Measurement of prompt photon in $\sqrt{s}$=200GeV pp collisions with isolation cut method

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RIKEN

JPS meeting at Kouchi Univ.

Motivation

- Physics meaning of direct photon
  - Is a good probe of parton structure in proton.
    - One of simple process at hadron collisions.
- Why direct photon at RHIC?
  - A reference for QGP search
  - A baseline for measurement of gluon spin
    - RHIC provide the highest energy as proton-proton collisions in the world.➔ another baseline for the structure in proton.
- Contents of this talk
  - Perform another isolation method following the previous talk (by Kensuke).
    - The method in this talk provides better S/N ratio than the previous one.
  - The direct photon and fragmentation photon can be separated by the isolation method.
  - Compare the result with the past experiments and an NLO-pQCD calculation.

Direct Photon Production

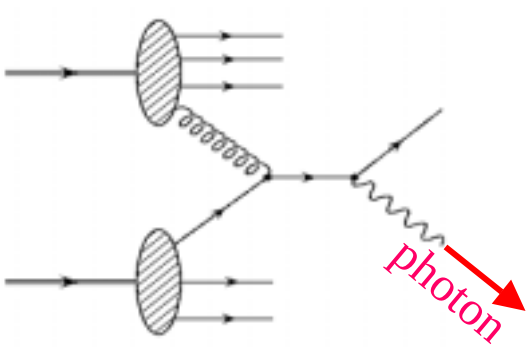
ハドロン衝突における単光子測定は、2つのプロセスからなる。

$$\sigma = \sigma_{dir} + \sigma_{frag} = \sum_{i,j,k} \int dx_i dx_j \times f_1^i(x_i,\mu) \cdot f_2^j(x_j,\mu) \times \left\{ \sigma(i+j \to \gamma) + \int dz\, \sigma(i+j \to k) \times D_k^3(z_k,\mu_F) \right\}$$

parton distribution function(PDF)

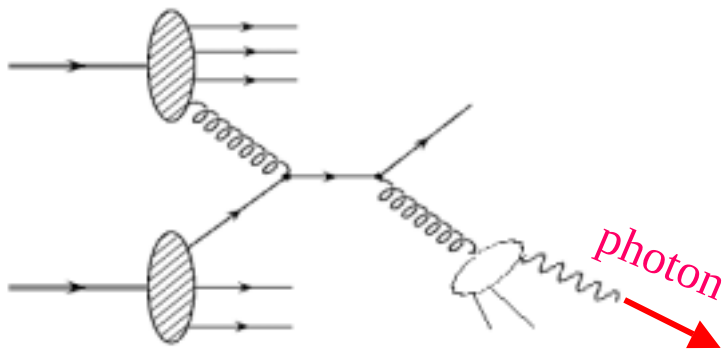
fragmentation function(FF)

Direct Process



Compton/Annihilation process

Fragmentation Process



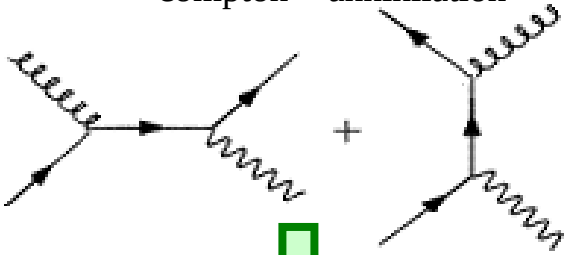
PDF/FF**は主に** deep inelastic scattering(DIS)/e^++e^-**消滅反応で測定。**

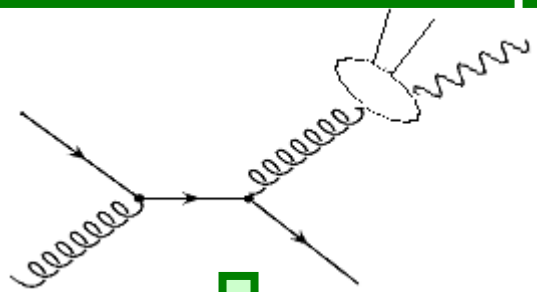
本研究では、これらのPDF/FF**を使った** next-to-leading order(NLO) pQCD**計算との比較を行う**

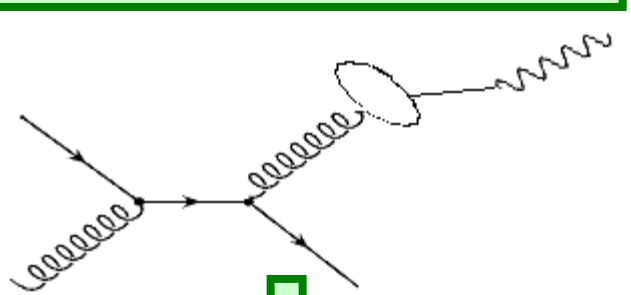
Strategy of Isolation Method

(1)Signal(direct) | (2)Signal(fragmentation) | (3)Background(hadron decay)

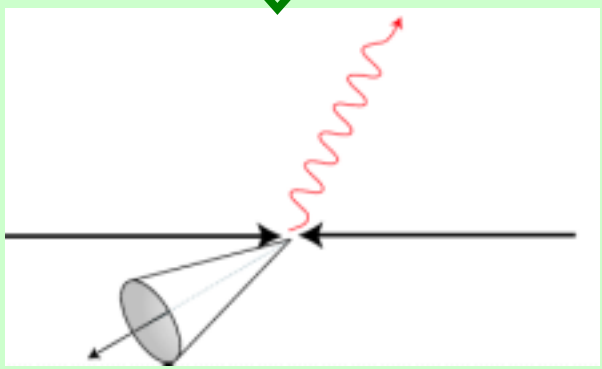
compton + annihilation



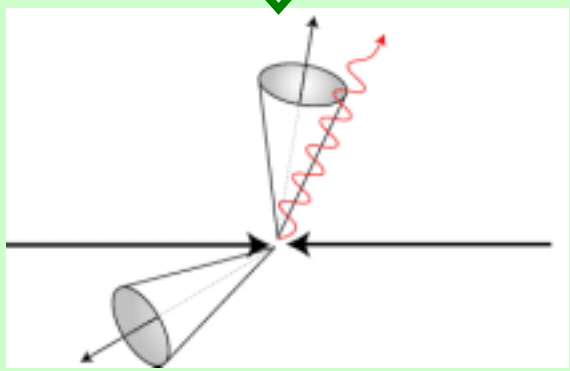




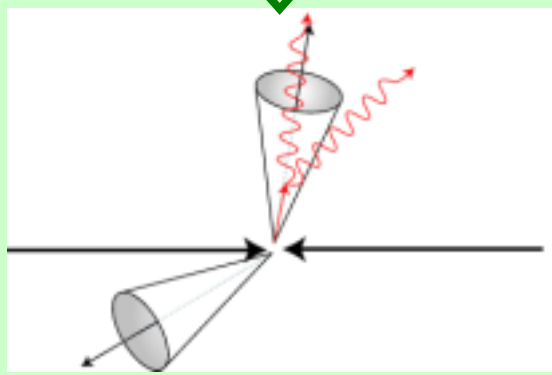
実験系でのイメージ



約30%@10GeV



約10%@10GeV

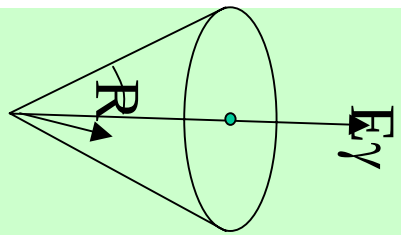


約50%@10GeV

Isolation cut to reduce background

$$R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.5$$

$$E_{sum}(R < 0.5) < E_\gamma \times 0.1$$



What is the efficiency by this cut for signal 1)&2)➔Next slide

Efficiency of the Isolation Cut

- What cause the efficiency/inefficiency?
  - Event structure
    - Especially, the signal of fragmentation type will be reduced by this cut.
  - PHENIX acceptance is not perfect so that it can't cover all the cone.
  - Underlying event due to the multi-parton scattering.
- The efficiency of the isolation cut needs to be estimated by Monte Carlo Simulation.
  - The simulation depends on the model of the Monte Carlo.
  - The estimated efficiency by PHTHIA simulation
    - For the signal(direct) >90% for pT>5GeV/c
    - For the signal(fragmentation) now working.

