PHENIX

# The Physics of the PHENIX Muon Arms

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Key PHENIX physics goals which rely heavily on the muon arms are described. Highlights of the present construction status are presented.

- PHENIX Muon Arms provide the muon detection for both the relativistic heavy ion and spin physics programs of PHENIX.

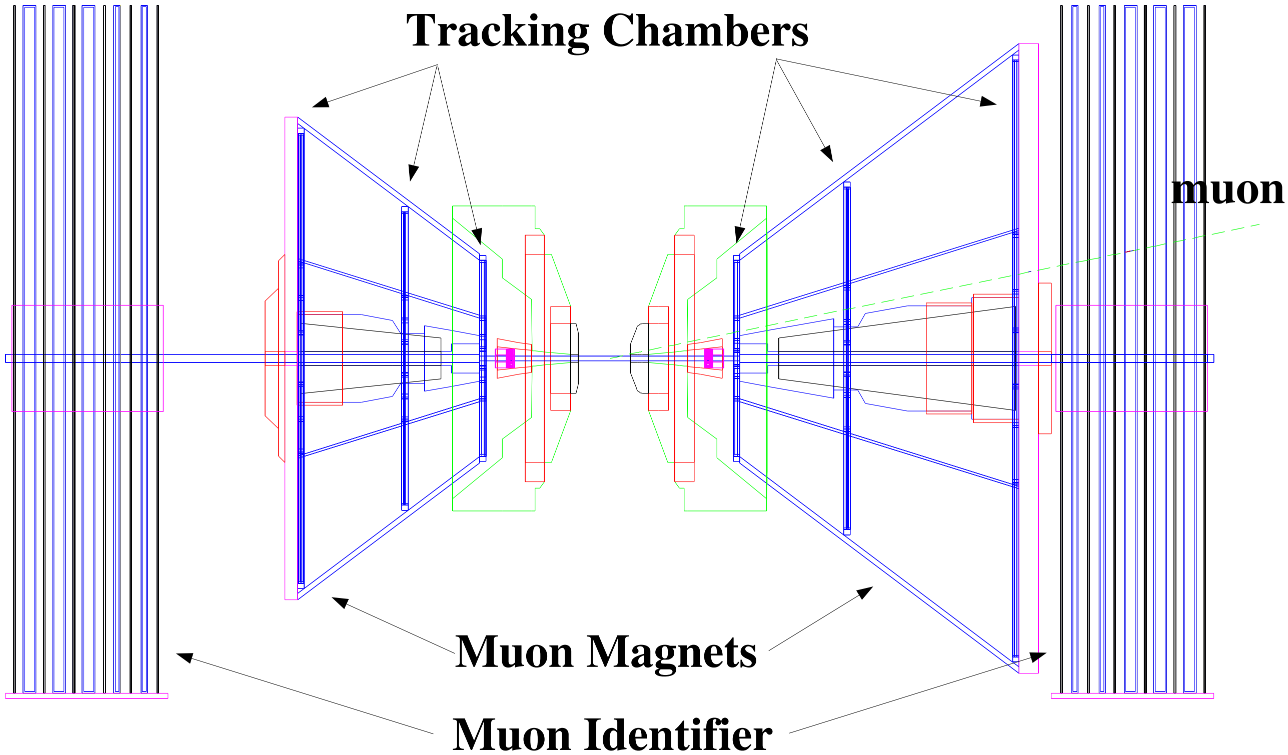
- Muons:
  - arise from several processes (vector mesons, charm, $\gamma^*$)
  - leave point of creation with "no" further interaction
  - can be detected with $\approx 10^{-4}$ pair background

- Each muon arm must both track and identify muons, as well as provide good rejection of pions and kaons; therefore, both a Muon Tracker and a Muon Identifier are needed.

- *Muon arms approved for construction in 1996!*

- *Muon Identifier to be installed by September 98!*

*Managed by Lockheed Martin Energy Research Corp. under contract DE-AC05-96OR22464 with the U.S. Department of Energy.




- Each arm of the Muon Tracker comprises three stations of tracking chambers inside the end-cap muon magnet. Each station has three planes of cathode strip chambers. This measures the momentum and a 3-dimensional trajectory.

- Cathode strip chambers with analog readout

- 100 $\mu m$ resolution goal

- Stereo readout to counteract projective ambiguities

- Each arm of the Muon Identifier comprises 5 gaps instrumented with plastic proportional tubes interleaved with 4 layers of steel absorber. Signals must arrive within 106 ns (beam crossing time) for use in Level-1 trigger decision.

- Steel absorber serves as a “filter” for muons. Steel preceding the muon identifier provides $10^{-2}$ of the overall $10^{-4}$ $\pi/\mu$ separation.

- Sufficient pointing accuracy to match unambiguously with muon tracker tracks.

- Require over 10 year longevity for all components.

- Chose plastic proportional tubes (Iarocci limited streamer tubes operating at reduced voltage in proportional mode).

- Eight wires in each tube are ganged together into one read-out channel to allow for low resolution tracking and to provide signals for the first and second level muon triggers.

- x-y readout of 8.5 cm wide tubes with readout from one end.

