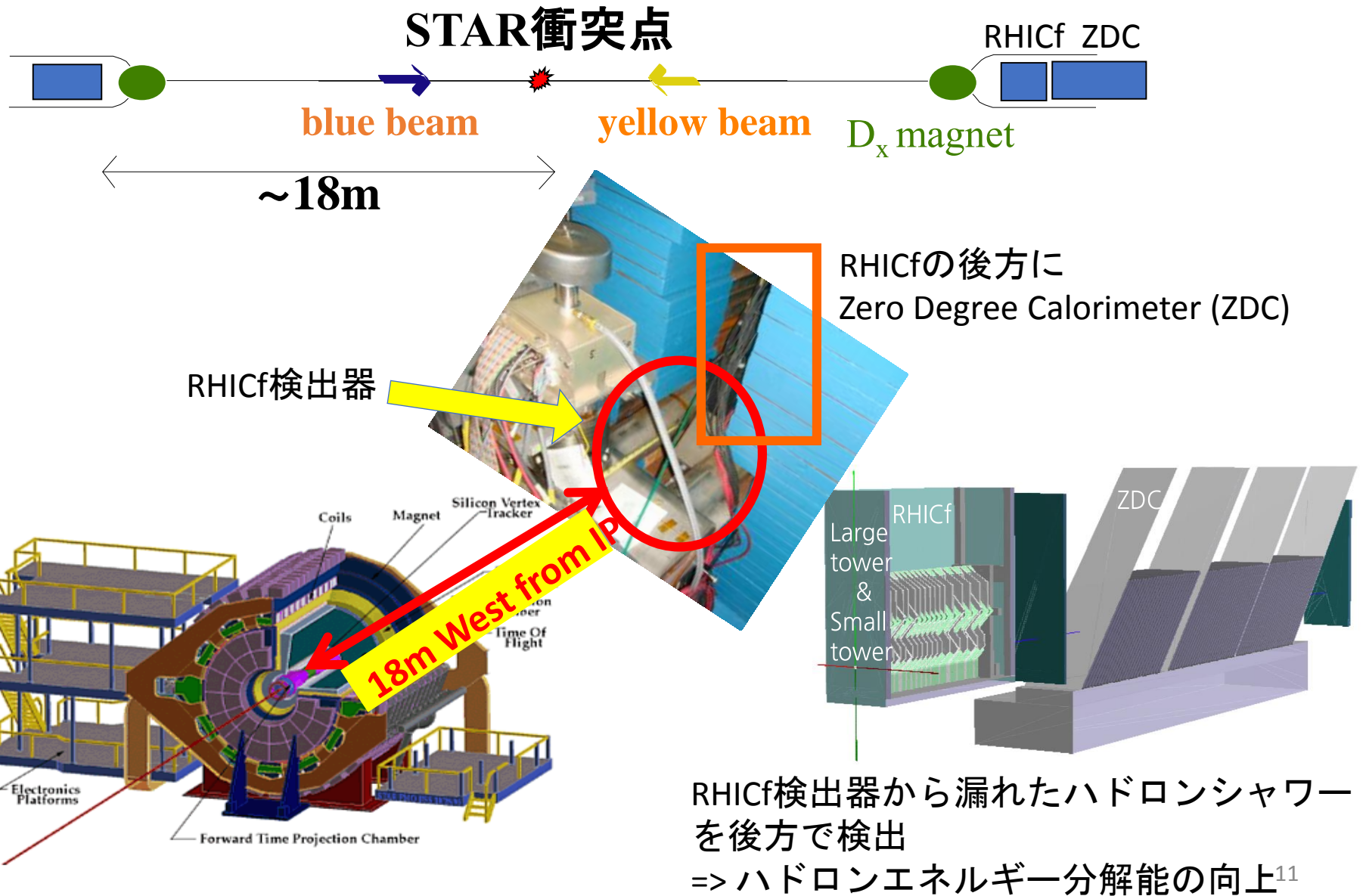
- 2台の位置検出型サンプリングカロリメータ
- タングステン 44 r.l., 16サンプリング層, 4XYペアの GSO bar hodoscope
- 光子(光子対により π^0 を同定)、中性子を検出
- 検出器を上下に動かすことで広い p_T をカバー(最大 1.2GeV/c)



