Longitudinal Double Spin Asymmetries in Neutral Pion Production at PHENIX

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for the PHENIX collaboration

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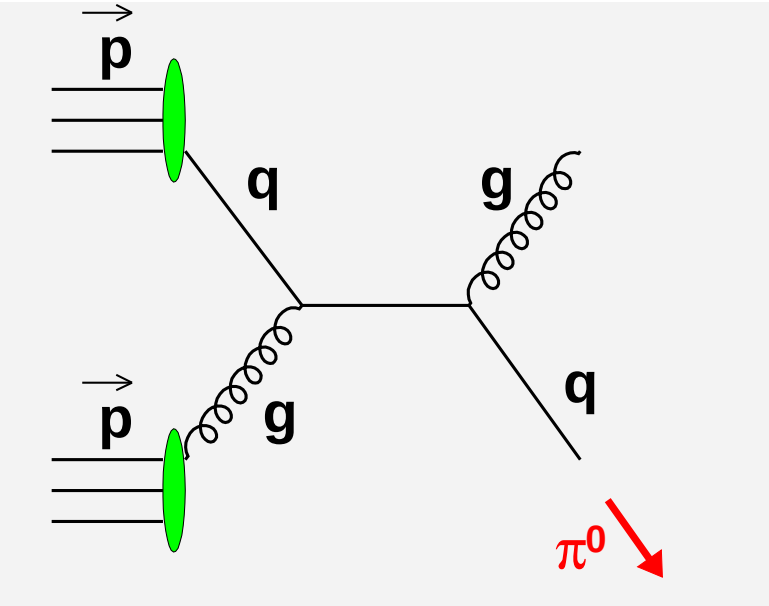
Motivation

Polarized proton-proton collisions can be used to probe ΔG

- High center-of mass energies ($\sqrt{s}$) makes pQCD calculations applicable
- Longitudinal double spin asymmetries (A_{LL}) are directly sensitive to ΔG. Possible process:



$$A_{LL} \propto \frac{\Delta q(x_1)}{q(x_1)} \cdot \frac{\Delta G(x_2)}{G(x_2)} \cdot \hat{a}_{ll}(qg \to qg)$$

$\Longrightarrow$ A_{LL} for inclusive π^0 production is a promising candidate.

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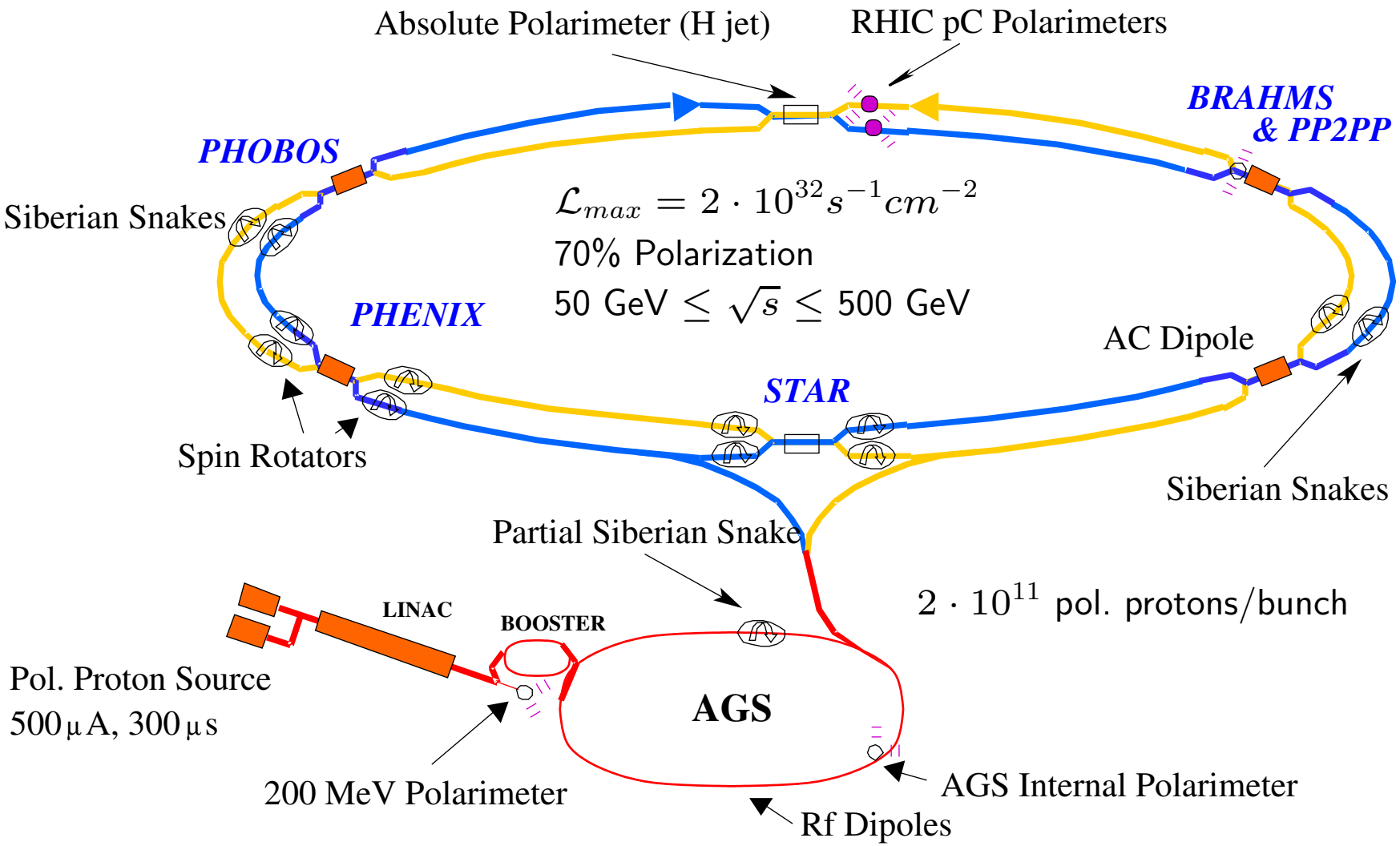
RHIC