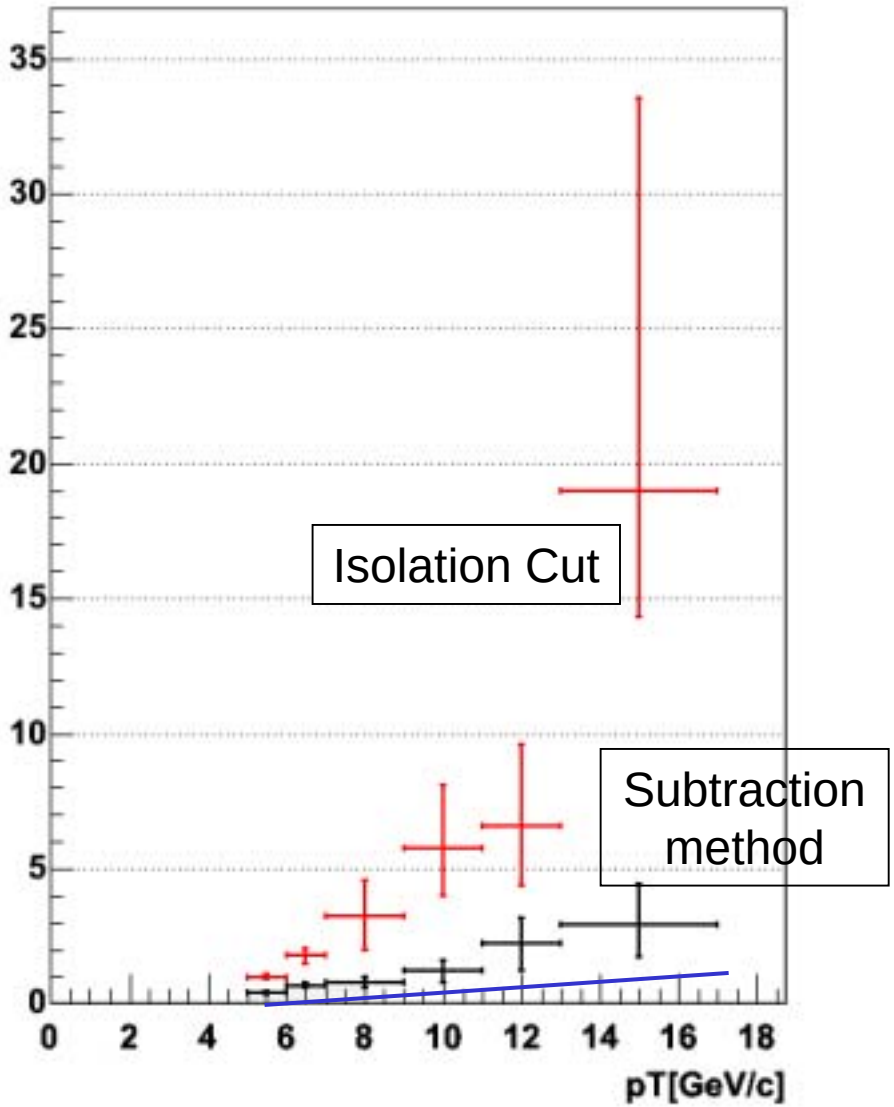
      T.Horaguchi and K.Nakano are working for these physics.
- In this talk, we compare the previous result shown by Kensuke and the result from the isolation method without correction for the efficiency.
  - The comparison may enable us to separate different two signals, direct or fragmentation photon.

Event Selection and Analysis

- Event Selection
  - Data are taken during Run3 p+p run.
    - 2003/Apr – May
    - Both photons are longitudinally polarized at PHENIX.
  - Data samples triggered by ERT is used in this analysis.
    - 266pb-1 equivalent.
- Analysis procedure.
  - The base samples are photons
    - EM shower is photon-like
    - No charge hit on chambers in front of EMCal.
    - Isolation cut .
  - Photons from pi0 decay is identified from data itself.
    - For the contribution of pi0 which was not able to be detected and for that of other hadrons (omega eta, etc), a Monte Carlo simulation used.
    - Cross section of pi0 and eta are
- Cross section calculation $$E\frac{d^3\sigma}{dp^3} = 1/L \times \frac{1}{2\pi p_T} \times \frac{N_{photon}}{\varepsilon_{eff} \times \varepsilon_{acc} \times \varepsilon_{triggerbias}}$$

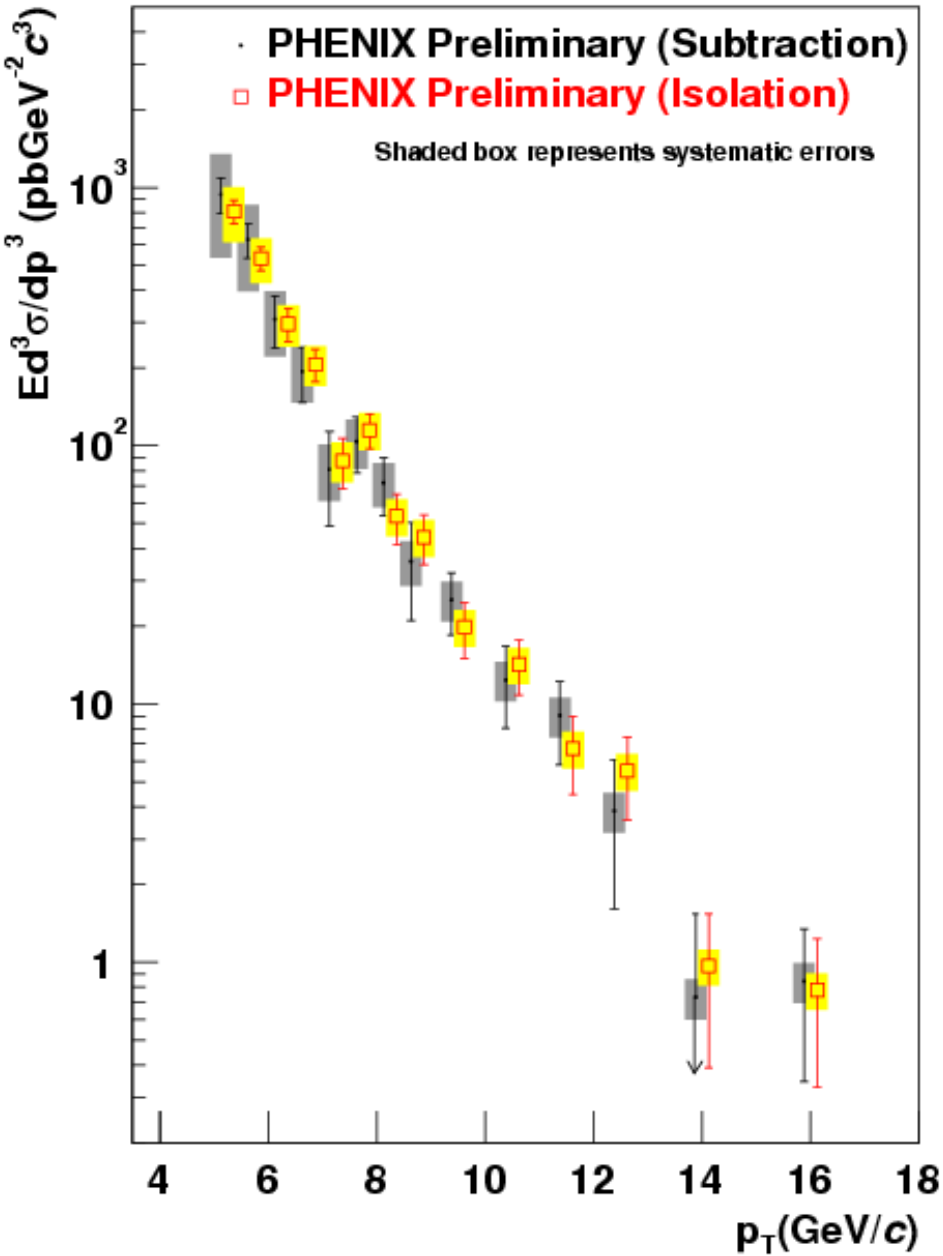
S/N Ratio with Isolation Cut

- The S/N ratio improve by a factor of about 5
  - Especially, in this method
- This method works very well!!!
  - Good S/N ratio is essential for the future ALL measurement.



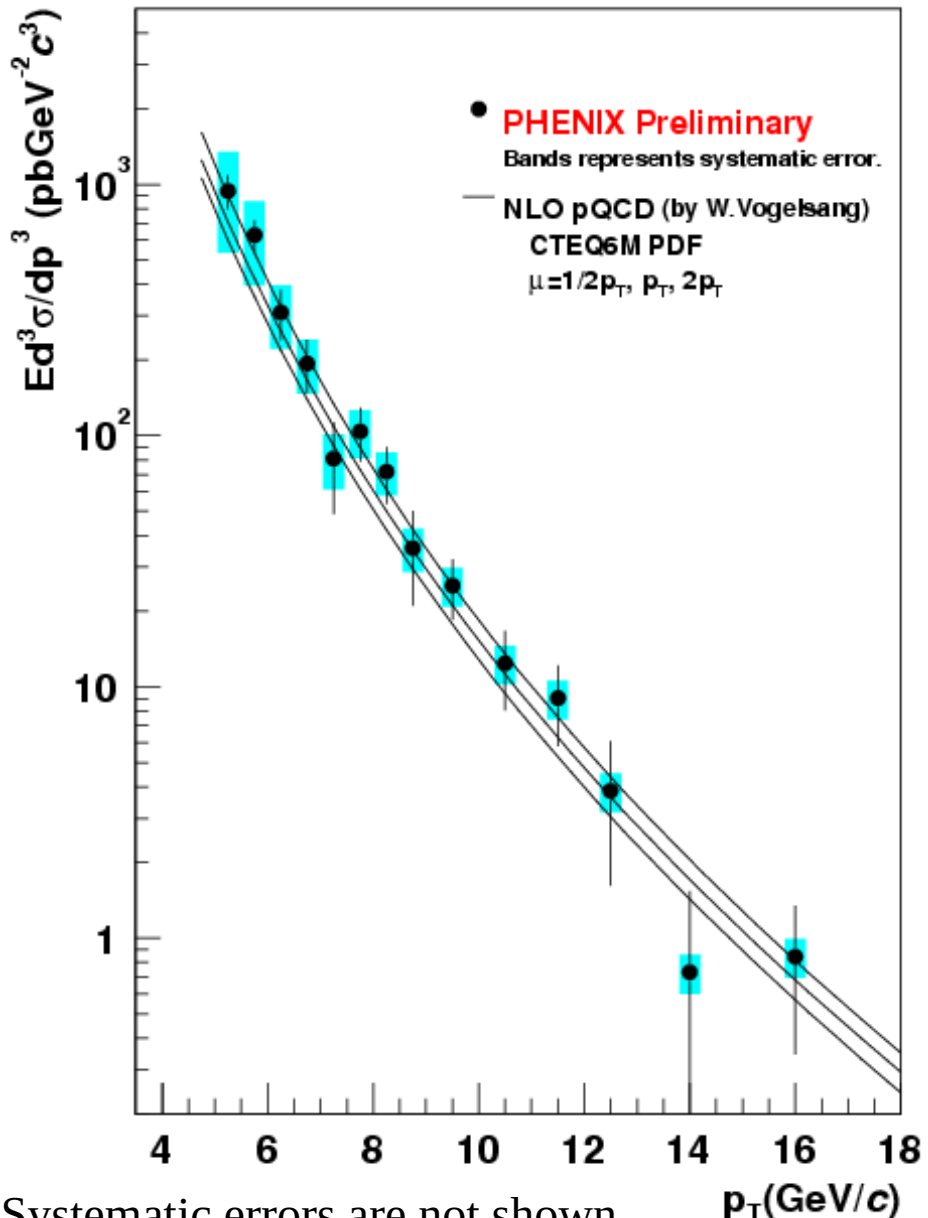
Results

- Comparison with the result by subtraction method shown by previous talker (Kensuke)
- The two results are not different as expected.
  - This fact indicates whether
  - The fragmentation photon pass through the isolation cut
  - Or
  - The measured prompt photon(shown by Kensuke) is dominated by direct photon.
- The further analysis is on going.