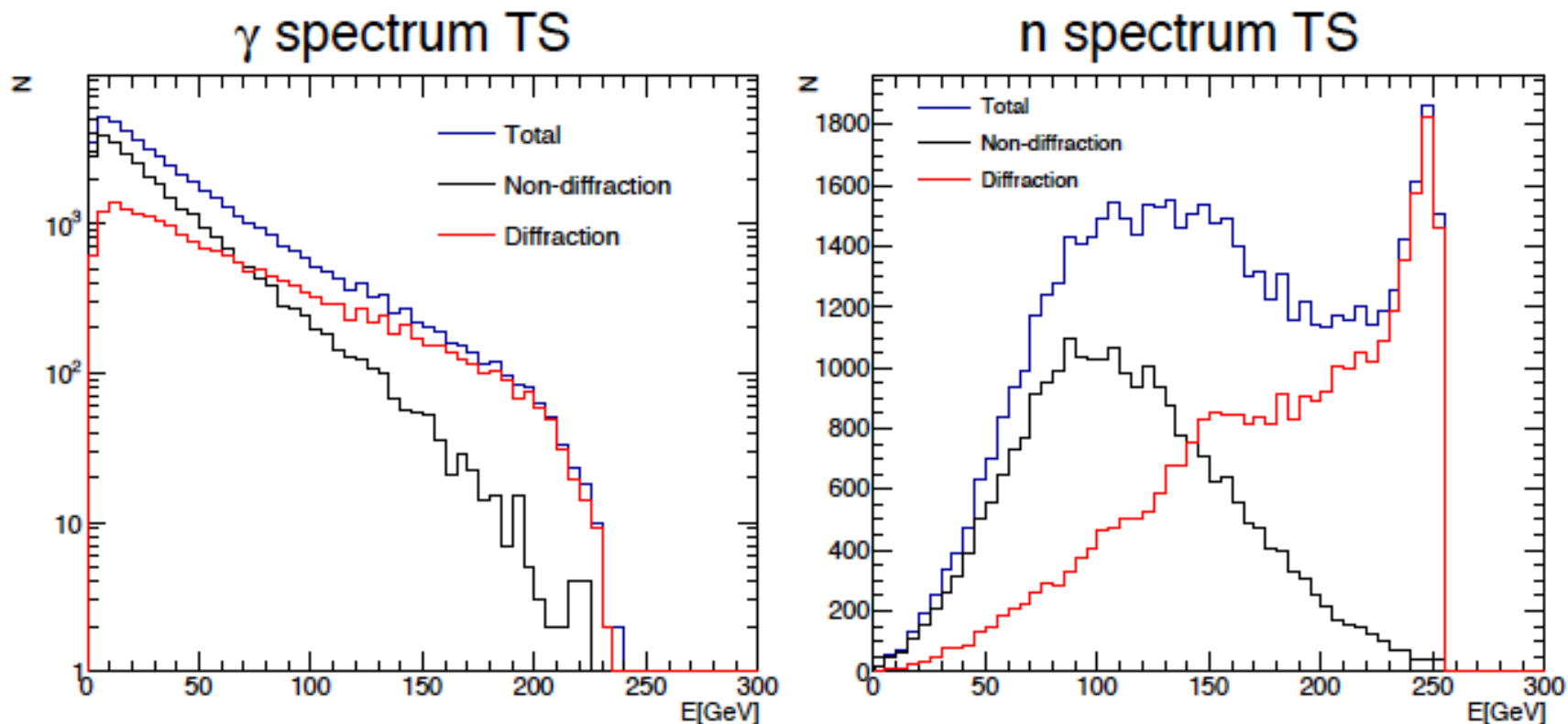
LHCf Arm1 Detector
20mmx20mm+40mmx40mm
4 XY GSO bar hodoscope



STARとの共同データ取得



diffractive vs. non diffractive at $\eta > 8.2$ with $\sqrt{s} = 510 \text{ GeV}$ p+p collisions