Absolute Polarimeter (H jet)
RHIC pC Polarimeters
BRAHMS
& PP2PP
PHOBOS
Siberian Snakes
$\mathcal{L}_{max} = 2 \cdot 10^{32} s^{-1} cm^{-2}$
70% Polarization
50 GeV $\leq \sqrt{s} \leq$ 500 GeV
PHENIX
AC Dipole
STAR
Spin Rotators
Siberian Snakes
Partial Siberian Snake
LINAC
BOOSTER
$2 \cdot 10^{11}$ pol. protons/bunch
Pol. Proton Source
500 μA, 300 μs
AGS
200 MeV Polarimeter
AGS Internal Polarimeter
Rf Dipoles

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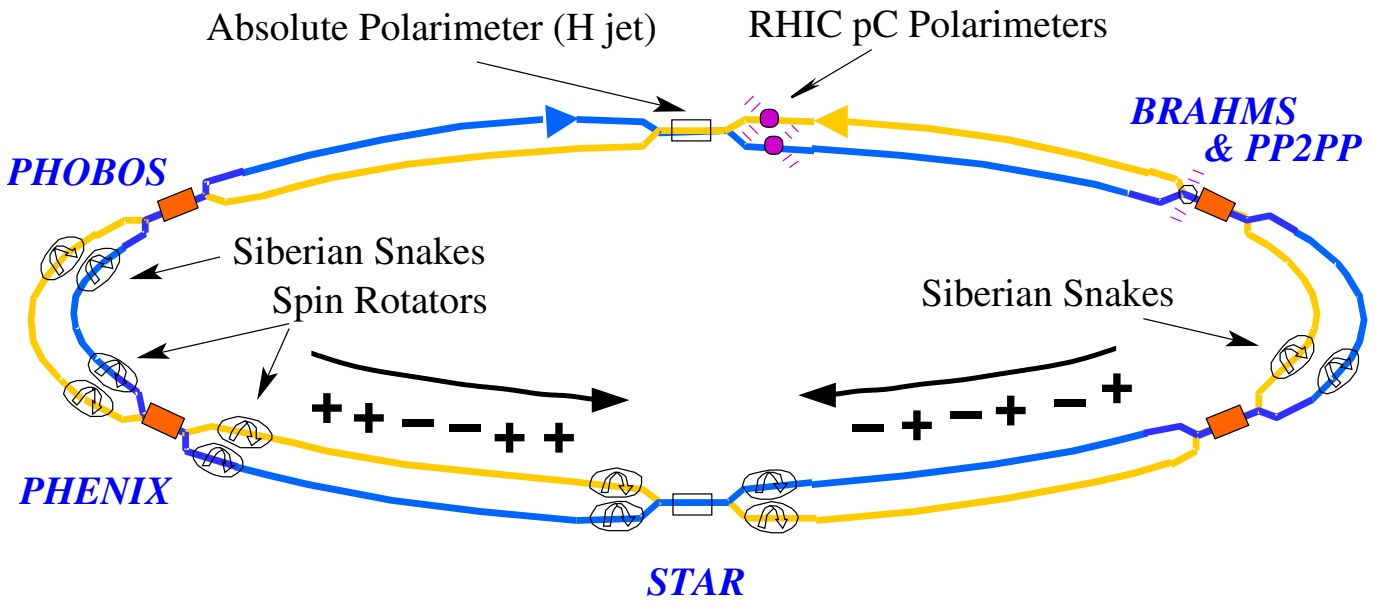
Polarized Protons at RHIC