Comparison with pQCD

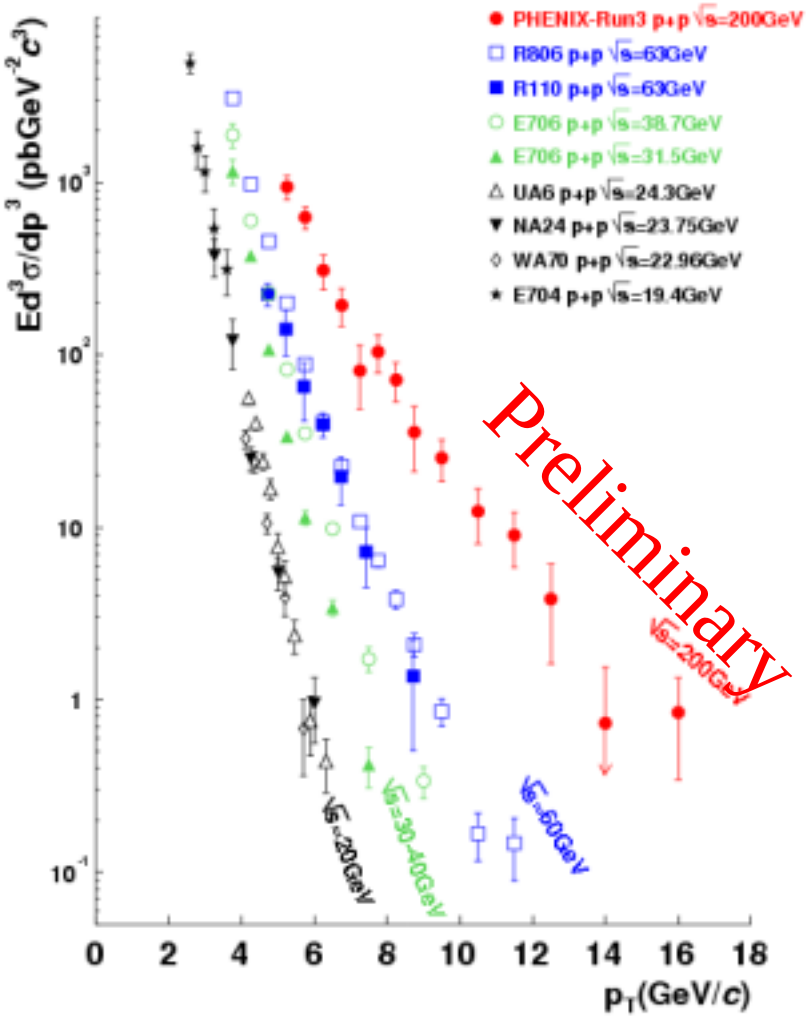
- Results
  - From subtraction method shown in the previous talker(Kensuke)
- Comparison with an NLO-pQCD calculation
  - Private communication with W.Vogelsang
  - With CTEQ6M PDF.
  - Three different scales.
- The present result is consistent within the pQCD calculation at three different scales.

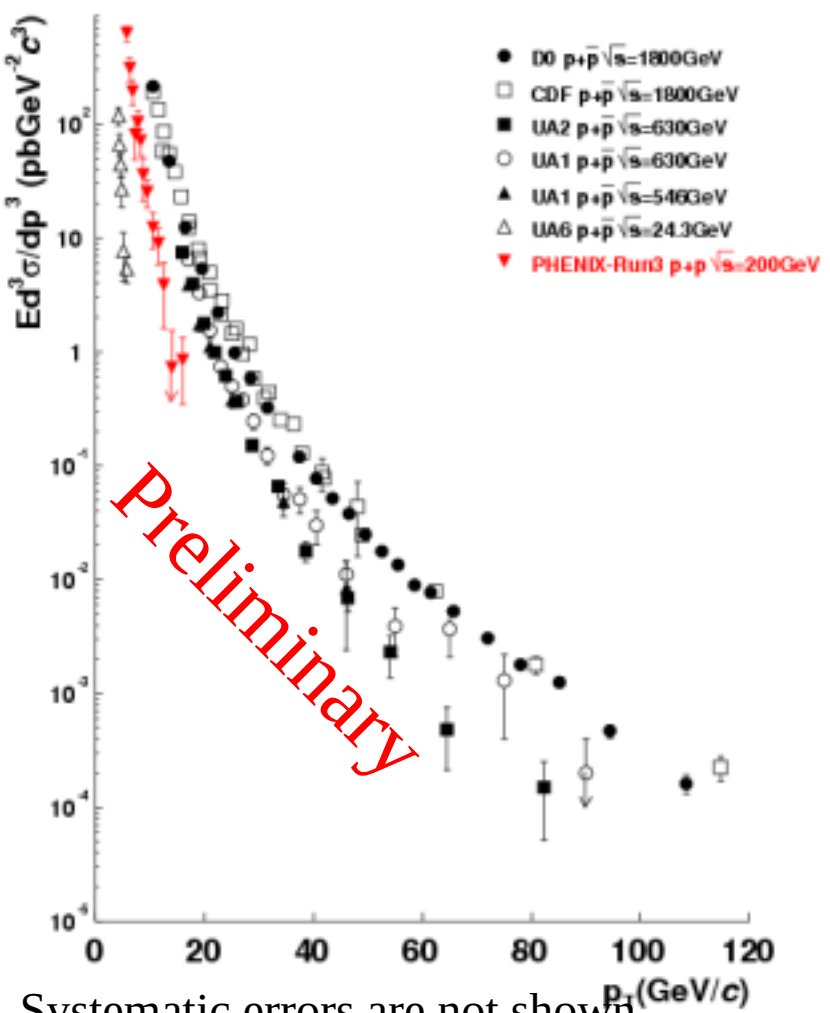


Systematic errors are not shown

Comparison

- Comparison with existing data from p+p and p+pbar collisions
  - The cross section increases systematically as the energy increases.