PYTHIA 8 simulation

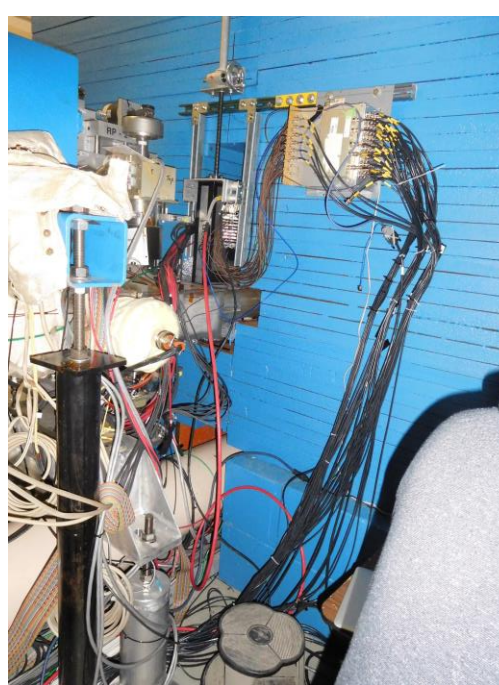
BLUE: inclusive spectra expected by RHICf only

RED: diffractive only ("RHICf + no central track in STAR" will be similar => TBC)

BLACK: non diffractive ("RHICf + ≥ 1 central track in STAR" => TBC)

RHICでの準備状況

- 検出器固定+可動機構の設置(by STAR)
- 30mケーブル(50本)の敷設
- 読み出しエレキの設置
- コントロールルームからの制御



STAR detector

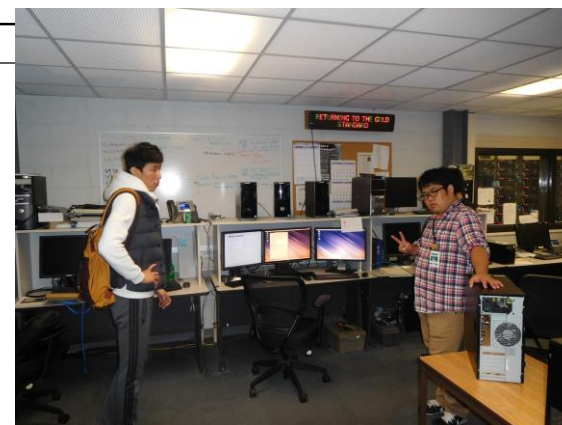
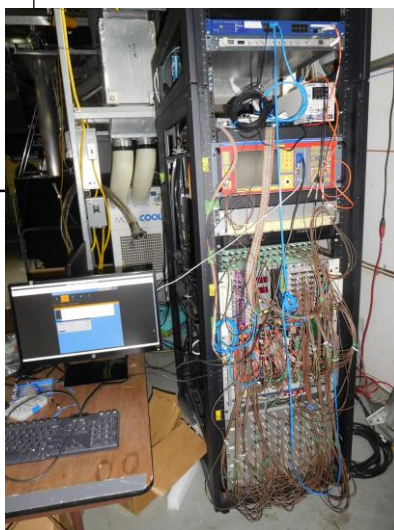
18m

DAQ
electronics

long cables

Rack room
(server PCs)