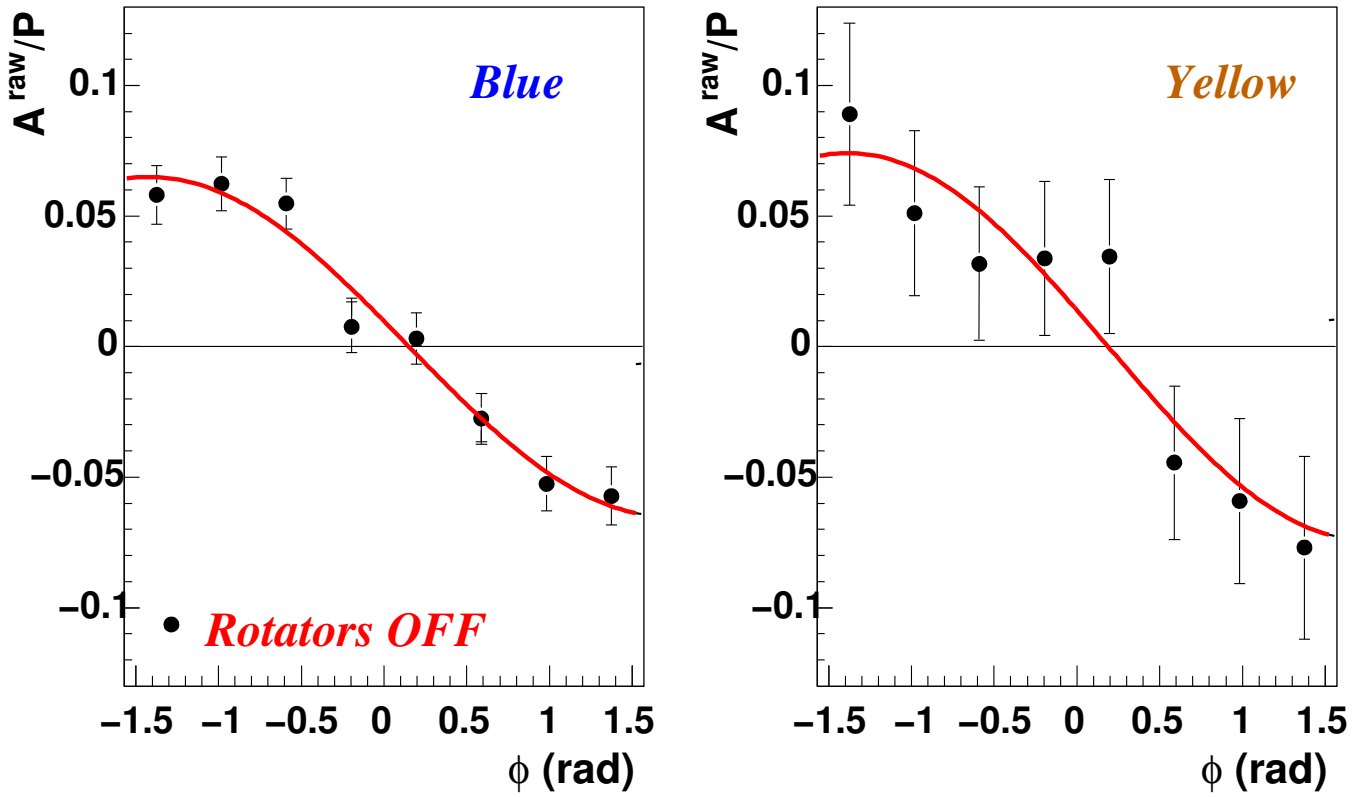


- Up to 112 bunches (5ns long, 100ns apart)
- Individual polarization pattern $\Longrightarrow$ different polarizations on very short time scales
- Avoid systematic errors caused by time dependent variations of the detector response

- Spin rotators around PHENIX and STAR $\Longrightarrow$ Longitudinal polarization

Longitudinal Polarization

Measurement of left-right asymmetries in forward neutron scattering:



Rotators OFF: Sizeable left-right asymmetry measured

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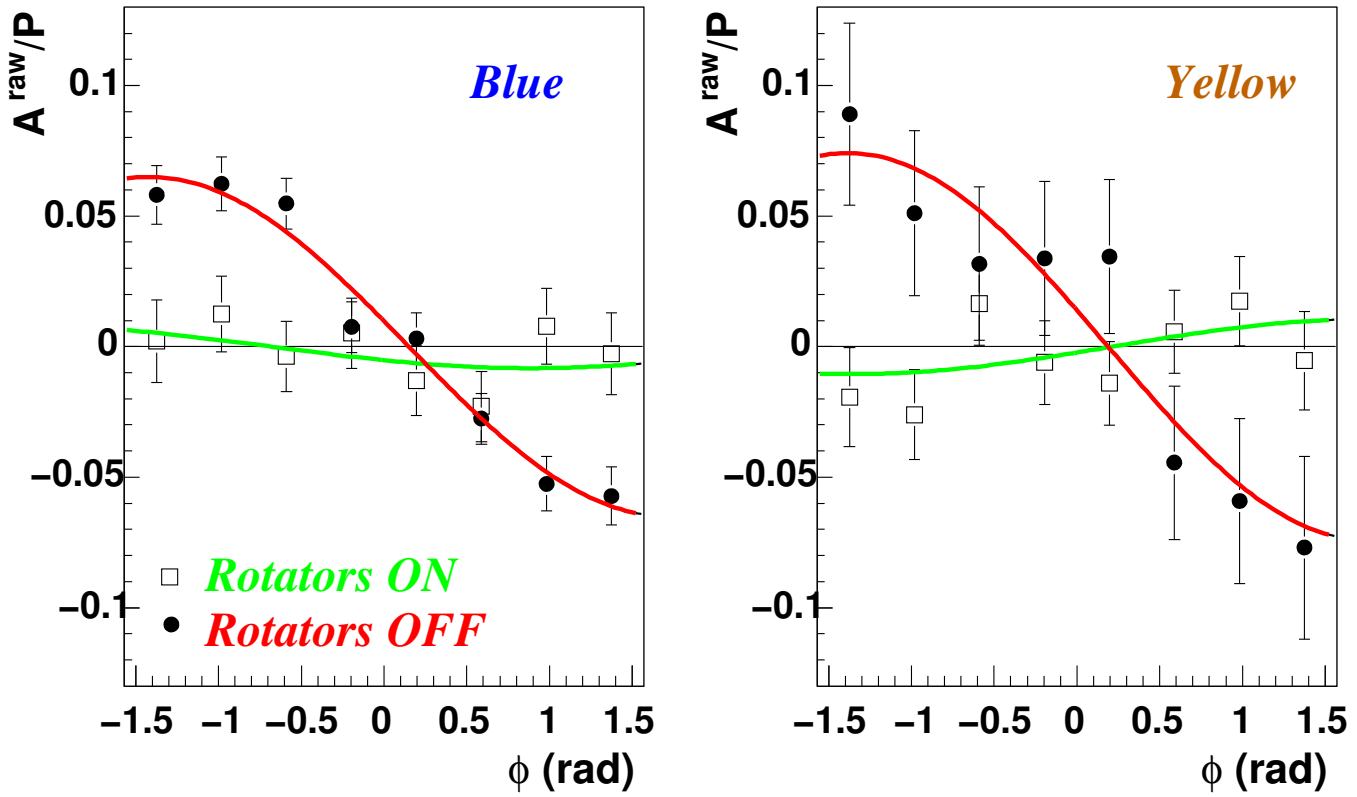
Longitudinal Polarization

