

(Anti) Penta Quark Search in $\sqrt{s}=200\text{GeV}$ p+p and d+Au Collisions at RHIC-PHENIX

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for the PHENIX Collaborations

JPS meeting at Kyushu Univ. 2003/Mar/27

動機

- **高エネルギー原子核反応にてペンタクォークは生成？**
 - HERA-B では、 $\sqrt{s}=41.6\text{GeV}$ p+C, p+Ti, p+W 衝突において見つかっておらず、統計モデルから予想する生成量と比較して
 - $\sqrt{s}=200\text{GeV}$ p+p, d+Au 衝突では？ (RHIC-PHENIX実験)
- **なぜ、反ペンタクォークに注目したのか？**
 - PHENIX実験では、 $\bar{\Theta}^- \rightarrow \bar{n} + K^-$ チャンネルに対するsensitivityが大きい。
 - Ks0チャンネルは、1)アクセプタンスが小さい、2)現在のセットアップでは decay vertexを特定することが難しい、等の理由により小さい。
 - 高エネルギー原子核衝突では、反粒子と粒子の比は1に近くなる。ex $\sigma(\bar{p})/\sigma(p) = 0.8$ at $\sqrt{s}=200\text{GeV}$ p+p collisions
- **ここでは、反中性子を(電磁)カロリメータにて同定する試みを紹介するとともに、 $\bar{\Theta}^-(\text{Anti-}\Theta^+) \rightarrow \bar{n} + K^-$ を用いた、反ペンタクォーク探索の現状を発表する。**
 - 1月に行われた国際会議にて発表した解析に重大な間違いが見つかり、解析のやり直しを行った。その途中結果を報告する。

Relativistic Heavy Ion Collider



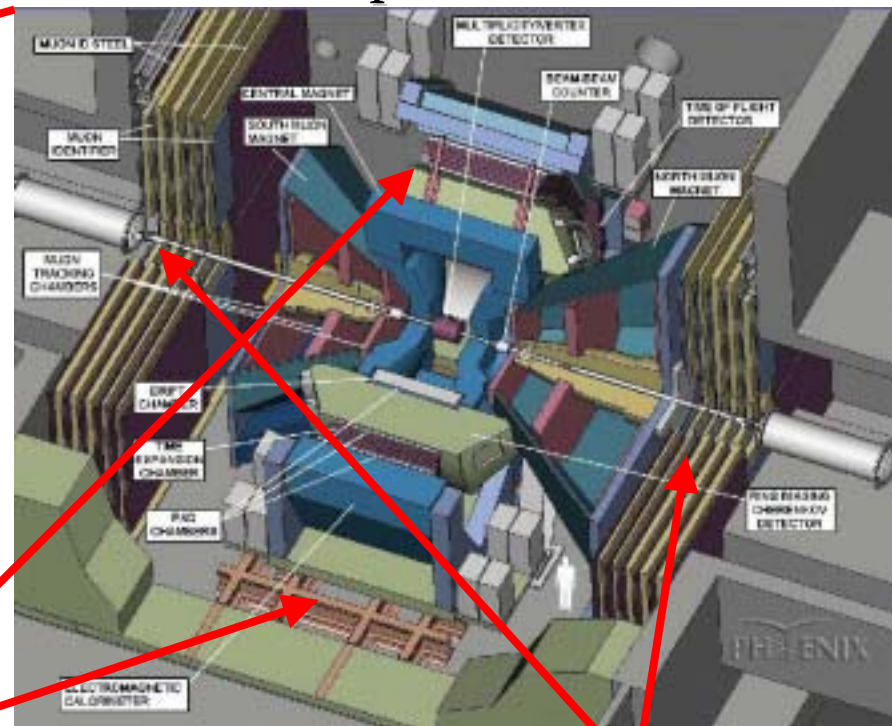
PHENIX実験



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 : $2 \times 10^{26} \text{cm}^{-2}\text{s}^{-2}$
 - p-p : $2 \times 10^{32} \text{cm}^{-2}\text{s}^{-2}$
- 6 の Crossing point



2 central Spectrometers

2 forward Spectrometers

- Luminosity、Vertex、Centrality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)

電磁カロリメータ(PbSc)

Lead Scintillator (PbSc)

–サンドイッチタイプカロリメータ

•鉛板 110.4x110.4x1.5mm

•シンチ板 55.2x55.2x4mm

–読み出しは Shish-kebab タイプ。

•Wave length shifter fiber 読み出し。

–6 sectors(15552 channels)

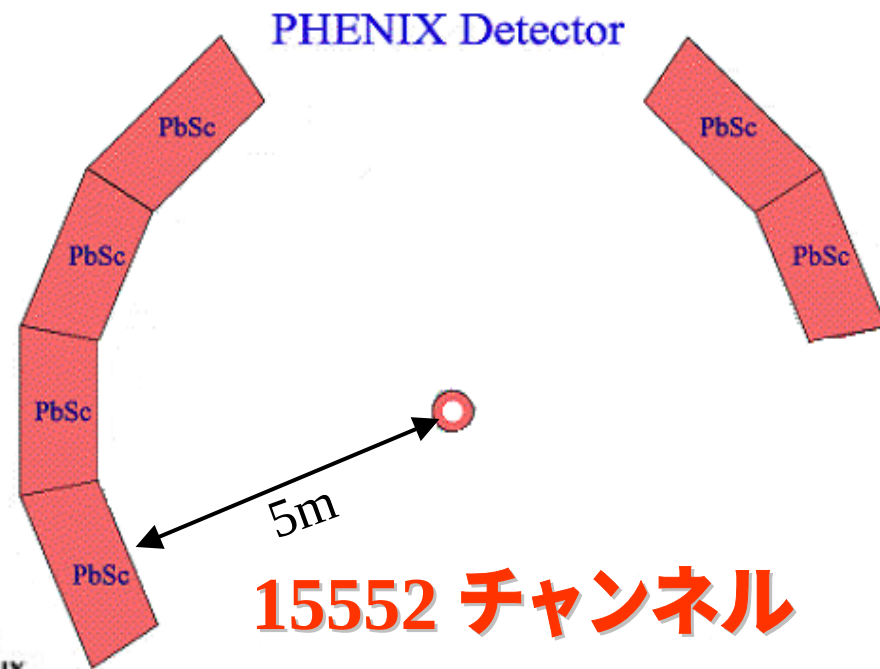
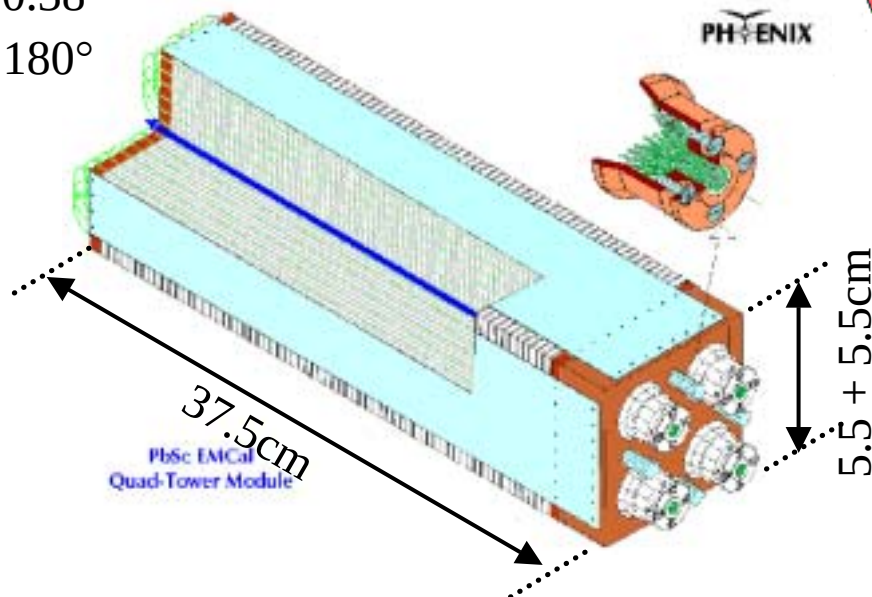
•衝突点からの直線距離