Systematic errors are not shown

x_Tスケーリング則

- QCD理論によると、以下の仮定
  - PDFとFFのQ^2スケーリング
  - Coupling constant(α_s)がQ^2に非依存

$$\sigma = \left(\sqrt{s}\right)^{-n} \times F\left(x_T\right)$$

n=定数。$x_T=2p_T/\sqrt{s}$

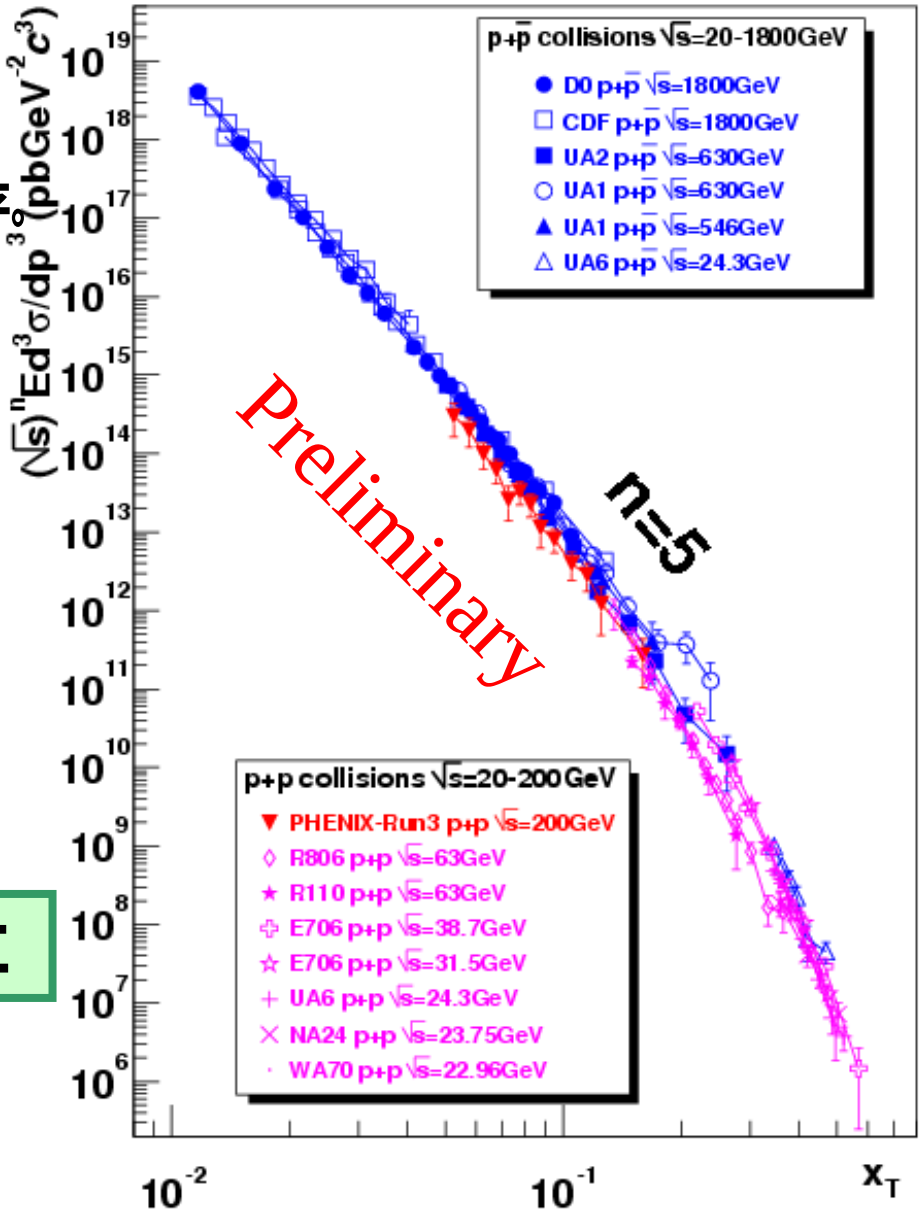
  - 相互作用項と構造を表す項に分離

➔x_Tスケーリング

  - 定数nに対する予想
    - Leading order n=4
    - Next-to-leading order: n=4+α

x_Tスケーリング則n=5付近で成立

今回得られたデータを過去のデータ($\sqrt{s}$>20GeV)と比較して、x_Tスケーリング則がn=5付近で成り立つ。



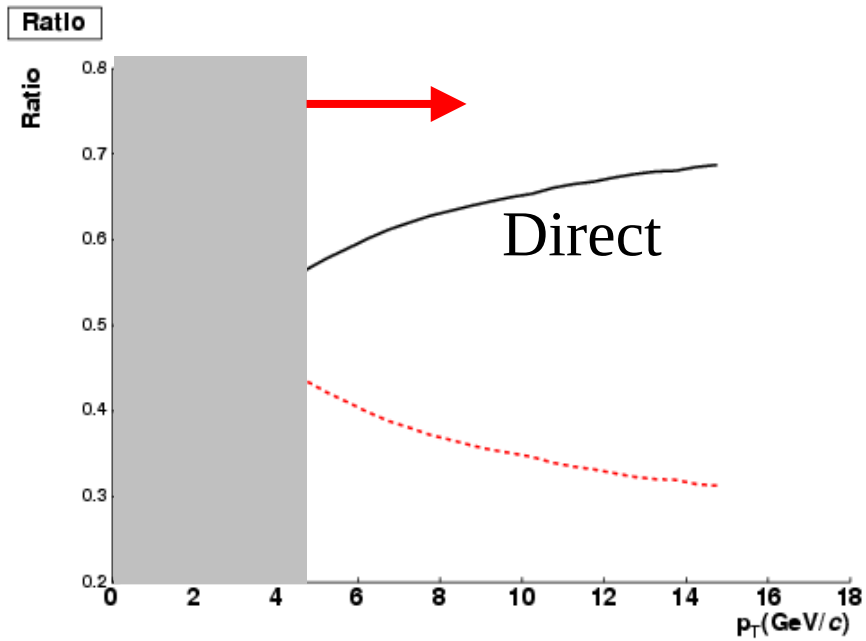
Conclusion

- Direct photon measurement at p-p collisions is very important for QGP search and spin physics at RHIC.
- Isolation method
  - Is expected to be useful to separate two signals, direct and fragmentation.
  - Works very well to improve the S/N.
    - Will be used for the future analysis of ALL measurement
  - Shows consistent result with the previous result (by Kensuke)
- Results
  - The result from isolation method is not so different from that from subtraction method.
    - This indicates whether
      - Fragmentation photon pass through the isolation cut
      - The measured prompt photon (reported by Kensuke) is dominated by direct photon.
  - pQCD calculation (with the PDF measured by DIS) can describe very well
    - The present result shows consistent information about the structure.
    - This fact is very essential for the future analysis of ALL.
  - X-T scaling shows a point like interaction of the measurement.

Backup Slides

Bias on Physics Process

- Two processes
  - Direct
  - Fragmentation



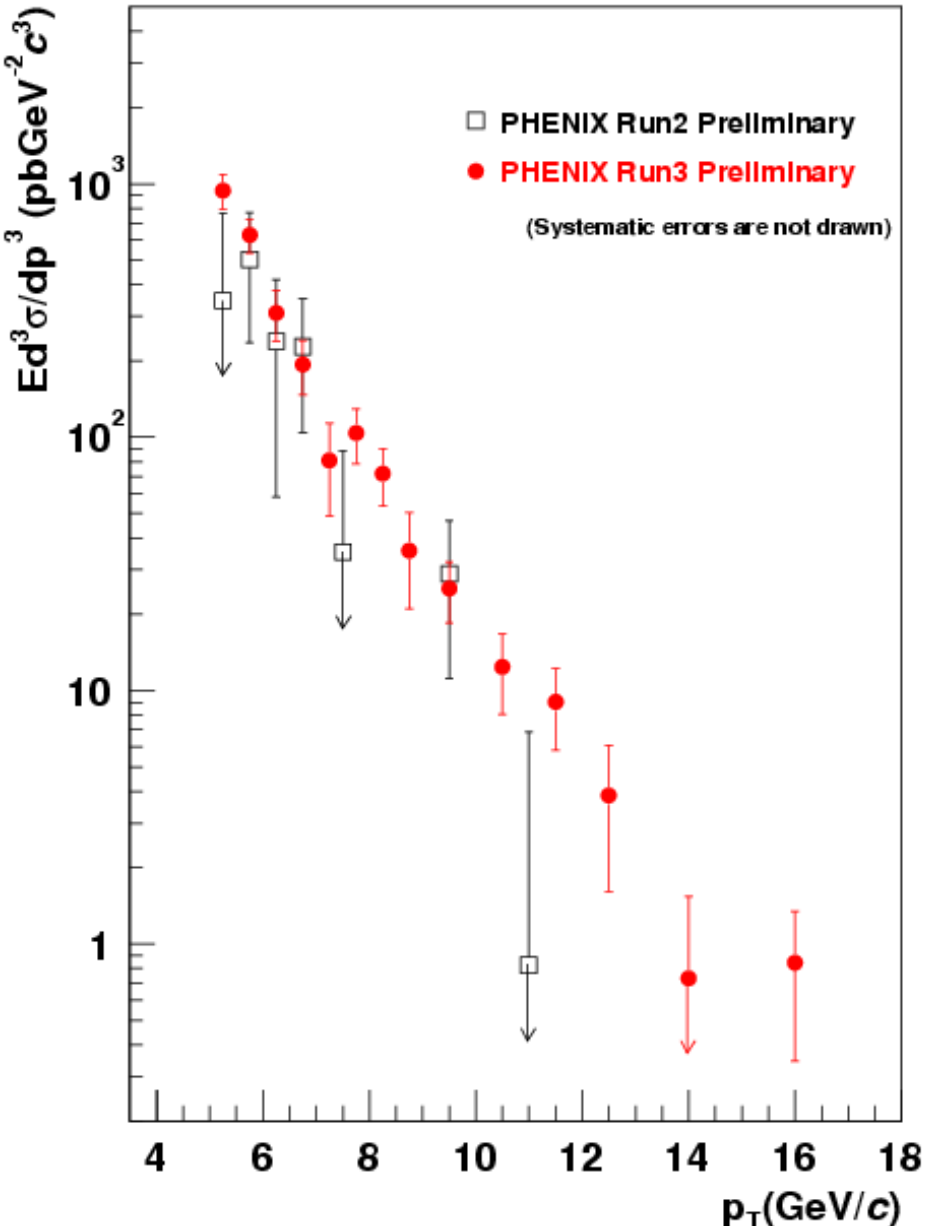
Private communication with W.Vogelsang

- Direct photon measurement at pT>5GeV/c is dominated by direct process.
  - The difference between two methods is small.