Rotators ON: Left-right asymmetries vanish $\Longrightarrow$ Longitudinal polarization



Longitudinal components: $0.993^{+0.005}_{-0.023}$ (blue) and $0.974^{+0.014}_{-0.041}$ (yellow)

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RHIC Performance in 2003

In 2003 RHIC was running at $\sqrt{s} = 200$ GeV with 56 bunches in each ring.

- Intensity per bunch : $0.65 \cdot 10^{11}$
  Peak Luminosity : $6 \cdot 10^{30}$ cm^{-2} s^{-1}
  - Limited by vacuum pressure rise and beam beam interactions

- Average Polarization: $\sqrt{\langle P_y \cdot P_b \rangle} \approx 0.26$
  - Mostly due to polarization loss in AGS

RHIC Performance in 2003

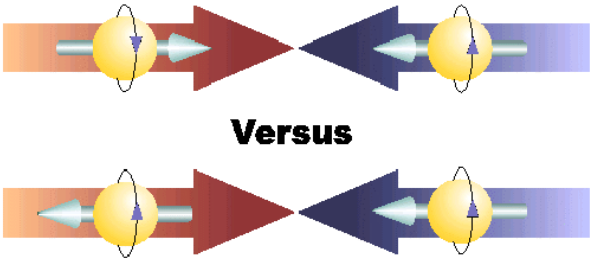
... and in the future

In 2003 RHIC was running at $\sqrt{s} = 200$ GeV with 56 bunches in each ring.

- Intensity per bunch : $0.65 \cdot 10^{11}$
  Peak Luminosity : $6 \cdot 10^{30}$ cm^{-2} s^{-1}
  - Limited by vacuum pressure rise and beam beam interactions
    - Very good performance in this years Au Au run
    - Integrated luminosity about a factor 2 higher than expected
- Average Polarization: $\sqrt{\langle P_y \cdot P_b \rangle} \approx 0.26$
  - Mostly due to polarization loss in AGS
    - A warm partial snake has been installed in the AGS:
      50% Polarization measured at extraction energy.
    - Superconducting snake in the AGS for future runs.

A_{LL} Determination

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} \quad \begin{cases} ++ & \text{same helicity} \\ +- & \text{opposite helicity} \end{cases}$$



Determination of A_{LL} by measuring yields and integrated luminosities:

$$A_{LL} = \frac{1}{|\langle P_B P_Y \rangle|} \cdot \frac{N_{++} - \mathcal{R} N_{+-}}{N_{++} + \mathcal{R} N_{+-}} \qquad \text{with} \qquad \mathcal{R} = \frac{\mathcal{L}_{++}}{\mathcal{L}_{+-}},$$

Three quantities are needed :

- ➢ Beam polarization
- ➢ π^0 yield
- ➢ Relative luminosities

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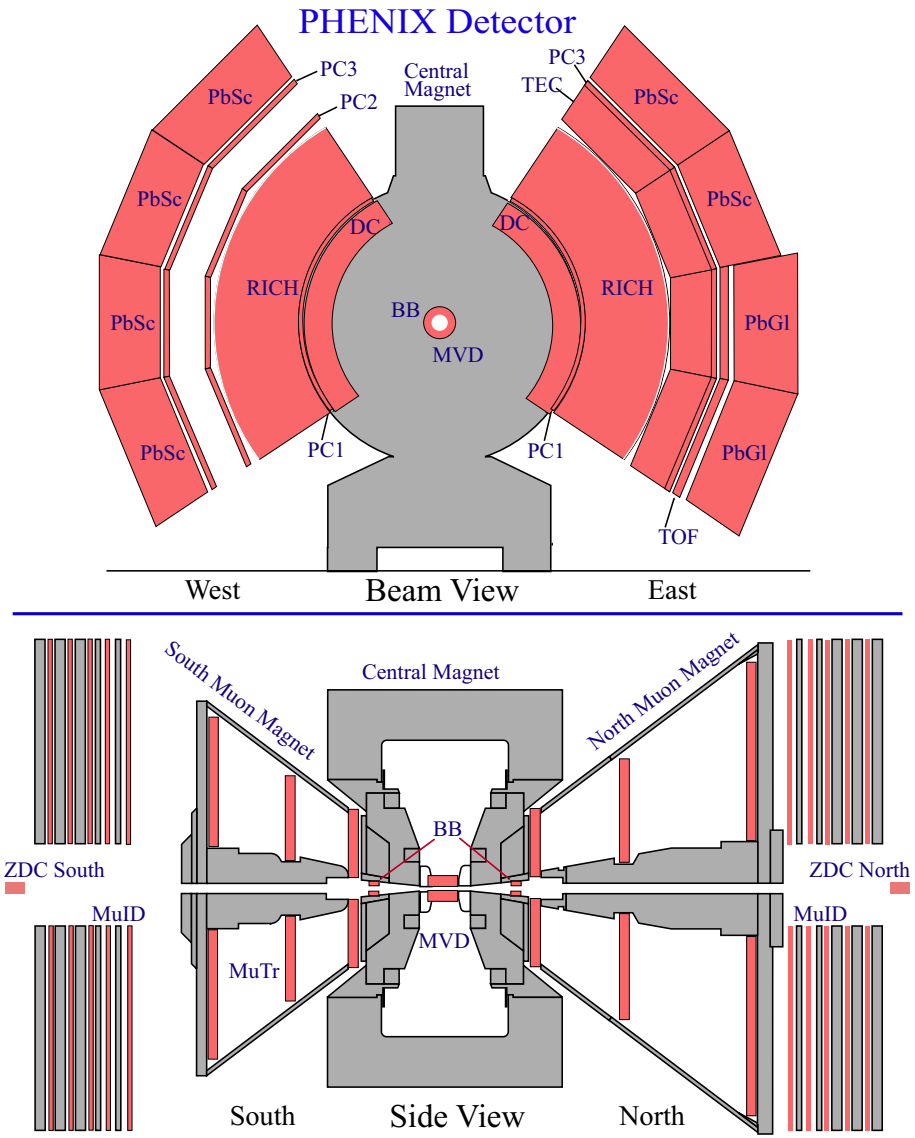
The PHENIX Detector