–507cm for PbSc

•Coverage

– $|\eta| < 0.38$

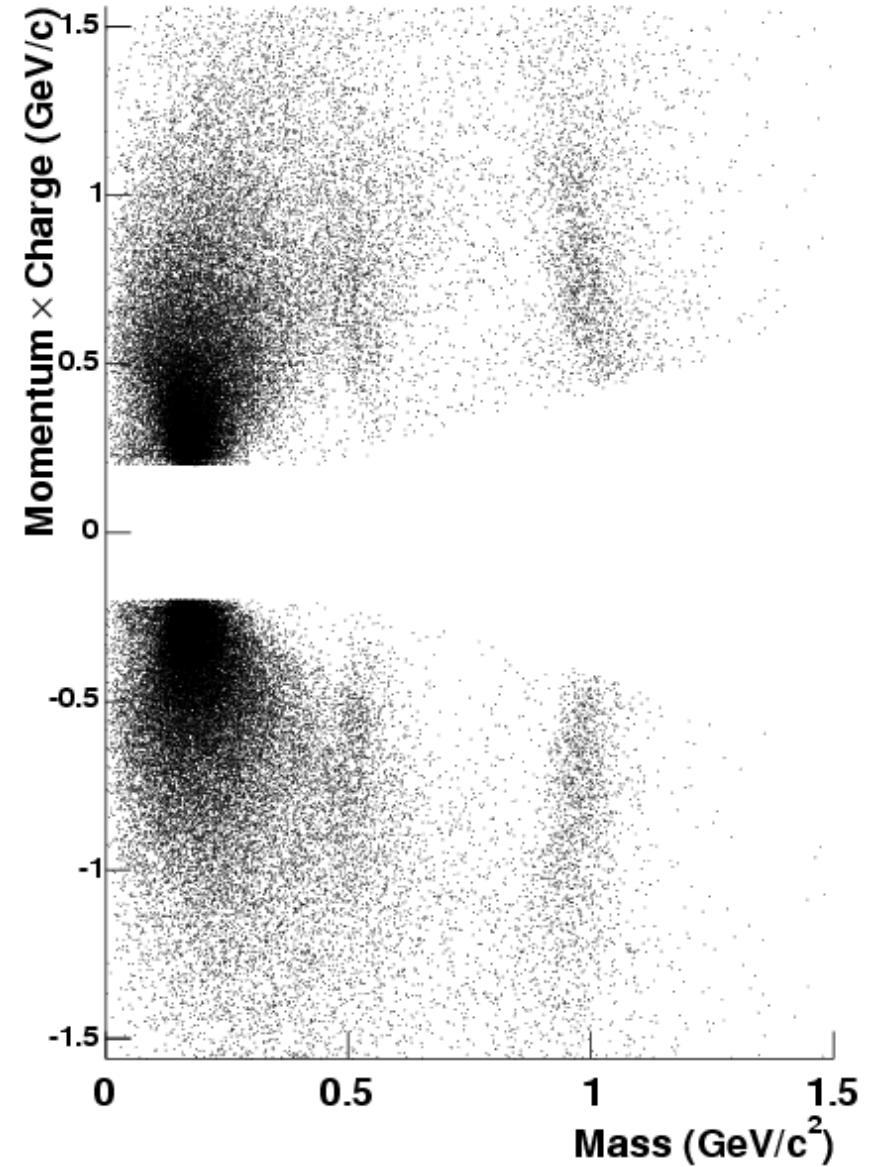
– $\phi = 180^\circ$



	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

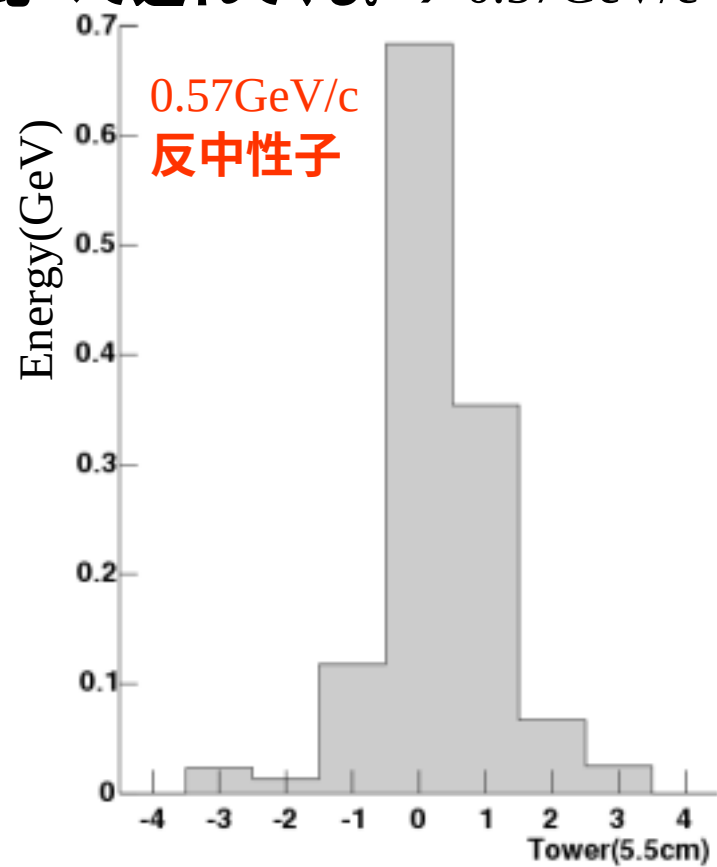
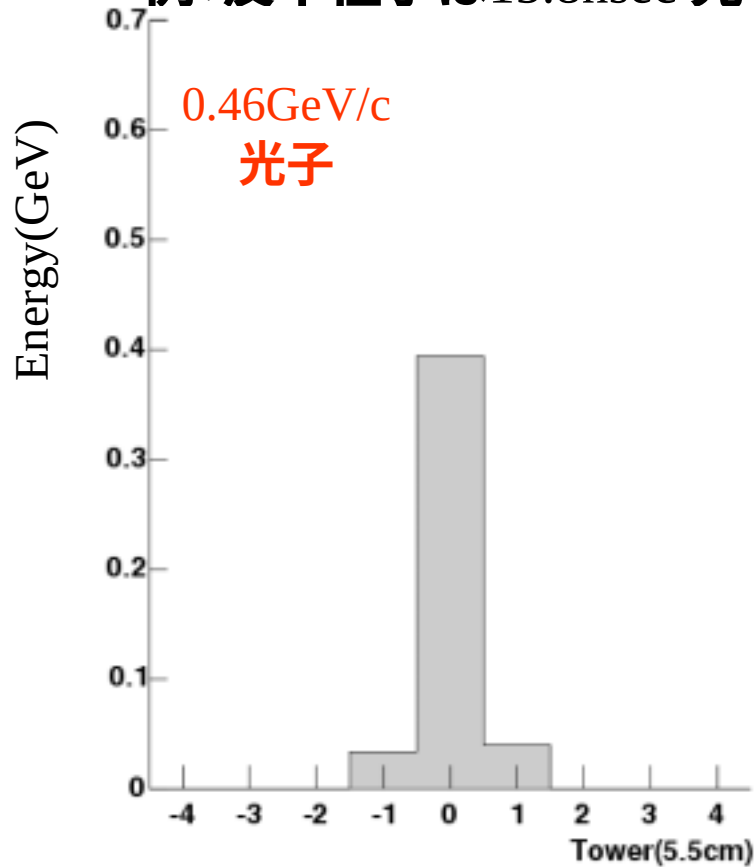
実験データ と 荷電粒子同定