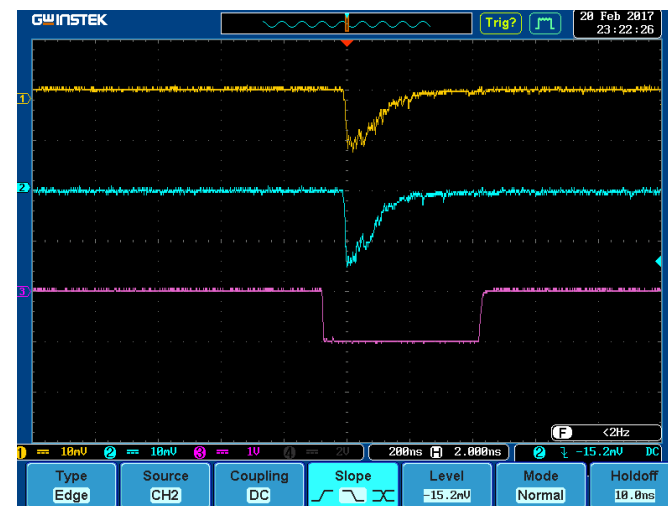
Control room



陽子衝突によるデータ収集試験



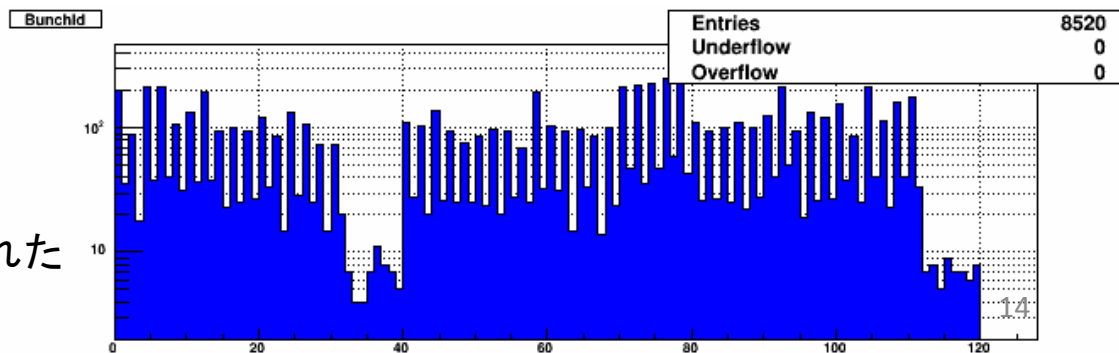
- RHICは2月20日にRUN17の最初の衝突を開始
- RHICfではすぐにPMTによるシャワー信号を確認、タイミング合わせを実施
- STAR実験との共同データ収集試験も開始
=> 試験は成功 (佐藤講演)
- 今後はonline解析等ソフトウェアの充実を図る



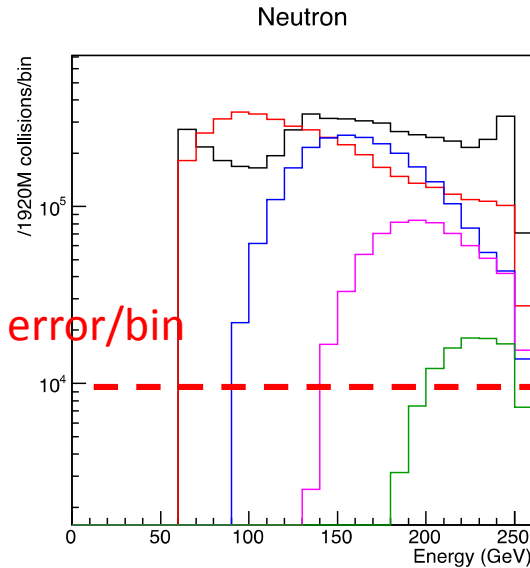
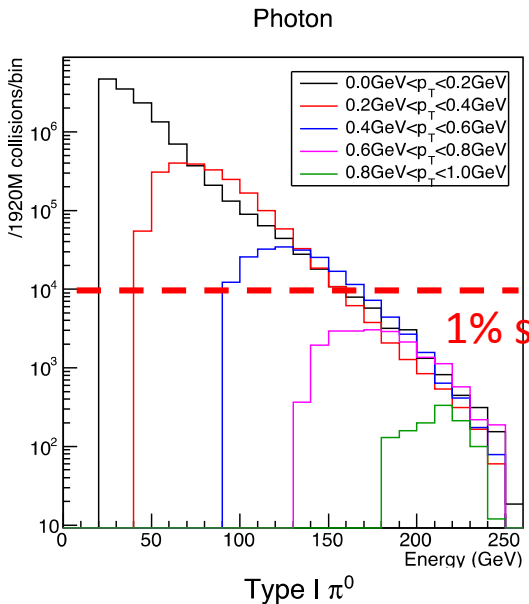
RHICf検出器のPMT信号と
タイミング調整後のADC Gate信号