PHENIX Central Arm :

- $|\eta| < 0.35$
- $\phi = 180^\circ$

π^0-Detection:

- PbSc:
- PbGl:

Trigger:

- Collision trigger: BBC
- High-p_T Photon trigger: EMCal

Luminosity Measurement:

- BBC
- ZDC

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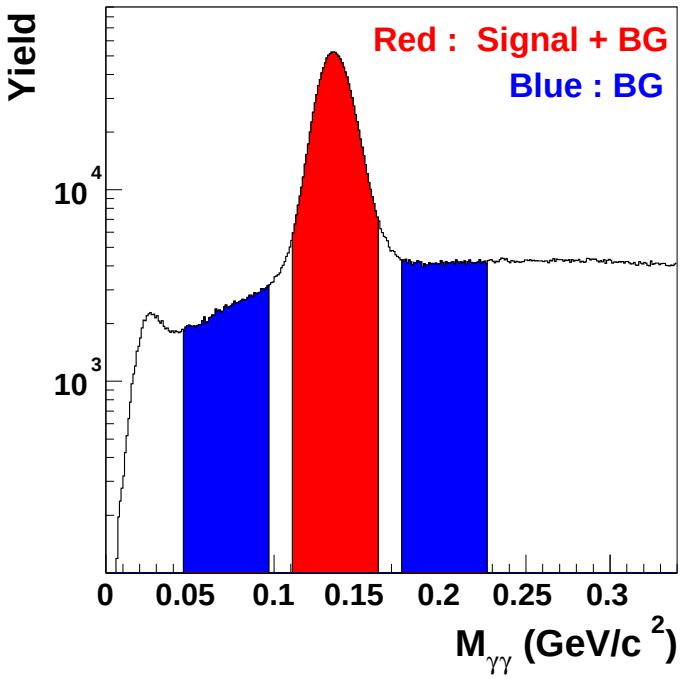
π^0 Reconstruction

Analyzed data sample : $43.5 \cdot 10^6$ events ($\approx 0.22 pb^{-1}$) with $\sqrt{\langle P_y \cdot P_b \rangle} \approx 0.26$.



Photon ID cuts

- Shower profile
- Time of Flight
- Charge Veto

to maximize Figure of Merit

- Minimize background (combinatorial + hadronic)
- Keeping the π^0 efficiency high (84% to 93%).

Data collected with high-p_T photon trigger.

$p_T(GeV/c)$	Trig. Eff. PbSc	Trig. Eff. PbGl	Bkgr. contr.
1 – 2	6%	13%	27%
2 – 3	54%	60%	15%
3 – 4	84%	84%	9%
4 – 5	91%	88%	8%

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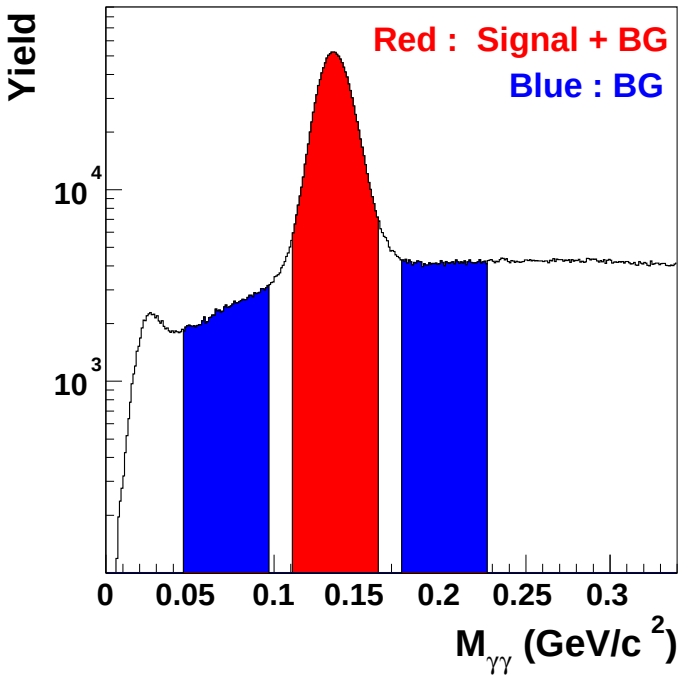
Background Correction