- 実験データ
 - RUN3 $\sqrt{s}=200\text{GeV}$ d+Au 衝突
 - 2003年10月~12月
 - 60M イベント
 - RUN3 $\sqrt{s}=200\text{GeV}$ p+p 衝突
 - 2004年1月~4月
 - 60M イベント 51%トリガー効率
- 電磁カロリメータで測定した飛行時間を元に、荷電粒子の同定を行った。
 - 時間分解能、 $\sim 500\text{psec}$
 - $p_T=0.8\text{GeV}/c$ まで π/K 分離が可能。



反中性子の同定

- 反中性子は原子核消滅反応により、
 - 約2GeVのエネルギーを発生する→ 測定エネルギーが大きい
 - シャワーの空間的な広がりが光子に比べて大きい。
- 飛行時間から中性子の質量を仮定して運動量を推定する。
 - 例：反中性子は15.8nsec 光子と比べて遅れてくる。→ 0.57GeV/c



反 $\Sigma^\pm$ 粒子の測定

- 反中性子検出の性能を調べるため、反 $\Sigma^\pm$ 粒子測定を行った。

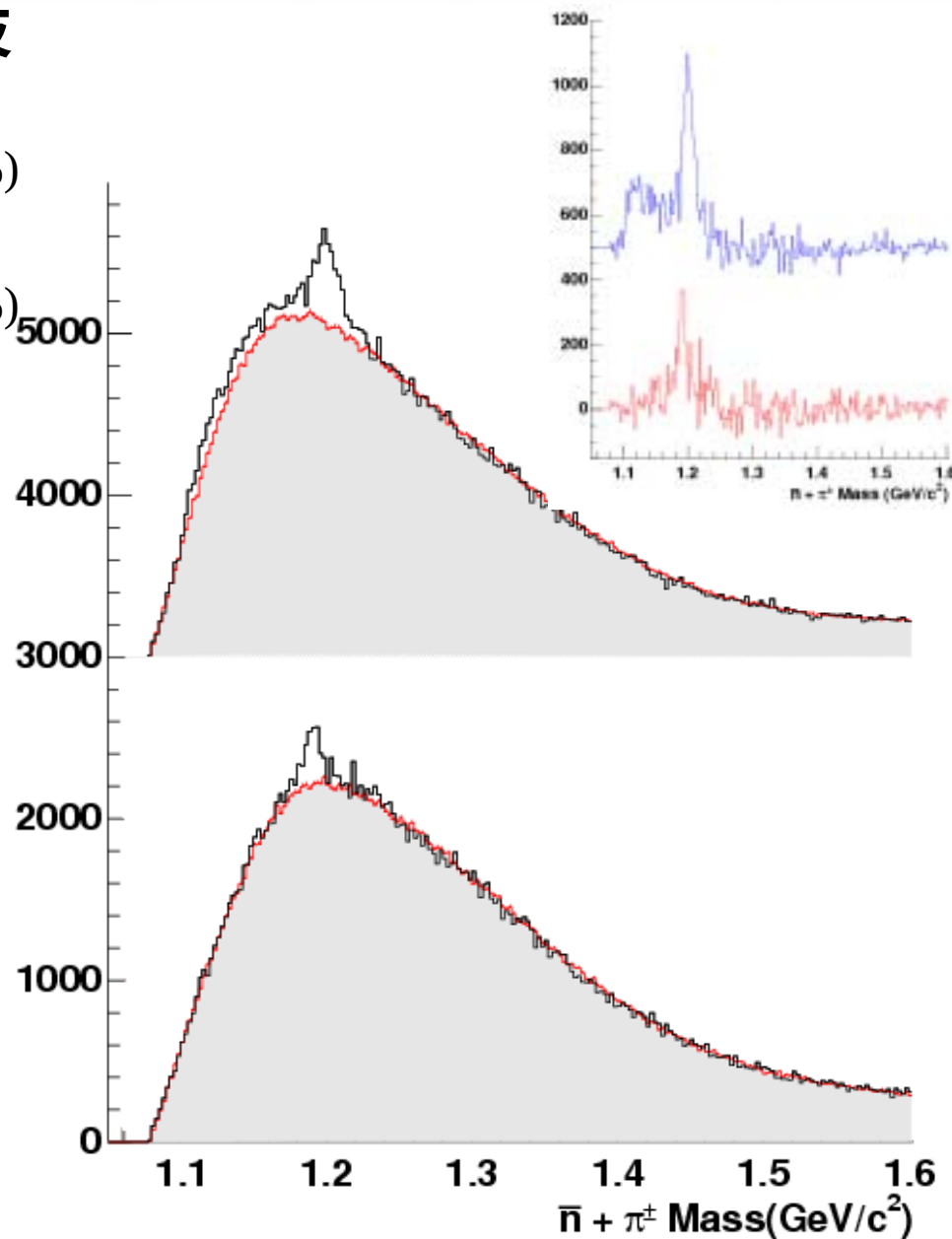
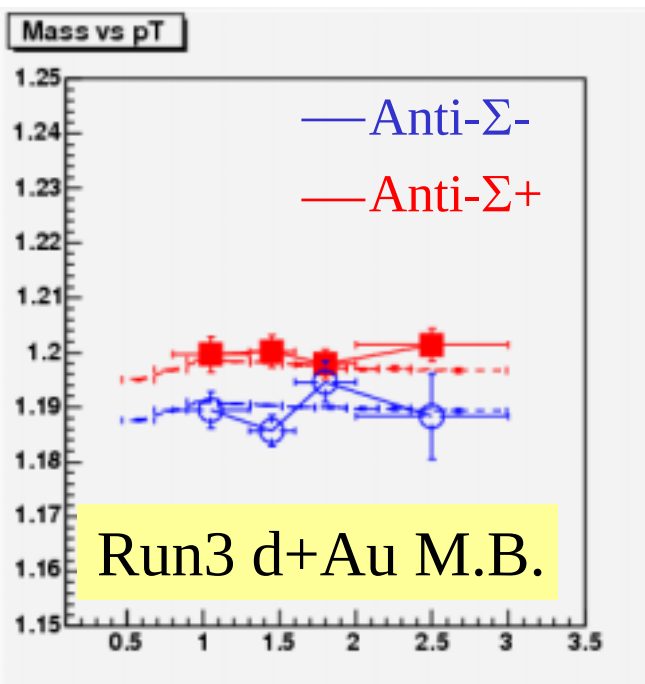
- Anti- $\Sigma^-(1189.4) \rightarrow \bar{n} + \pi^-$ (99.85%)