6月始めに物理ラン！！

RHICfトリガーによって記録された
STARのイベントタイミング

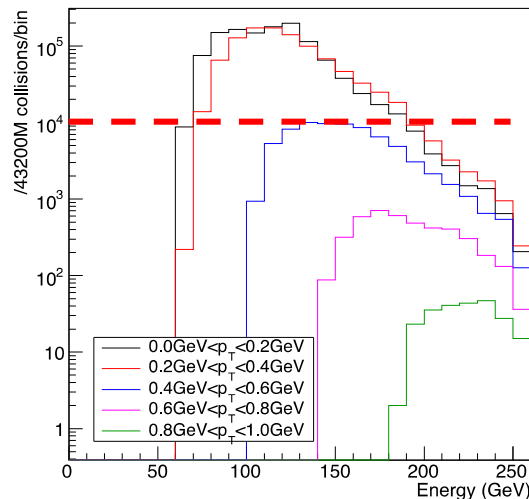


12時間の運転で期待されるイベント数



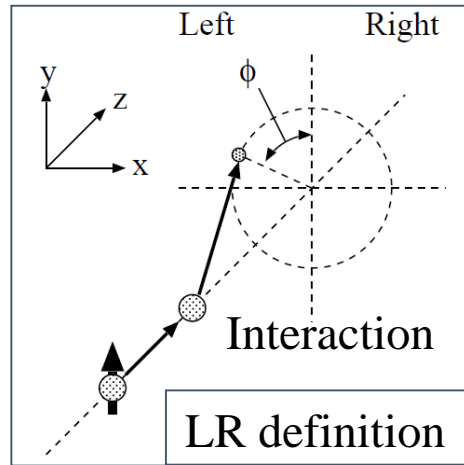
Neutron SSA

p_T (GeV)	N ($\times 10^3$)	δA
0.0–0.1	2,310	0.0013
0.1–0.2	2,570	0.0012
0.2–0.3	1,710	0.0015
0.3–0.4	2,190	0.0014
0.4–0.5	1,210	0.0018
0.5–0.6	1,130	0.0019
0.6–0.7	402	0.0032
0.7–0.8	260	0.0039
0.8–1.2	104	0.0062



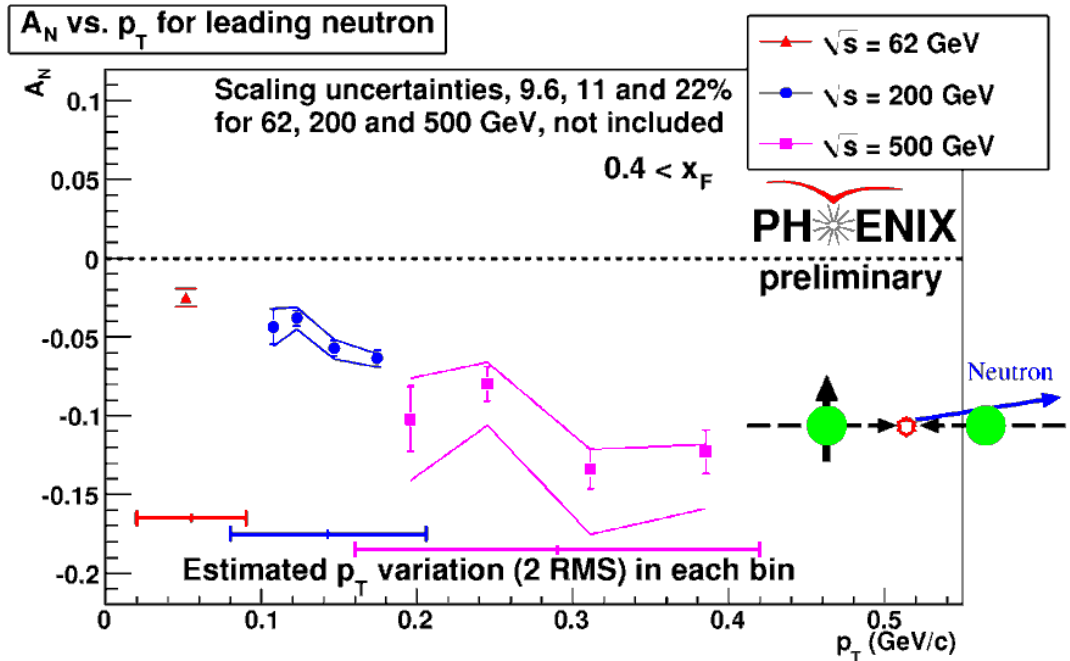
- 一週間のマシンタイム
= ビーム調整(二日) + physics測定 (二日) + contingency
- Luminosity決定精度は5%程度
- 高エネルギー光子事象増加のための special trigger準備中