Background

- Asymmetry of background is determined from the blue region near the π^0 mass region.
- Background under π^0 peak and background are normalized (r)

A_{LL}-values are corrected for the background contribution:

$$A_{LL}^{\pi^0} = \frac{A_{LL} - r A_{LL}^{bckg}}{1-r} \quad \text{and} \quad \sigma_{A_{LL}^{\pi^0}} = \frac{\sqrt{\sigma_{A_{LL}}^2 + r^2 \sigma_{A_{LL}^{bckg}}^2}}{1-r}$$

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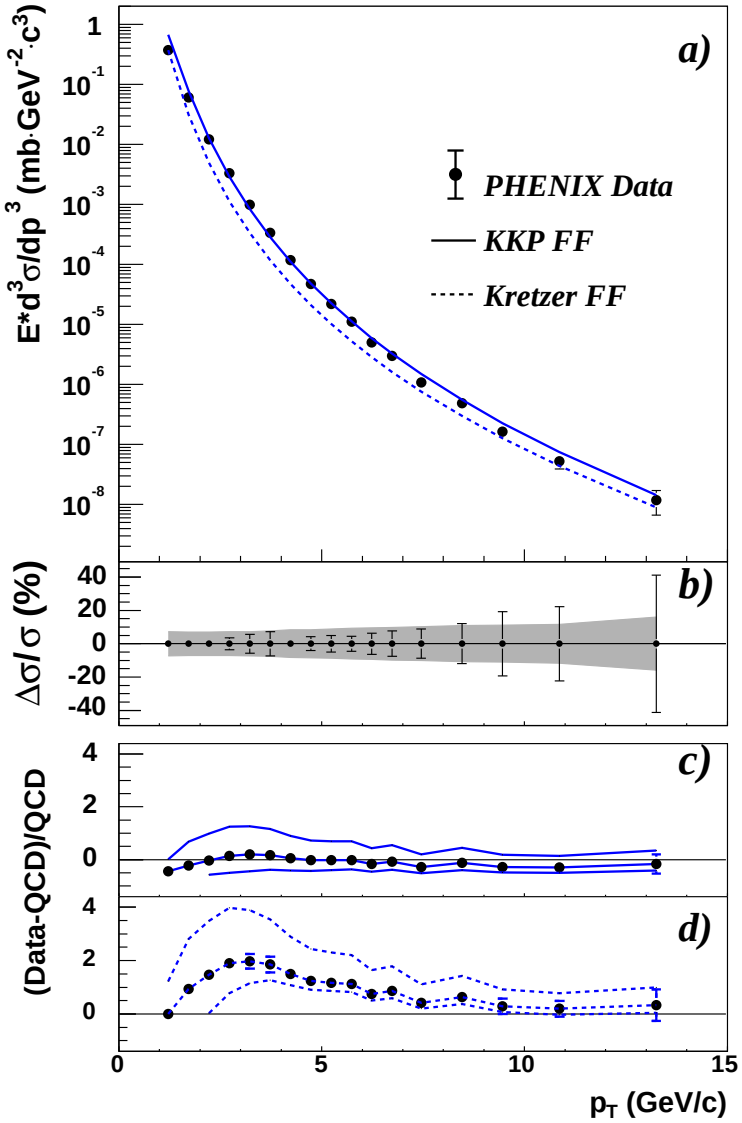
π^0 Cross Section



- π^0 cross section measured over 8 orders of magnitude
- Published in Phys. Rev. Lett. 91, 241803 (2003).
- Good agreement with NLO pQCD calculations to low p_T