- $c\tau(\text{Anti-}\Sigma^-) = c\tau(\Sigma^+) = 2.396\text{cm}$

- Anti- $\Sigma^+(1197.4) \rightarrow \bar{n} + \pi^+$ (48.31%)

- $c\tau(\text{Anti-}\Sigma^+) = c\tau(\Sigma^-) = 4.434\text{cm}$

- 消滅反応による反陽子との



反中性子測定のパフォーマンスと 反ペンタクォークに対する予測

反中性子測定のパフォーマンス

時間分解能 $\sim 600\text{psec}$ (光子- 350psec)

運動量分解能

-2% ($0.5\text{GeV}/c$) 5% ($1.0\text{GeV}/c$) 15% ($2.0\text{GeV}/c$)

運動量絶対値は 5% 以内 (未補正)

検出効率 $40\% - 60\%$

バックグラウンドの含有率

–Photon $\sim 10\%$

Hadron 計算中

モンテカルロシミュレーション

反ペンタクォーク生成の仮定

•経験則にもとずいたmT scaling

実験装置からくる効果

ピーク幅

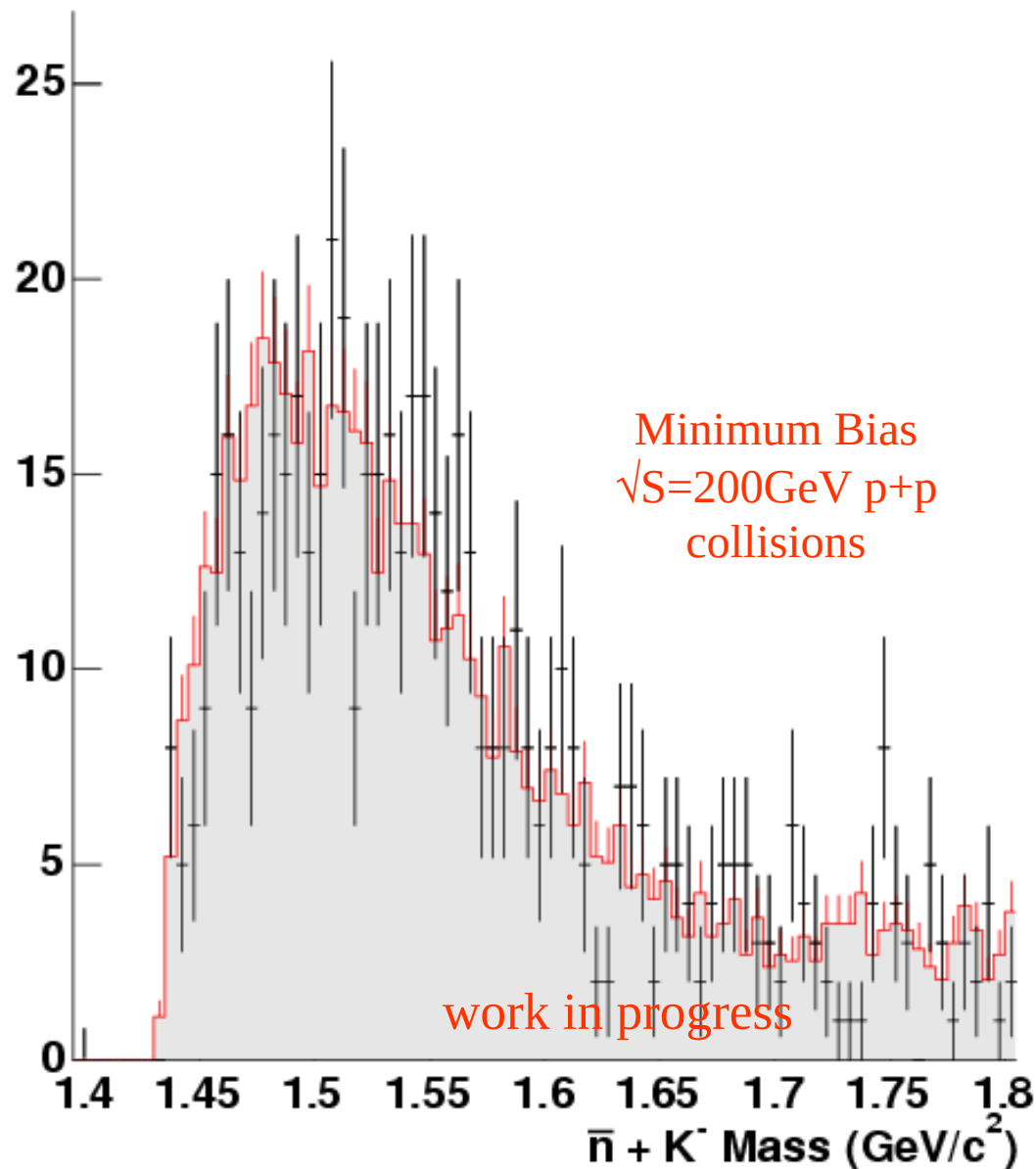
$\rightarrow 5\text{MeV}/c^2$

ピーク値のずれ

$\rightarrow < 5\text{MeV}/c^2$

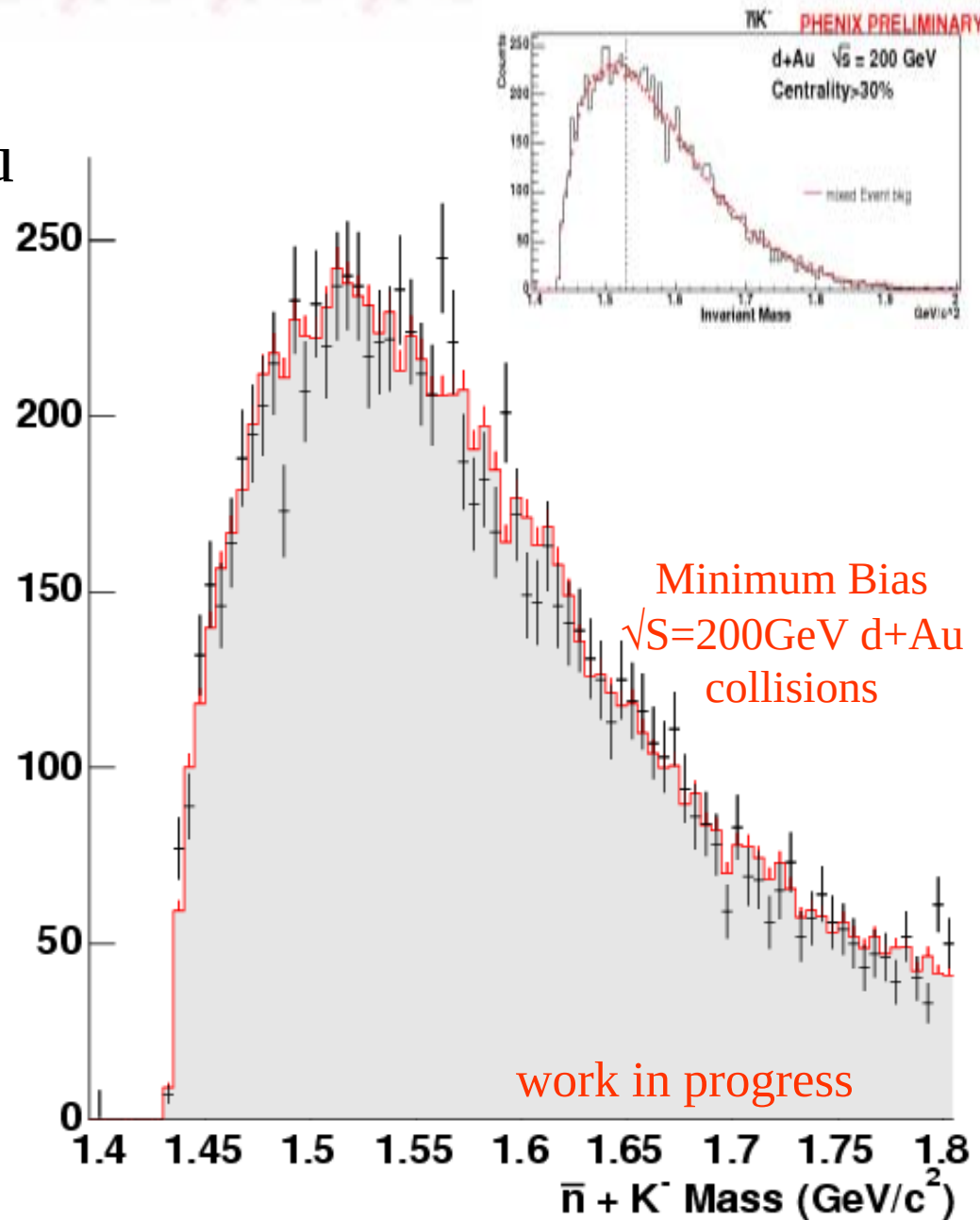
Results at p+p Collisions

- RunIII $\sqrt{s}=200\text{GeV}$ p+p
 - M.B Trigger
 - 50M events = ? mb-1
- 5MeV/c² per bin
- No significant peak in the current statistics
 - The statistics is too small.



Results in d+Au Collisions

- RunIII $\sqrt{s}=200\text{GeV}$ d+Au
 - M.B Trigger
 - 50M events
- 5MeV/c² per bin
- No Significant peak is observed in the current statistics.



Summary

- Question?
 Θ^- production in high energy nucleus collisions?
 - PHENIX have feasibility to measure $\bar{n}$
 - Deposited energy and timing is used for the identification.
 - Clear $\Sigma^\pm$ is observed. $\rightarrow$ useful to calibrate $\bar{n}$.
 - First trial of $\bar{\Theta}^-$ search in PHENIX was performed.
 - In $\bar{\Theta}^- \rightarrow \bar{n} + K^-$ decay channel
- $\rightarrow$ No significant peak was observed**
- at $\sqrt{s}=200\text{GeV}$ p+p Collisions in 50M events (equiv. $\sim\text{mbarn}^{-1}$)
 - at $\sqrt{s}=200\text{GeV}$ d+Au Collisions in 80M events