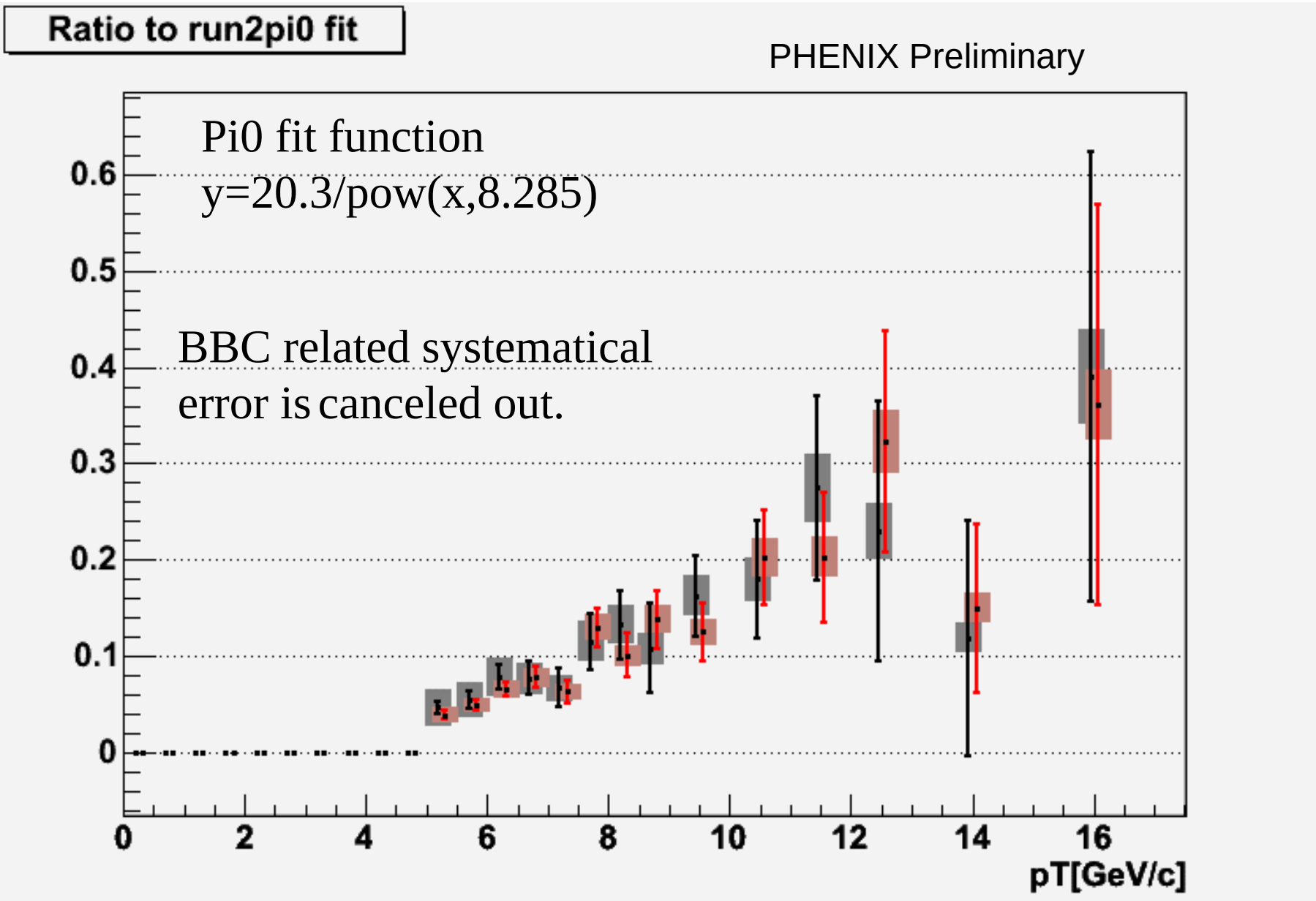
Fragmentation

Comparison with the RunII

- Comparison
- RunII and RunIII are consistent
- RunIII provide larger statistics
  - Pt = 5-18GeV/c
  - Cross section 1 – 10^3 pbGeV-2c3

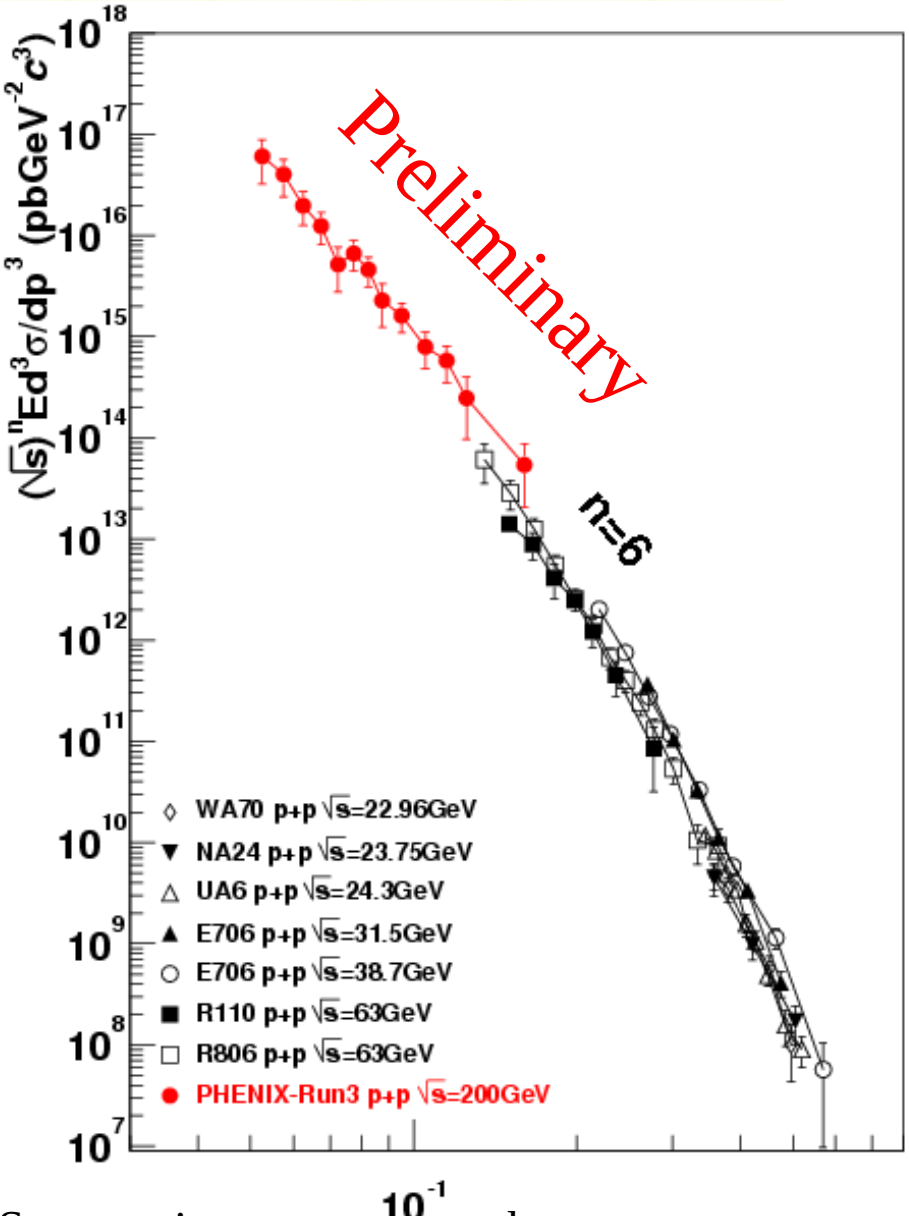


Results


Ratio to run2pi0 fit
PHENIX Preliminary
Pi0 fit function
y=20.3/pow(x,8.285)
BBC related systematical
error is canceled out.
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
pT[GeV/c]