9.6% normalization error is not shown

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Relative Luminosity

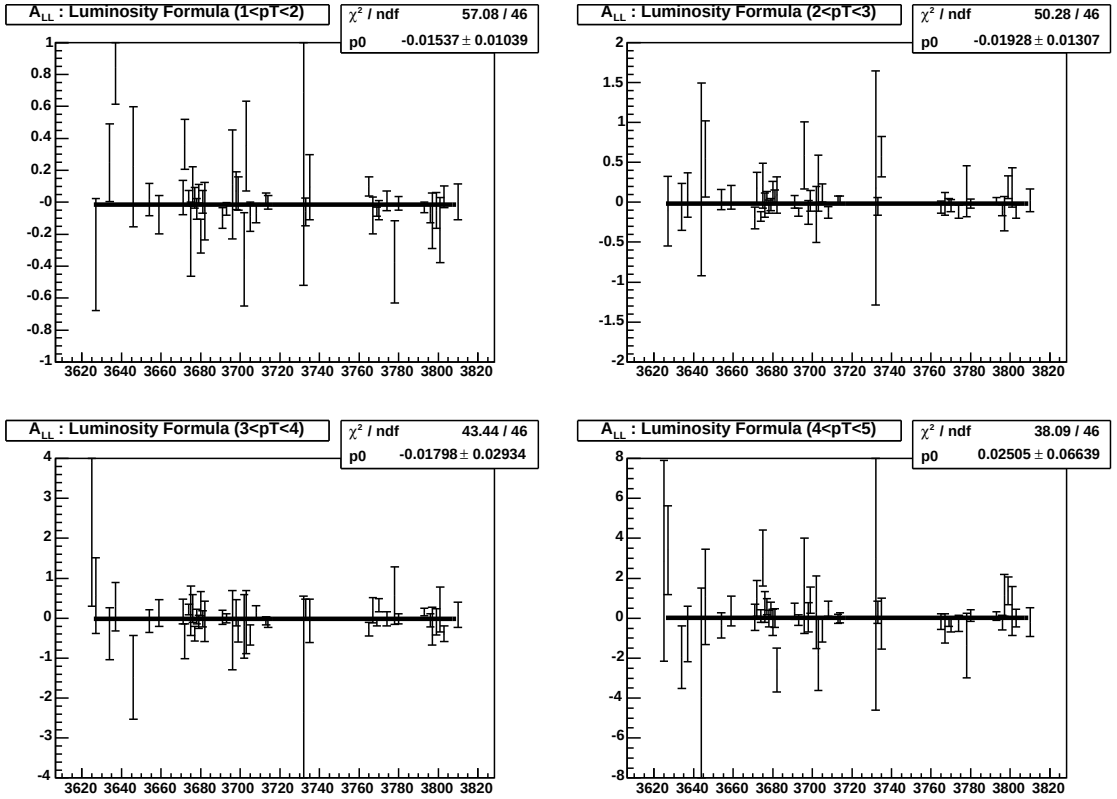
The BBC is used as a relative luminosity monitor, because of

- Low background ($\sim 10^{-4}$)
- High statistics

The ZDC is used as a cross check.

- Luminosity measurements of BBC and ZDC consistent
- Accuracy of luminosity measurement : $\delta\mathcal{R} = 2.5 \cdot 10^{-4}$
- Therefore : $\delta A_{LL} = 1.8 \cdot 10^{-3}$

Determination of A_{LL}



- A_{LL} is determined for every fill
- Fit of a constant to the data
- Final result is the mean value
- Polarization constant within fill
- Good χ^2-distribution

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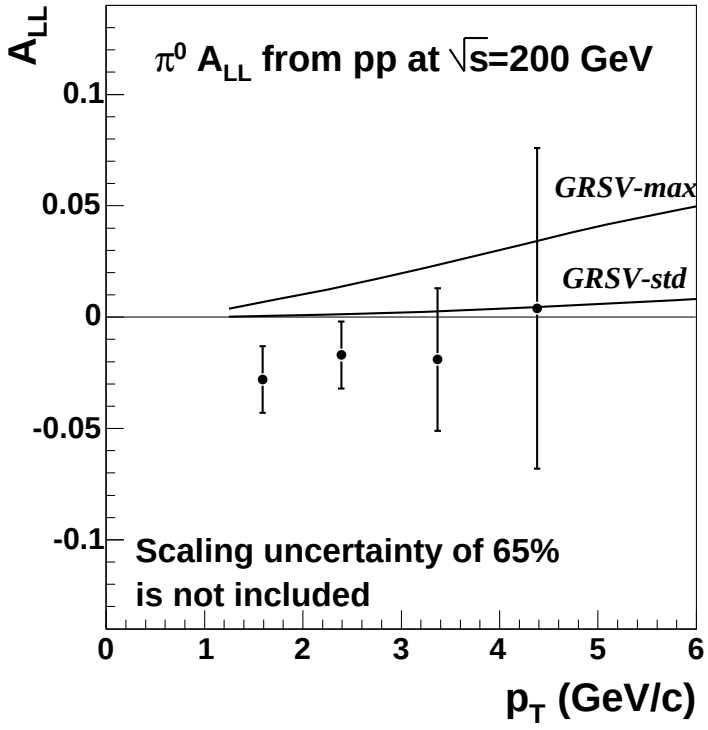
Results



Comparison with two NLO calculations:
Phys. Rev. **D63**(2001), 094005

Consistency with data:

- GRSV-std: CL 21-25%
- GRSV-max: CL 0.1-8%

(no theoretical uncertainty included)

$p_T(GeV/c)$	Bckg. contr.	$A_{LL}^{\pi^0+bckg}$	A_{LL}^{bckg}	$A_{LL}^{\pi^0}$
1-2	27%	-0.015 $\pm$ 0.010	-0.018 $\pm$ 0.016	-0.028 $\pm$ 0.015
2-3	15%	-0.019 $\pm$ 0.013	-0.031 $\pm$ 0.028	-0.017 $\pm$ 0.015
3-4	9%	-0.018 $\pm$ 0.029	-0.008 $\pm$ 0.079	-0.019 $\pm$ 0.032
4-5	8%	0.025 $\pm$ 0.066	0.26 $\pm$ 0.20	0.004 $\pm$ 0.072