To extract the upper limit, many works are in progress

Brazil University of São Paulo, São Paulo
China Academia Sinica, Taipei, Taiwan
 China Institute of Atomic Energy, Beijing
 Peking University, Beijing

France LPC, University de Clermont-Ferrand, Clermont-Ferrand
 Dapnia, CEA Saclay, Gif-sur-Yvette
 IPN-Orsay, Université Paris Sud, CNRS-IN2P3, Orsay
 LLR, École Polytechnique, CNRS-IN2P3, Palaiseau
 SUBATECH, École des Mines at Nantes, Nantes

Germany University of Münster, Münster

Hungary Central Research Institute for Physics (KFKI), Budapest
 Debrecen University, Debrecen
 Eötvös Loránd University (ELTE), Budapest

India Banaras Hindu University, Banaras
 Bhabha Atomic Research Centre, Bombay

Israel Weizmann Institute, Rehovot

Japan Center for Nuclear Study, University of Tokyo, Tokyo
 Hiroshima University, Higashi-Hiroshima
 KEK, Institute for High Energy Physics, Tsukuba
 Kyoto University, Kyoto
 Nagasaki Institute of Applied Science, Nagasaki
 RIKEN, Institute for Physical and Chemical Research, Wako
 RIKEN-BNL Research Center, Upton, NY
 Rikkyo University, Tokyo
 Tokyo Institute of Technology, Tokyo
 University of Tsukuba, Tsukuba
 Waseda University, Tokyo

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 Kangnung National University, Kangnung
 Korea University, Seoul
 Myong Ji University, Yongin City
 System Electronics Laboratory, Seoul Nat. University, Seoul
 Yonsei University, Seoul

Russia Institute of High Energy Physics, Protvino
 Joint Institute for Nuclear Research, Dubna
 Kurchatov Institute, Moscow
 PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
 St. Petersburg State Technical University, St. Petersburg