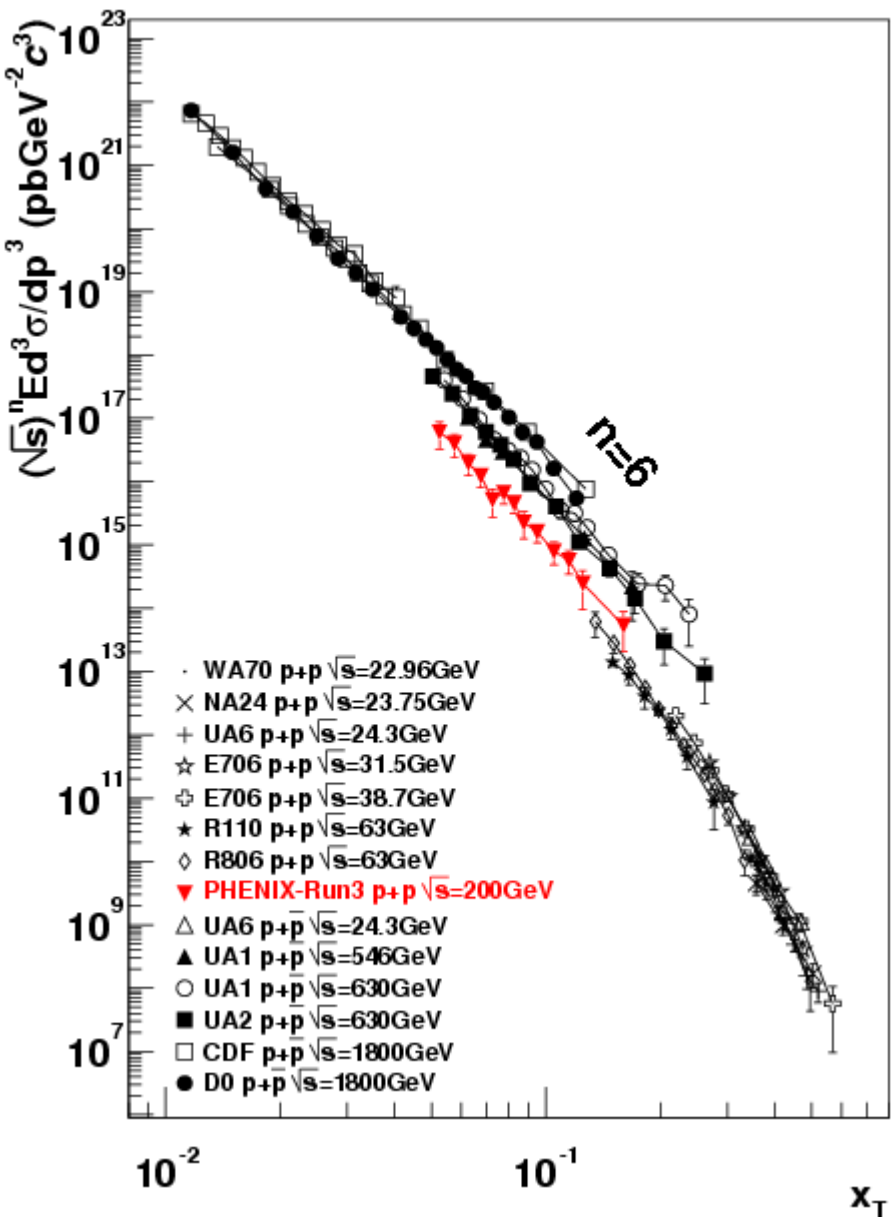
X_T Scaling

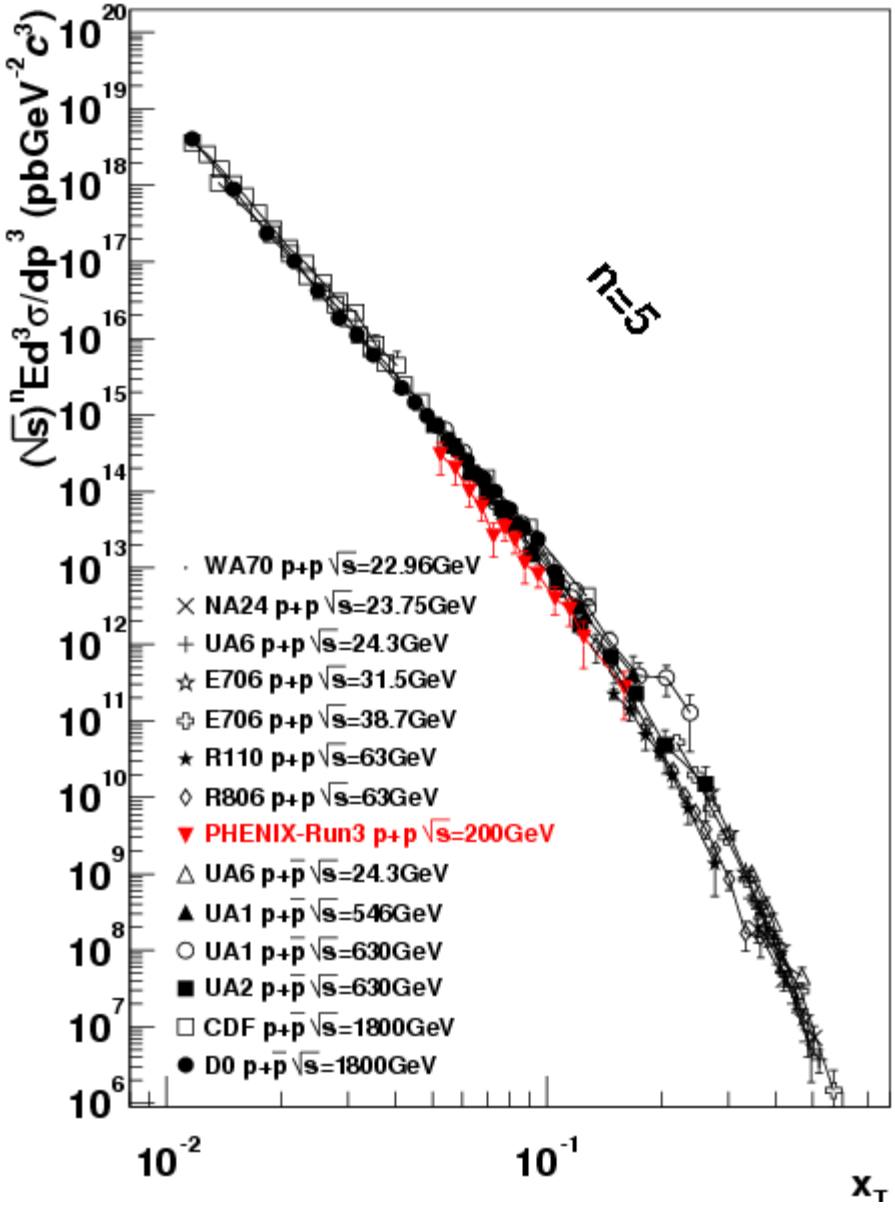
- From eye-ball fitting,
  - n=6 shows better agreement
    - Between 20 – 200GeV
    - x_T = 0.05 – 0.5
- I'd like to emphasize that the present result covers x_T down to 0.05
  - We can go down lower x_T range in the future → next slide.
- I'd like to show this comparison at JPS meeting.



Systematic errors are not shown

xT-scaling with p+pbar data

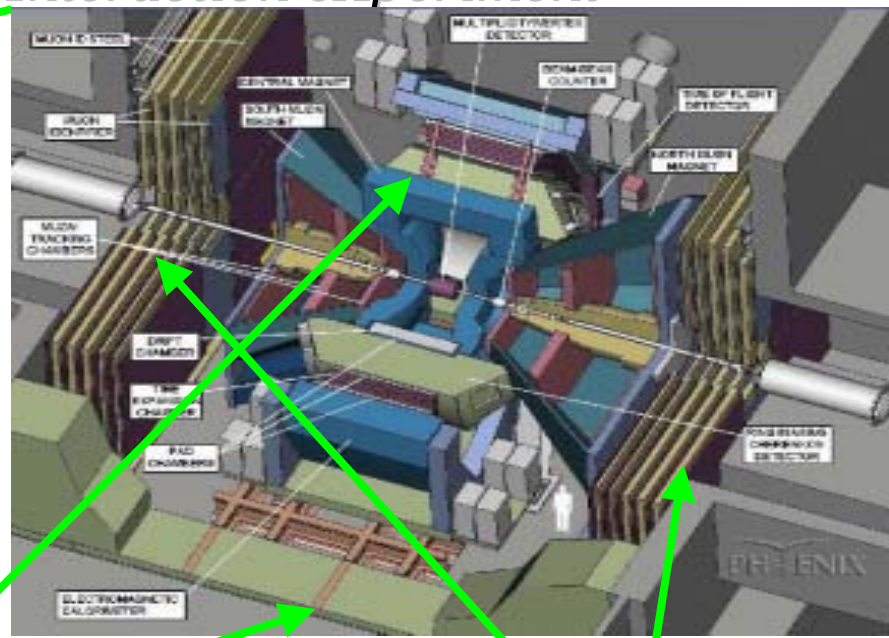




Relativistic Heavy Ion Collider

PHENIX実験

Pioneering High Energy Nuclear Interaction eXperiment



- **全周**3.8km 2**リング**
  - 120bunch/ring
  - 106ns crossing time
- **最大エネルギー**
  - 250GeV for p(polarized)
  - 100GeV/nucleon for Au
- Luminosity
  - Au-Au : 2 x $10^{26}cm^{-2}s^{-2}$
  - p-p : 2 x $10^{32}cm^{-2}s^{-2}$
- 6 **の**Crossing point

2 central Spectrometers

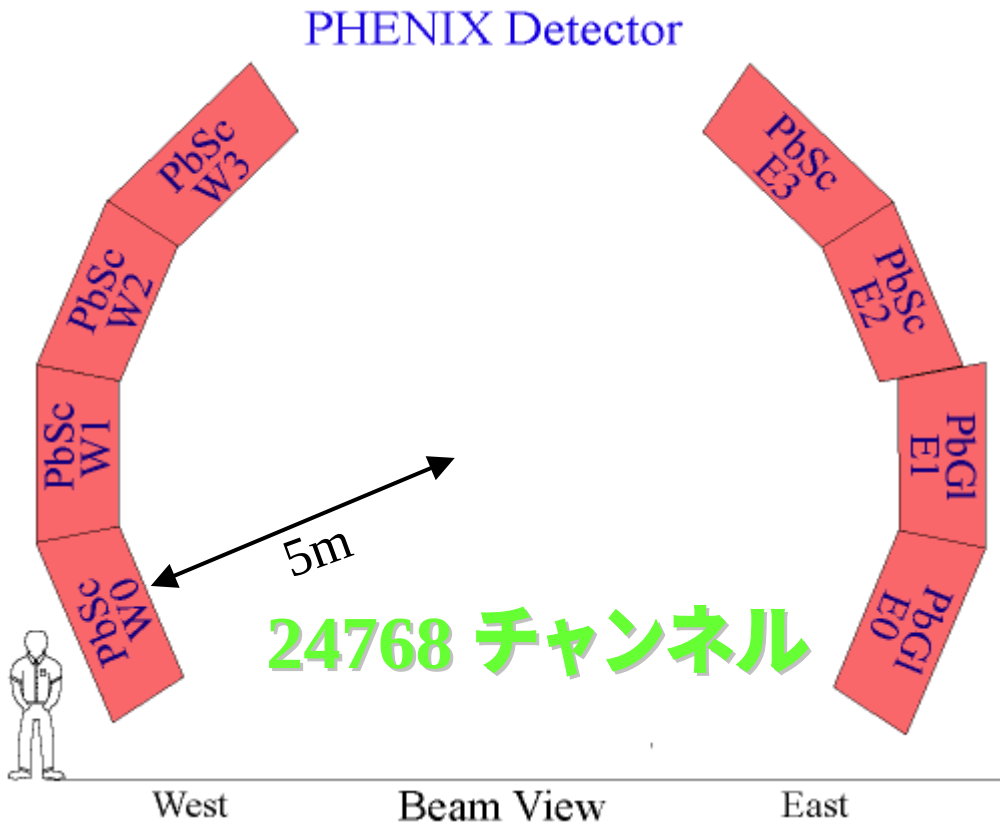
2 forward Spectrometers

衝突点、ルミノシティー、中心度を決めるための3つの detector **がインストールされている。**

- Beam Beam Counter(BBC)
- Zero Degree Calorimeter(ZDC)
- Multiplicity and Vertex Detector(MVD)