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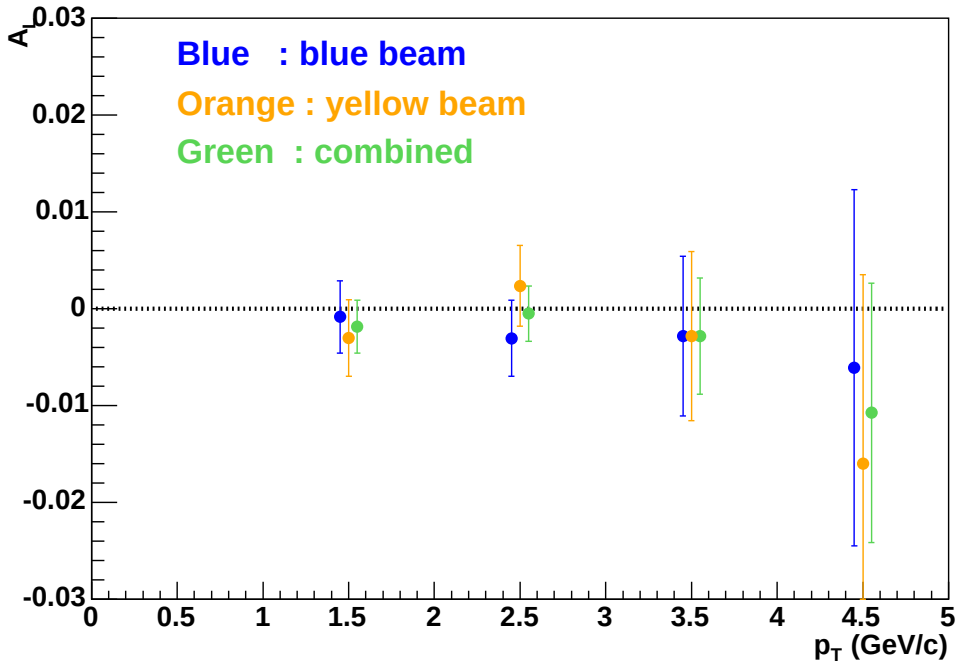
Parity Violating Asymmetry A_L

Parity violating asymmetries

- Asymmetries between $(++)$ and $(--)$
- Asymmetries between $(+-)$ and $(-+)$
- $A_L = -\frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$

} are all consistent with 0.



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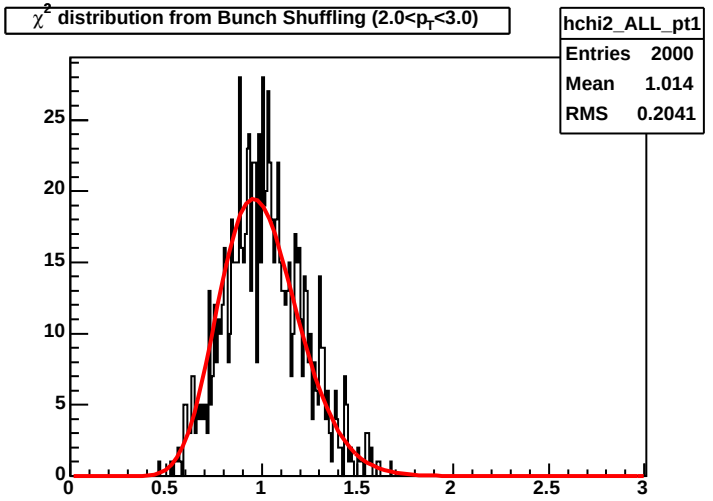
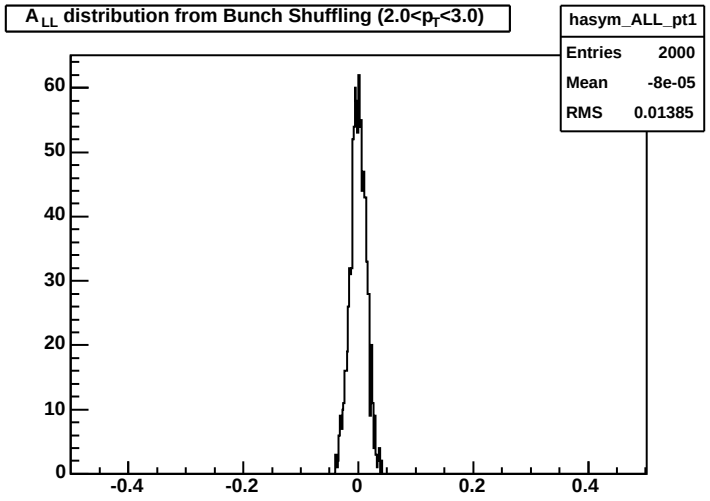
Systematic Checks

Bunch shuffling:

- ➢ Randomly assign helicity signs to every bunch crossing
  $\Longrightarrow$ Average Polarization 0
- ➢ Determine A_{LL} for each fill
- ➢ Determine the mean value for A_{LL}
- ➢ Repeat this process 1000 times



χ^2/DOF



A_{LL}

- Width of A_{LL}-distributions are consistent with errors assigned to A_{LL}
- This indicates that uncorrelated systematic errors are much smaller than the statistical errors

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Summary and Outlook

Summary

- PHENIX has measured A_{LL} in inclusive π^0 production
- First evaluation of the polarized gluon distribution from RHIC
- Observed Asymmetry is small
- Level of uncertainty is comparable to global fits to existing DIS data

Outlook

- Higher polarizations and higher luminosities expected in the near future
- Absolute polarization measurement this year

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12 Countries; 58 Institutions; 480 Participants*

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, Universite Paris Sud, CNRS-IN2P3, Orsay
	LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
	SUBATECH, Ecòle 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
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	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
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	Korea University, Seoul
	Myong Ji University, Yongin City
	System Electronics Laboratory, Seoul Nat. University, Seoul
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	Joint Institute for Nuclear Research, Dubna
	Kurchatov Institute, Moscow
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	Florida State University, Tallahassee, FL
	Florida Technical University, Melbourne, FL
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	Los Alamos National Laboratory, Los Alamos, NM
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*as of January 2004

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