Sweden Lund University, Lund



12 Countries; 58 Institutions; 480 Participants*

USA Abilene Christian University, Abilene, TX
 Brookhaven National Laboratory, Upton, NY
 University of California - Riverside, Riverside, CA
 University of Colorado, Boulder, CO
 Columbia University, Nevis Laboratories, Irvington, NY
 Florida State University, Tallahassee, FL
 Florida Technical University, Melbourne, FL
 Georgia State University, Atlanta, GA
 University of Illinois Urbana Champaign, Urbana-Champaign, IL
 Iowa State University and Ames Laboratory, Ames, IA
 Los Alamos National Laboratory, Los Alamos, NM
 Lawrence Livermore National Laboratory, Livermore, Ca
 University of New Mexico, Albuquerque, NM
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 Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
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 Oak Ridge National Laboratory, Oak Ridge, TN
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 Vanderbilt University, Nashville, TN

***as of January 2004**



Backup Slide

実験データ

- **実験データ**

- RUN3 $\sqrt{s}=200\text{GeV}$ d+Au **衝突**

- 2003**年10月**~12月

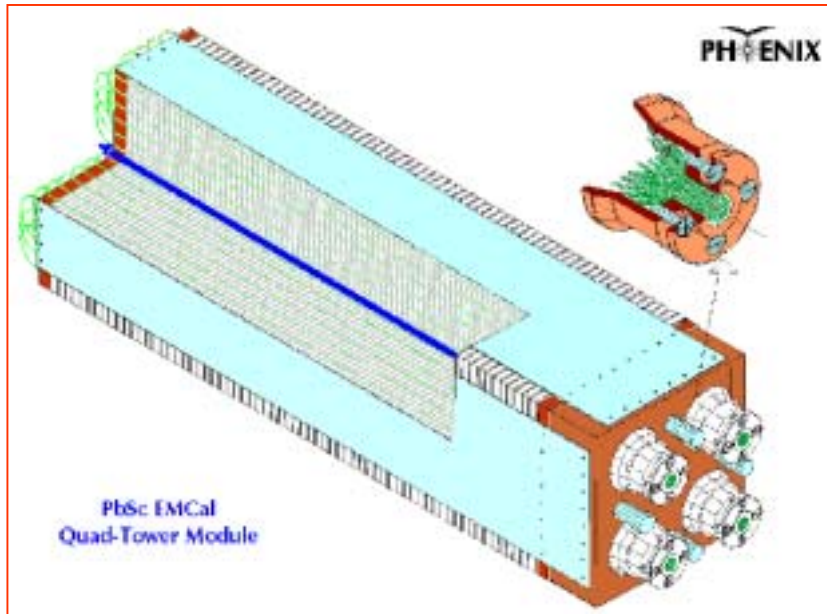
- 60M **イベント**

- RUN3 $\sqrt{s}=200\text{GeV}$ p+p **衝突**

- 2004**年1月**~4月

- 60M**イベント** 51% trigger efficiency

PbSc Calorimeter



	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 $\rightarrow$ 1 PMT = 1 tower