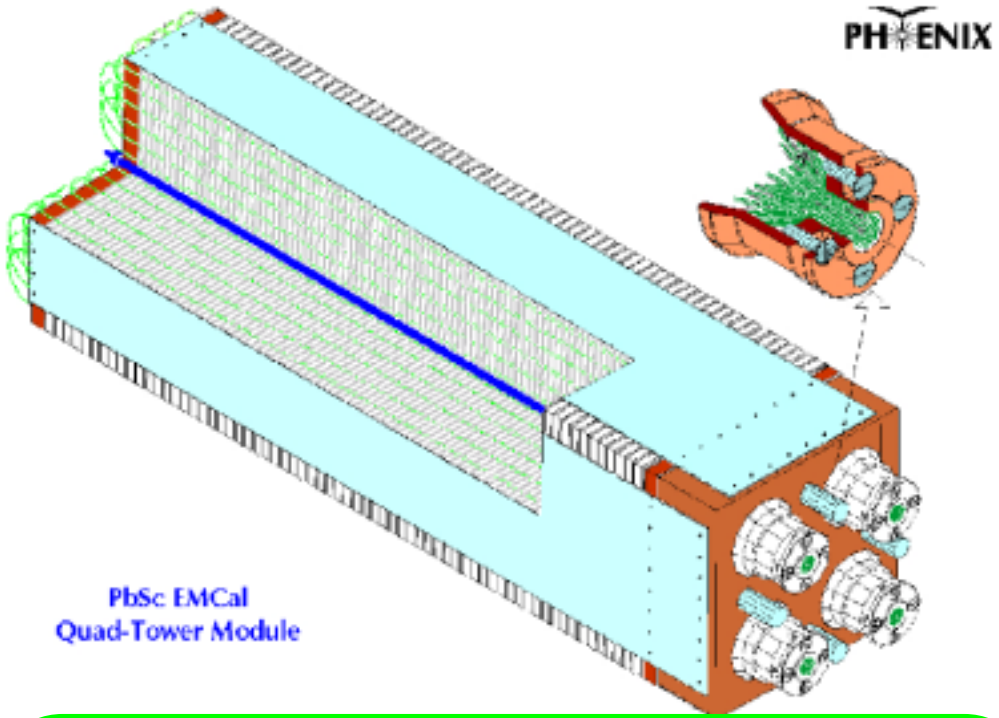
電磁カロリーメータ

- π^0測定のための検出器
- 2種類の電磁カロリーメータ
  - PbSc型
    - Lead Scintillation Type
  - PbGl型
    - Lead Glass Type
- EMCal RICH Level1 Trigger(ERT)
  - High-p_Tのπ^0測定に必要不可欠



- ここから8ページにわたって両方の装置の説明

PbSc型カロリーメータ



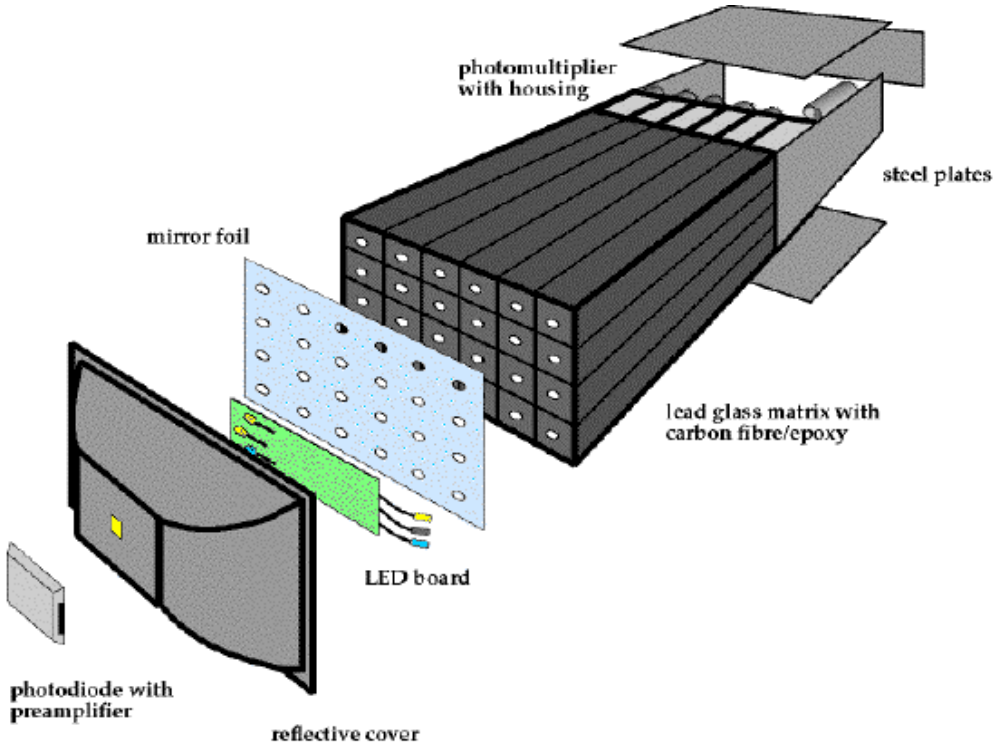
	PbSc
Size(cm x cm)	5.52 x 5.52
Depth(cm)	37.5
Number of towers	15552
Sampling fraction	~ 20%
η cov.	0.7
ϕ cov.	90+45deg
η/mod	0.011
ϕ/mod	0.011
X_0	18
Molière Radius	~ 3cm

Sandwich type calorimeter
- Lead plates 55.2x55.2x1.5mm
- Scintillator plates 110.4x110.4x4mm

Shish-kebab geometry wave shifter fiber readout
- 6x6 fibers → 1 PMT = 1 tower
- 2 x 2 towers = 1 module
- 6 x 6 module = 1 super module
- 6 x 3 super module = 1 sector

PbSc sector 2.0m x 4.0m

PbGl型カロリーメータ



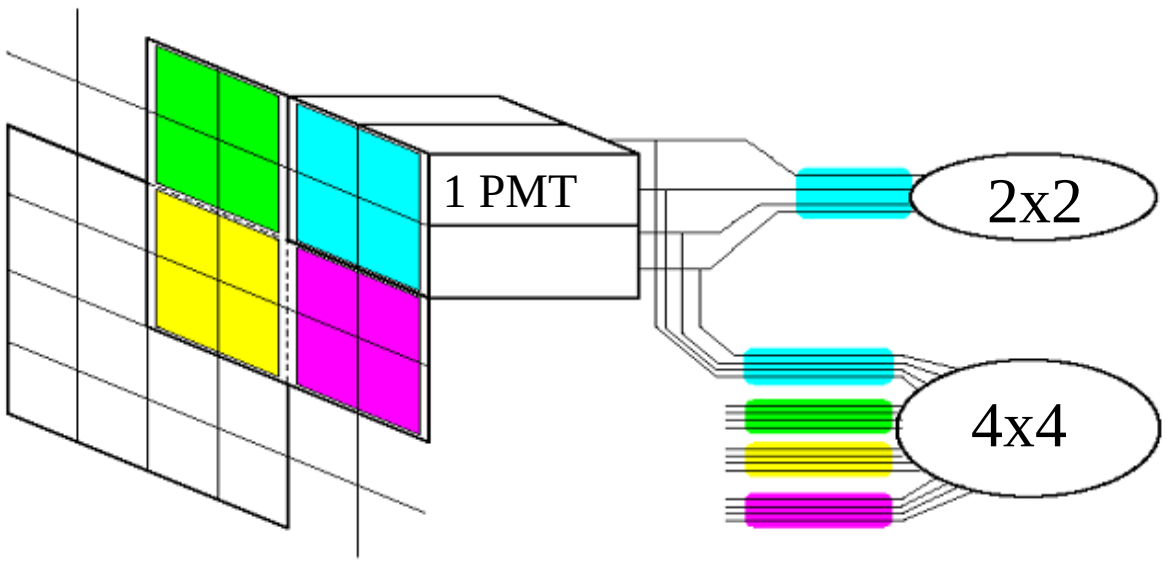
	PbGl
Size(cm x cm)	4.0 x 4.0
Depth(cm)	40
Number of towers	9216
Sampling fraction	100%
η cov.	0.7
ϕ cov.	45deg
η/mod	0.008
ϕ/mod	0.008
X_0	14.4
Molière Radius	3.68cm

Lead Glass calorimeter
Lead Glass 40x40x400mm
used at WA98 exp.
4x6 towers = 1 super module
15*12 super module = 1 sector

PbGl sector 2.1m x 3.9m

ERT トリガー

- EMCal RICH level1 Trigger(ERT)
  - electron, di-electron, photon, high-p_T $\pi^{\pm}$ **をトリガーする目的。**
  - **本研究では、**ERT**の**EMCal**部分のみを使用**
- **電磁シャワーのエネルギーを得るために、タワー**
  (5.5x5.5cm^2[PbSc] 4x4cm^2[PbGl])**のエネルギーの合計をとる必要がある。**
  - 2x2 towers non-overlapping sum (threshold=0.8GeV)
  - 4x4 towers overlapping sum (threshold=2 and 3GeV)
- **本研究での**π^0**測定には、**2x2 non-overlapping sum**を使用。**
  - Enhances high-pT π^0 by a factor of 50