SSA of forward neutron production

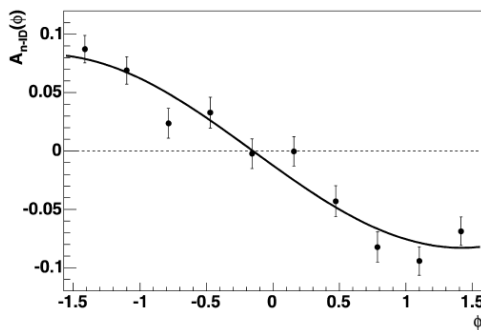


$$A_N \equiv \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow} = \frac{\sigma_L^\uparrow - \sigma_R^\uparrow}{\sigma_L^\uparrow + \sigma_R^\uparrow}$$

$$A_N = \frac{1}{P} \cdot \varepsilon_N$$



PHENIX, Journal of Phys. Conf. Ser., 295 (2011) 012097.



Y. Fukao, et al.,
Phys. Lett. B 650 (2007) 325.

- 偏極陽子衝突における前方中性子の非対称生成
- PHENIXが非対称振幅 A_N の p_T 依存性を報告
(異なる衝突エネルギーデータを利用)
- RHICfは、単一衝突エネルギー(510GeV)でPHENIXよりも広い p_T 範囲で A_N を測定可能

Theoretical explanation

- Pion- a_1 interference: results
 - The data agree well with independence of energy
- The asymmetry has a sensitivity to presence of different mechanisms, e.g. Reggeon exchanges with spin-non-flip amplitude, even if they are small amplitudes

$$A_N \approx \frac{2 \operatorname{Im}(fg^*)}{|f|^2 + |g|^2}$$

f : spin non-flip amplitude
 g : spin flip amplitude

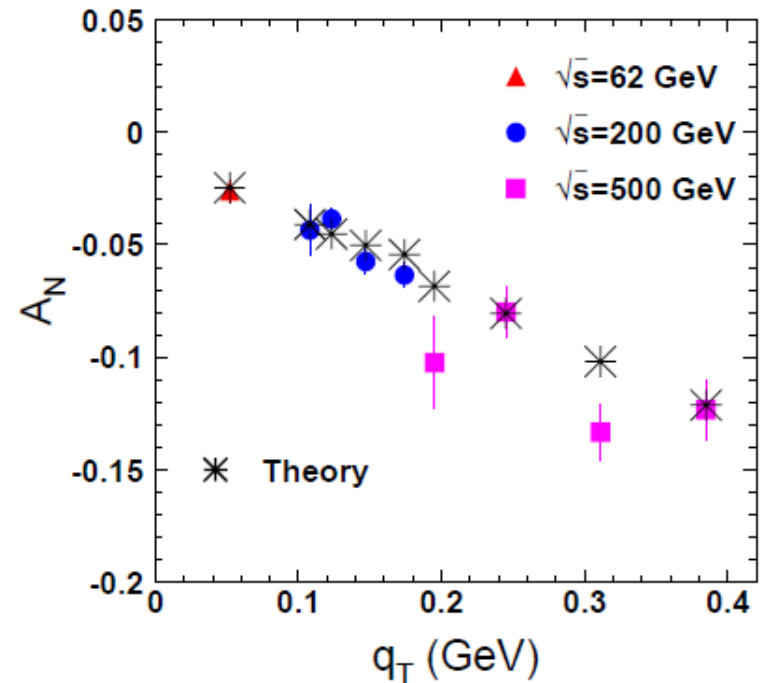


FIG. 1: (Color online) Single transverse spin asymmetry A_N in the reaction $pp \rightarrow nX$, measured at $\sqrt{s} = 62, 200, 500$ GeV [1] (preliminary data). The asterisks show the result of our calculation, Eq. (38), which was done point by point, since each experimental point has a specific value of z (see Table I).