2 x 2 towers = 1 module

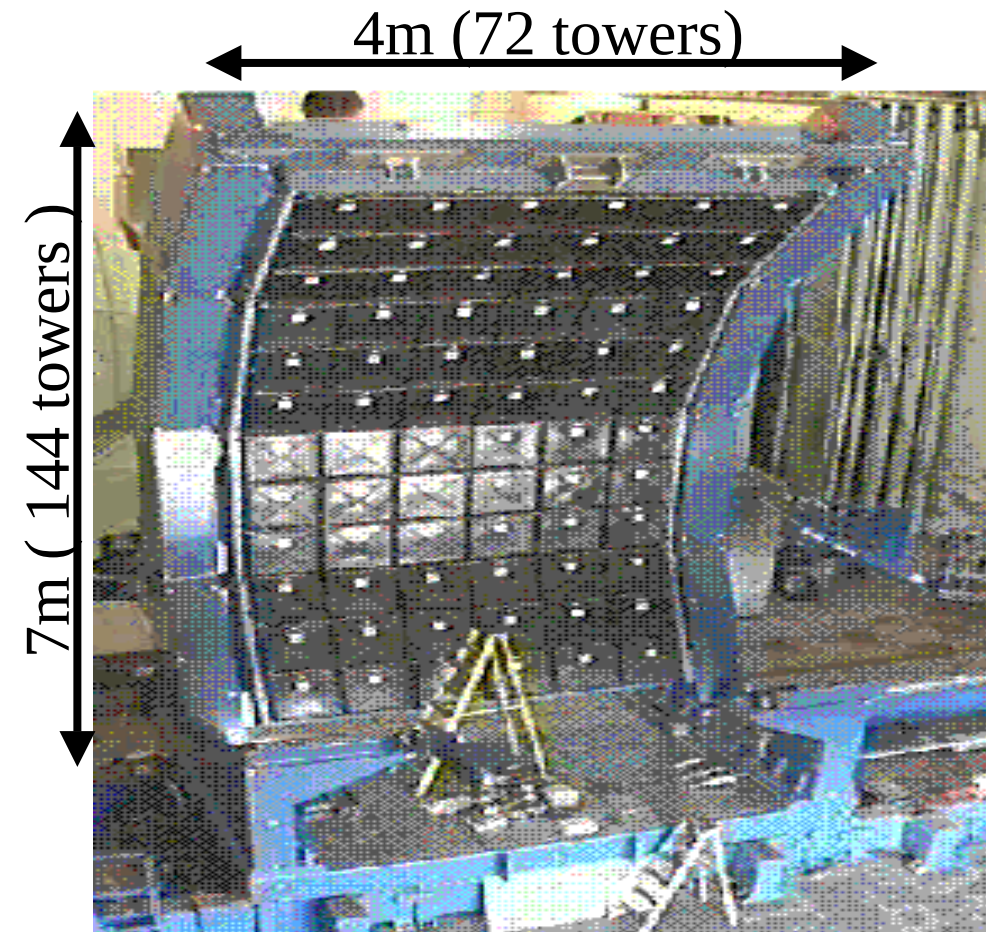
6 x 6 module = 1 super module

6 x 3 super module = 1 sector

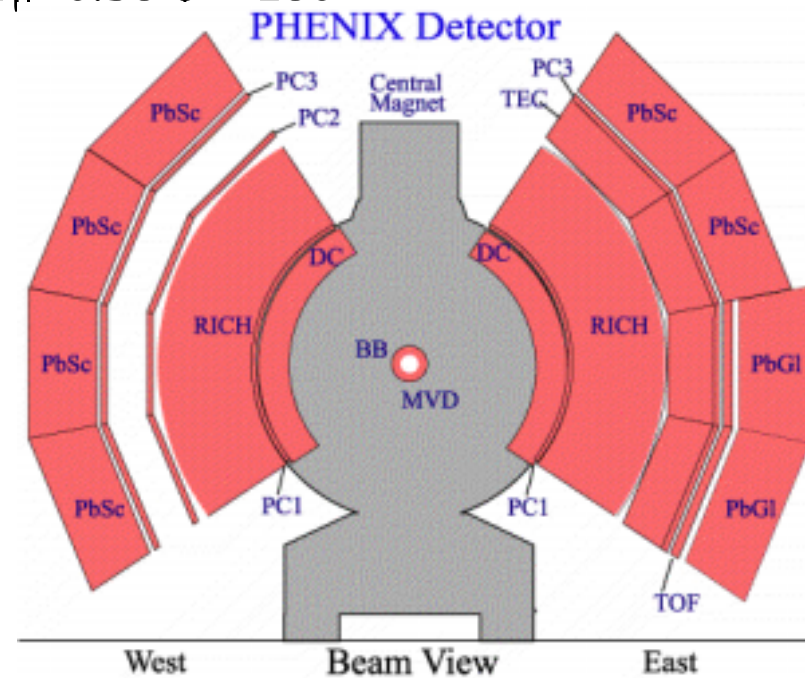


PbSc sector 2.0m x 4.0m

PHENIX Configuration



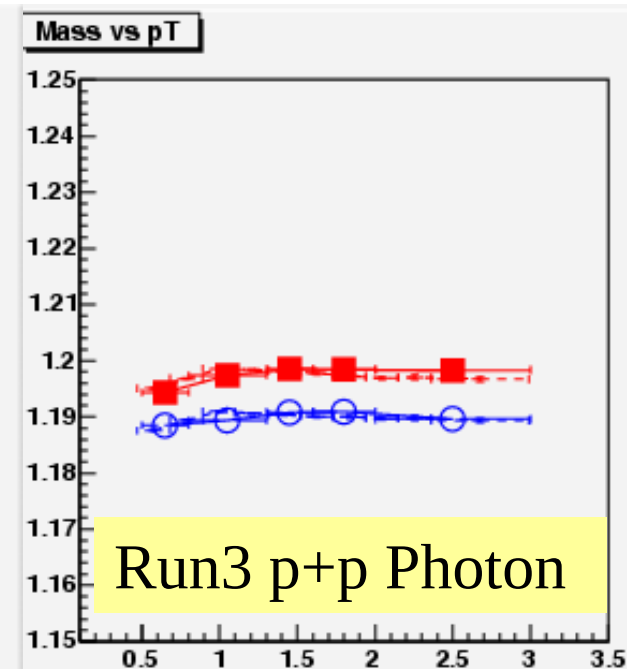
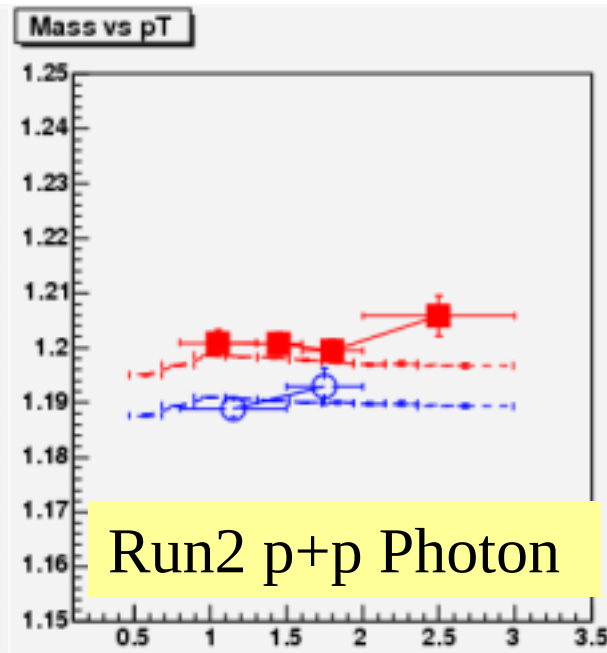
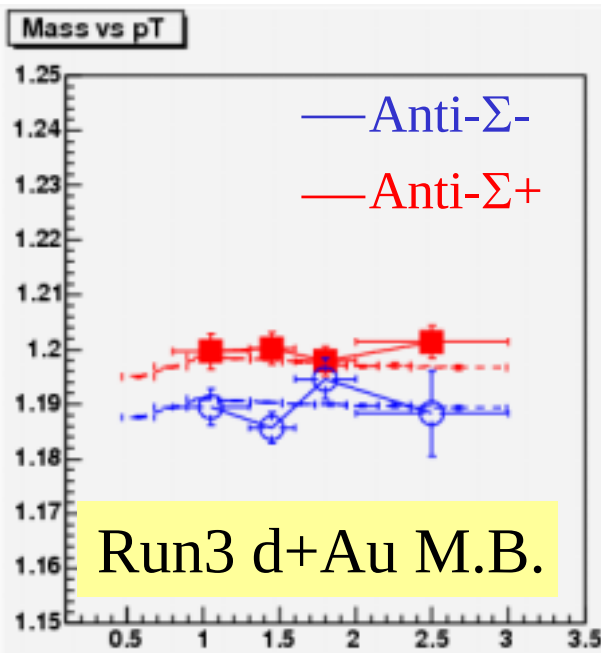
- 2 Arm $\times$ 4 sectors
 - Lead Scintillator(PbSc)
6 sectors(15552 channels)
 - Lead Glass (PbGl)
2sectors (9216 channels)
- $\sim 5\text{m}$ distance from collision point
- $|\eta| < 0.38$ $\phi = 180^\circ$



Comparison of DATA and Toy MC Peak Position

- Peaks of both Anti- $\Sigma^\pm$ are consistent with MC
 - Mass of Σ^+ :1189.4MeV
 - Mass of Σ^- :1197.4MeV