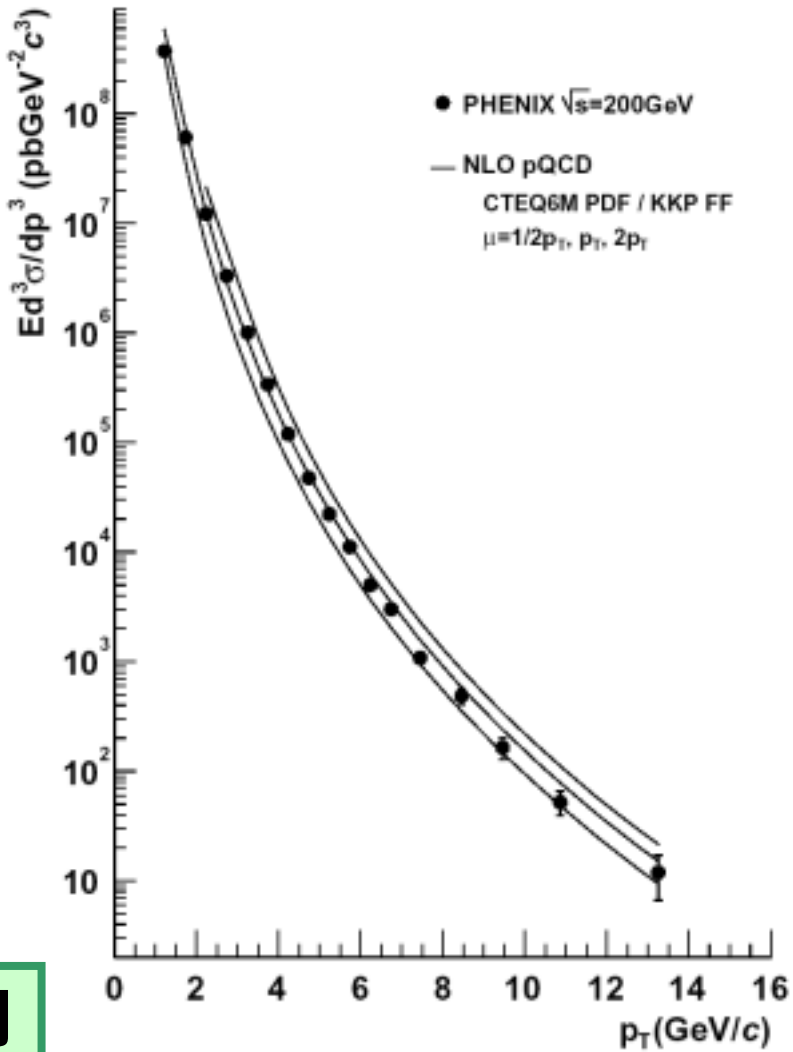
PHENIX実験

NLO-pQCD計算との比較

- Next-to-leading order(NLO) pQCD**計算のパラメータ**
  - Parton distribution function(PDF): CTEQ6M
  - Fragmentation function(FF): KKP
  - Matrix calculation by Aversa, et. al.
  - Renormalization and factorization scales are set to be equal and set to

    $1/2p_T$, p_T, $2p_T$

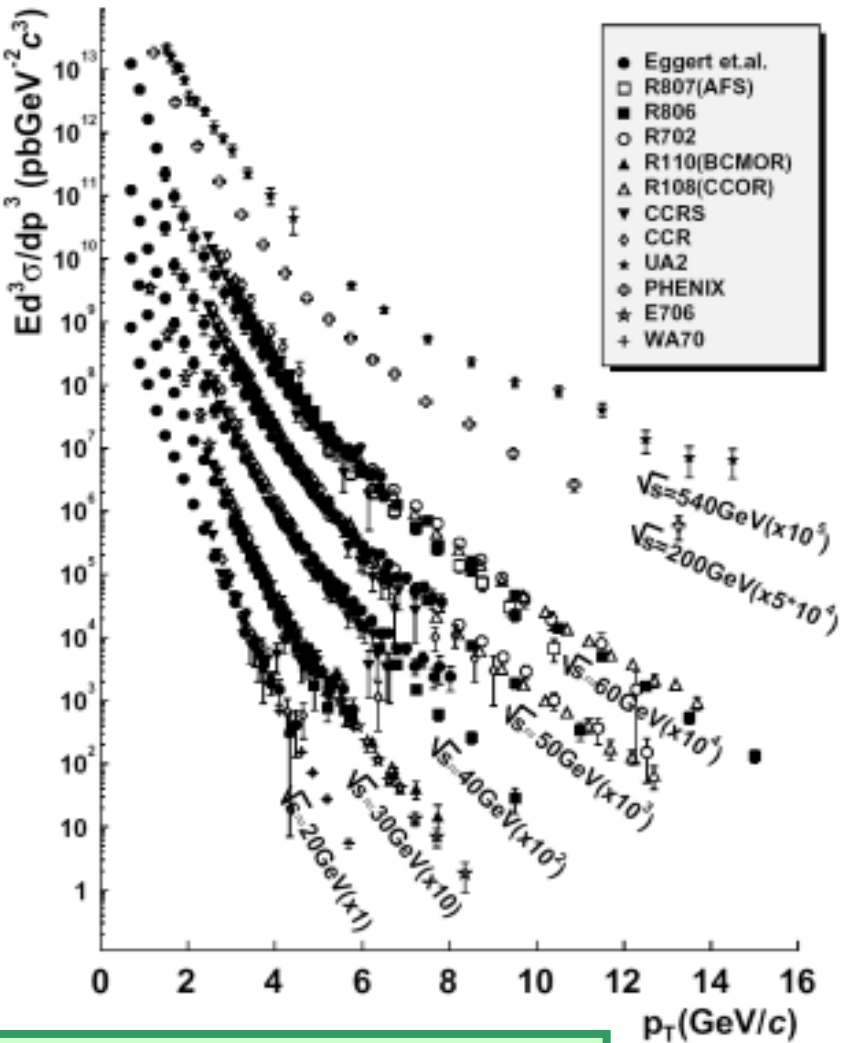
    - W.Vogelsang**との**private communication**による計算結果と一致している。**



得られたデータは、3つのスケールを用いた計算結果の範囲で一致している。

過去のデータとの比較

- **陽子陽子衝突では最高エネルギー**
  - CERN
    - ISR (1971~) p+p $\sqrt{s}$=10-60GeV
    - SPS(1977~) p-beam p≤450GeV
    - S$p\bar{p}$S(1981~) p+ $\bar{p}$ $\sqrt{s}$≤640GeV
  - FermiLab
    - Syncrotron(1972~) p-beam p≤400GeV
    - Tevatron(1981~) p-beam p≤0.9TeV
- **p_T分布**
  - High p_T **では、$\sqrt{s}$が大きくなるにつれて、p_T分布の形の傾きは緩やか。**
  - Low p_T**では、傾きは$\sqrt{s}$によらずほぼ一定に収束している。**



今回得られたp_T分布が、パートン(QCD)描像で説明できることを、過去のデータとの比較において考察を行う。

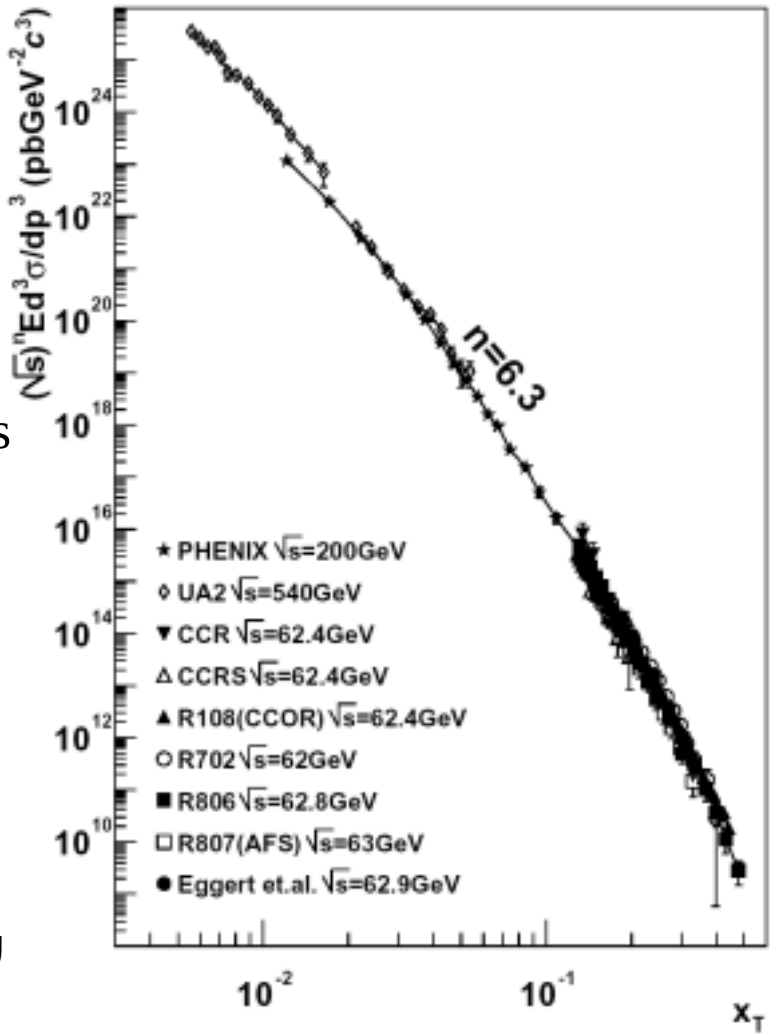
x_Tスケーリング

- QCD理論によると、以下の仮定
  - PDFとFFのQ^2スケーリング
  - Coupling constant(α_s)がQ^2に非依存。

$$\sigma = \left(\sqrt{s}\right)^{-n} \times F\left(x_T\right)$$

n=定数。$x_T=2p_T/\sqrt{s}$

  - 定数nに対する予想
    - Leading order n=4
    - Next-to-leading order: n=4+α
    - 過去の実験から n=6.3 (by R108 collaboration)
  - x_T分布は√sに依存しない



➔x_Tスケーリング

  - ここでは、今回得られたデータと過去のデータ√s>60GeVと比較して、x_Tスケーリングがn=6.3で成り立つかどうか見る。

x_Tスケーリングがn=6.3で成り立つ➔パートン描像