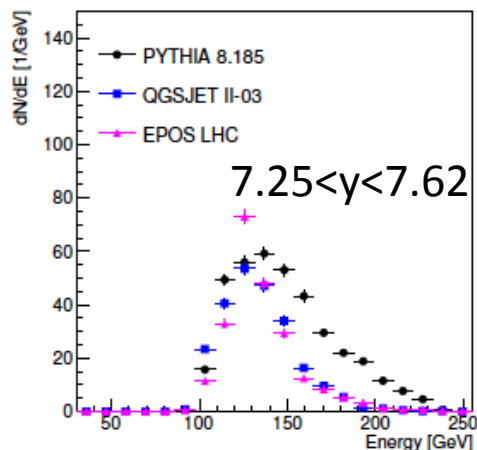
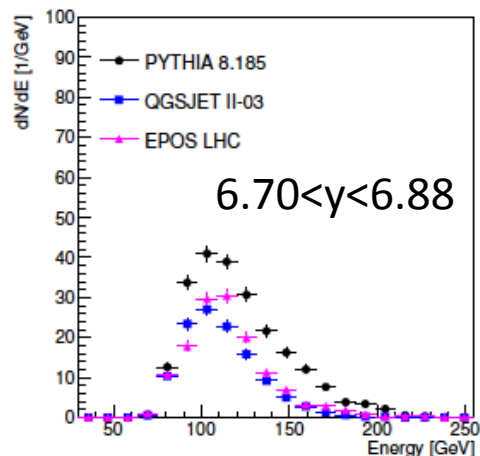
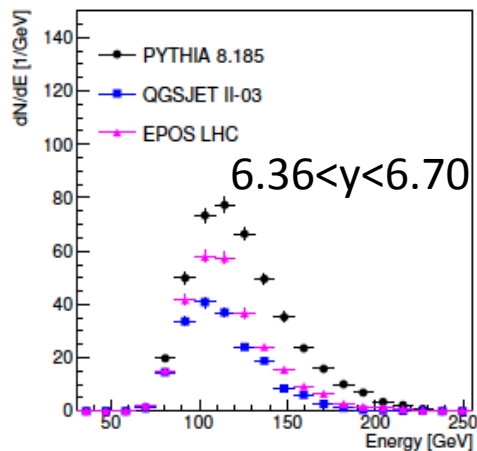
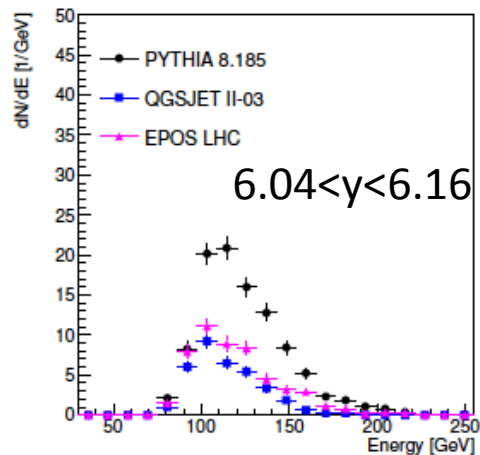
Kopeliovich, Potashnikova, Schmidt, Soffer: Phys. Rev. D 84 (2011) 114012.

まとめ

- RHICでLHCfと同様の測定 RHICfを実施する
 - LHC低エネルギー衝突でできるんじゃない？
=> NO. LHCでは p_T coverageが狭すぎる
 - 低エネルギーではモデルに不定性はないんじゃない？
=> NO. モデル tuneがすすんだのはLHCが始まってから
 - 衝突エネルギー(\sqrt{s})依存性なんてないんじゃない？
=> これを実験で検証することが宇宙線に重要
- RHICf実験の準備進行中
 - 今年の6月に $\sqrt{s}=510\text{GeV}$ で物理データ取得予定
 - STARとの共同データ収集も準備OK
 - 偏極陽子衝突による素過程(meson exchange)の追求も実施