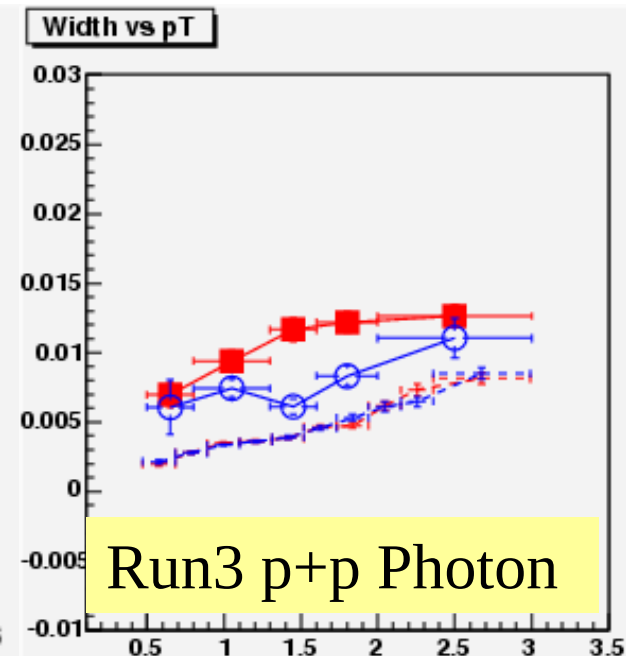
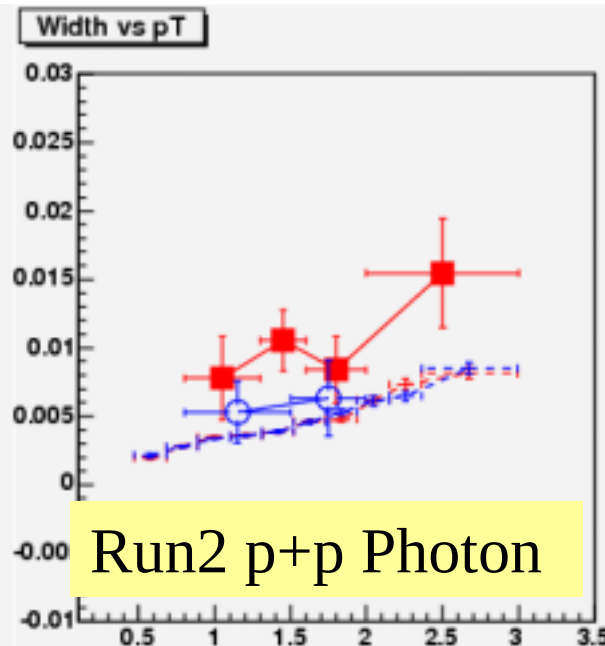
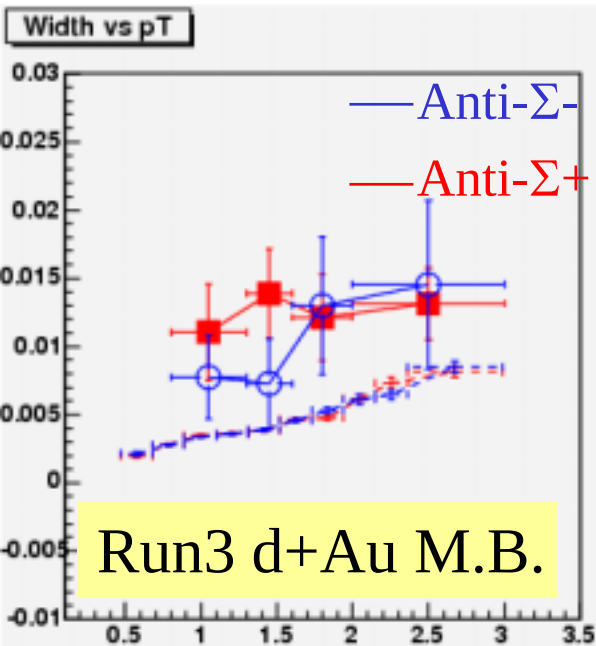
Run2pp and run3pp are
TRIGGERED data!!!



Comparison of DATA and Toy MC Peak Width

- Width are wider than in MC
 - Width(Anti- Σ^+) > Width(Anti- Σ^-)
 - This might be related with the different decay time.
 - $c\tau(\text{Anti-}\Sigma^+) = c\tau(\Sigma^-) = 4.434\text{cm}$
 - $c\tau(\text{Anti-}\Sigma^-) = c\tau(\Sigma^+) = 2.396\text{cm}$

Run2pp and run3pp are
TRIGGERED data!!!



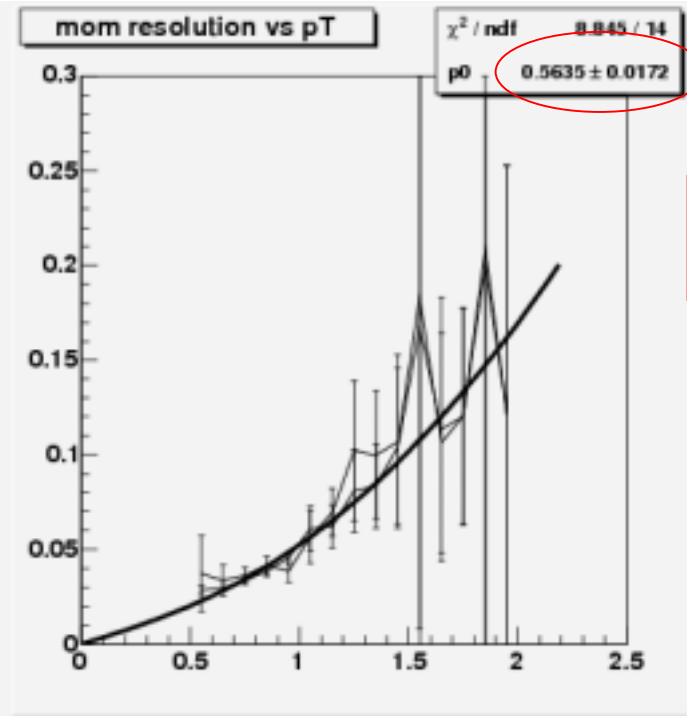
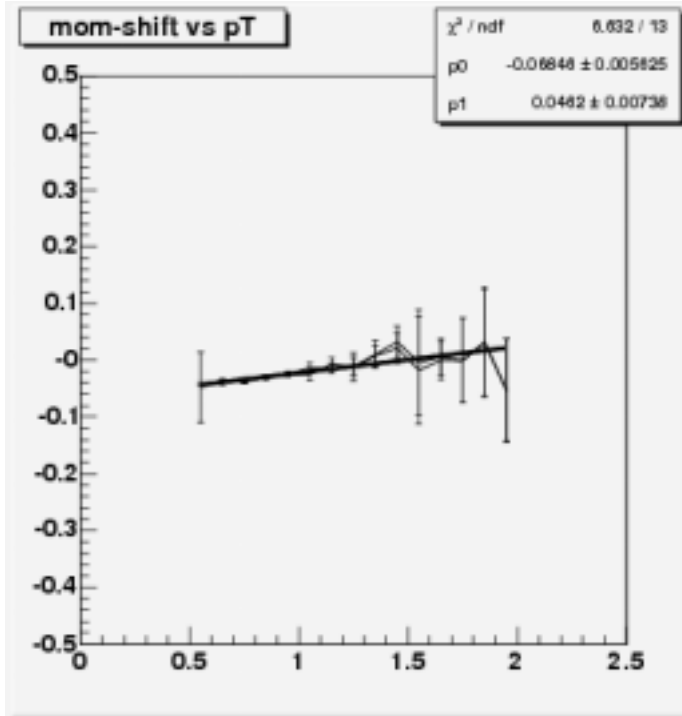
Toy MC (for nbar)

- Efficiency are assumed to be no momentum dependent.
- Resolution and Momentum Scale
 - Masashi's results are fitted by

$$\frac{p_{measured} - p_{real}}{p_{real}} = \alpha + \beta \times p_{measured}$$

$$\frac{dp}{p} = \frac{\sqrt{m^2 + p^2} \cdot p}{m^2} \cdot \frac{c}{L} dt$$

$$c/L = 0.3/5.08 \text{ (constant)}$$



0.56nsec time resolution