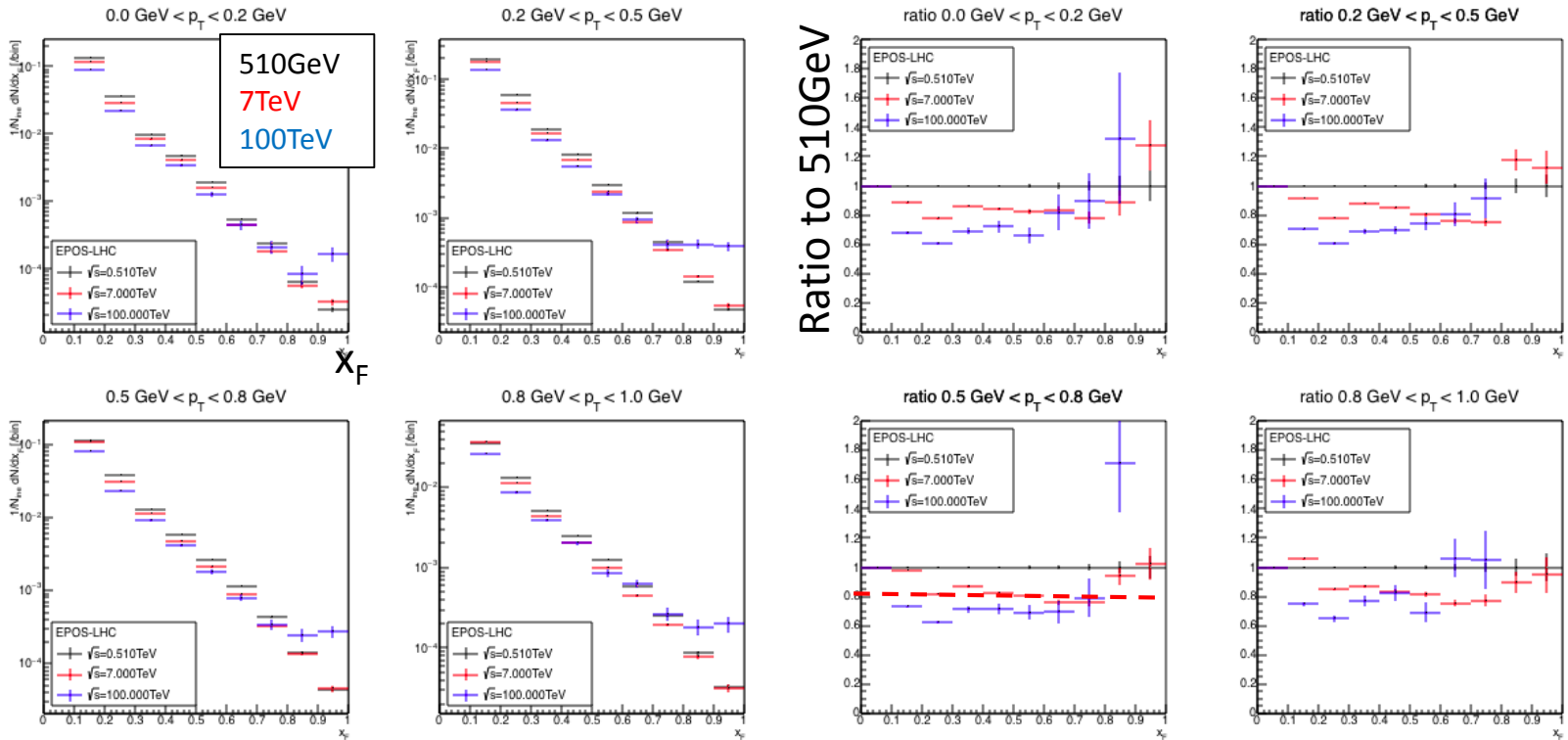
backup

Expected Results (π^0)



- ✓ 4 rapidityでの π^0 のエネルギースペクトル
- ✓ $\pi^0 \rightarrow \gamma\gamma$ の二光子の開き角の制限より $>60\text{GeV}$ で測定可能
- ✓ **24分**の測定相当 (12 nb^{-1} effective luminosity; 12 nb^{-1} delivered)

Scaling in interaction model



π^0 cross section by EPOS-LHC model

20% reduction in cross section is predicted from 510GeV to 7TeV