# HEAVY ION PHYSICS PROGRAM

- Primary goal is to detect new phase of matter, the Quark Gluon Plasma (QGP), and measure its properties via simultaneous measurements of various signatures. Muon Arms are a major contributor to the total physics program.

- Measurement of the production of vector mesons decaying into dimuons in heavy ion collisions for masses ranging from the $\phi$ to the $\Upsilon$.

- Measurement of the differential suppression of $J/\psi$ and $\psi'$ production will provide information concerning "deconfinement," *i.e.* screening of the QCD potential. (The $\Upsilon(1S)$ serves as a "control" measurement.)

- Two muon arms provide large acceptance for high mass pairs at central rapidity – very important for these important scarce events.

- Measurement of the Drell-Yan dimuon continuum as a "reference" and in its own right to understand scaling with A.

- Measurement of charm and bottom production cross sections using high $p_t$ single muons to tag event as a heavy quark decay. Use to probe temperature of possible phase transition.

- Measurement of the muon (in coincidence with $e$ from the central arms) for the process $D\overline{D} \rightarrow \mu + e + X$.

- Level-1 trigger simulations indicate that muon identifier will be able to efficiently identify muons (about 96% of those reaching gap 3) and not have an unacceptable false hypothesis Level-1 trigger rate due to expected backgrounds.

- $10^{-4}$ $\pi/\mu$ rejection ratio achieved after Level-1 by using information from the muon tracker in conjunction with the muon identifier.

- Simulated mass resolutions and acceptances:

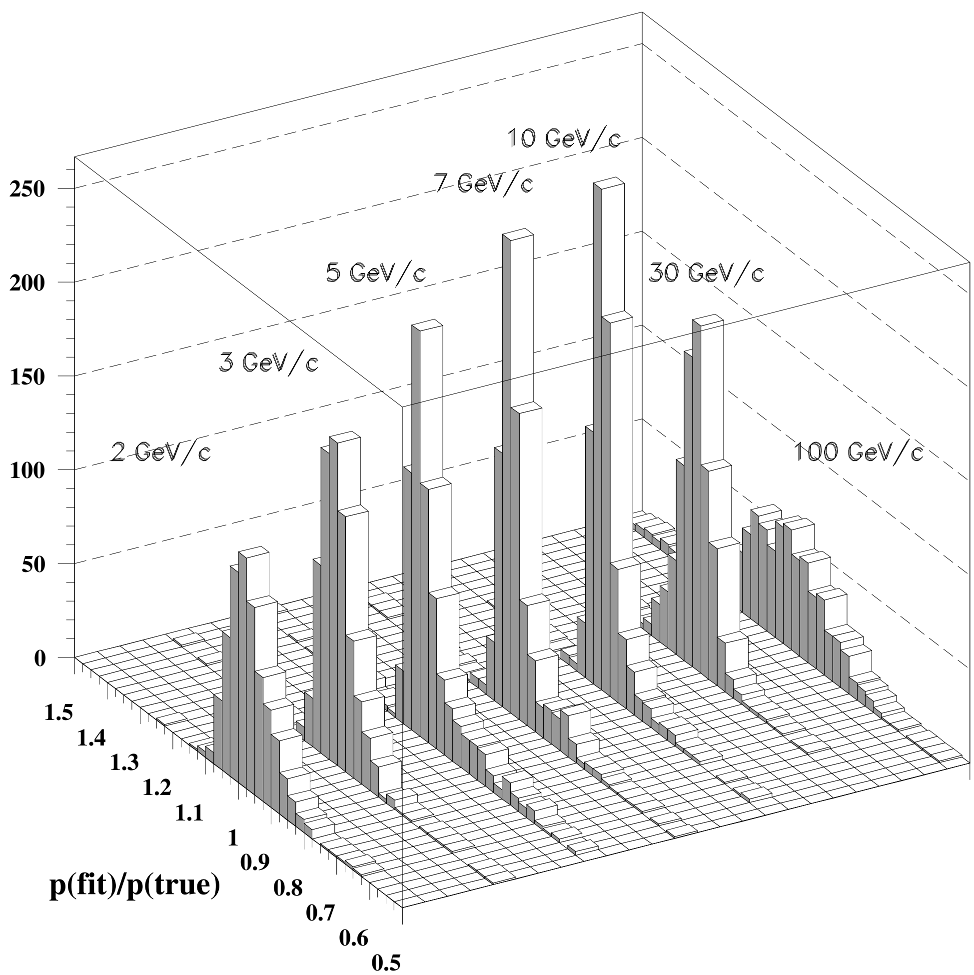
| Particle | Mass Resolution (MeV/$c^2$) | Acceptance (%) | Events/year in North Arm |
|---|---|---|---|
| $\phi$ | 60 | 0.58 | $4 \times 10^4$ |
| $J/\psi$ | 105 | 4.3 | $6.7 \times 10^5$ |
| $\psi'$ | 105 | 4.3 | $1.2 \times 10^4$ |
| $\Upsilon$ | 180 | 3.0 | 382 |

- 0.6 million $J/\psi$ per arm per RHIC-year of $Au + Au$ minimum bias collisions (at design luminosity of $2 \times 10^{26}$ cm$^{-2}$s$^{-1}$). $J/\psi$ production cross section assumed to be $9.0 \times 10^{-27}$cm$^2$.

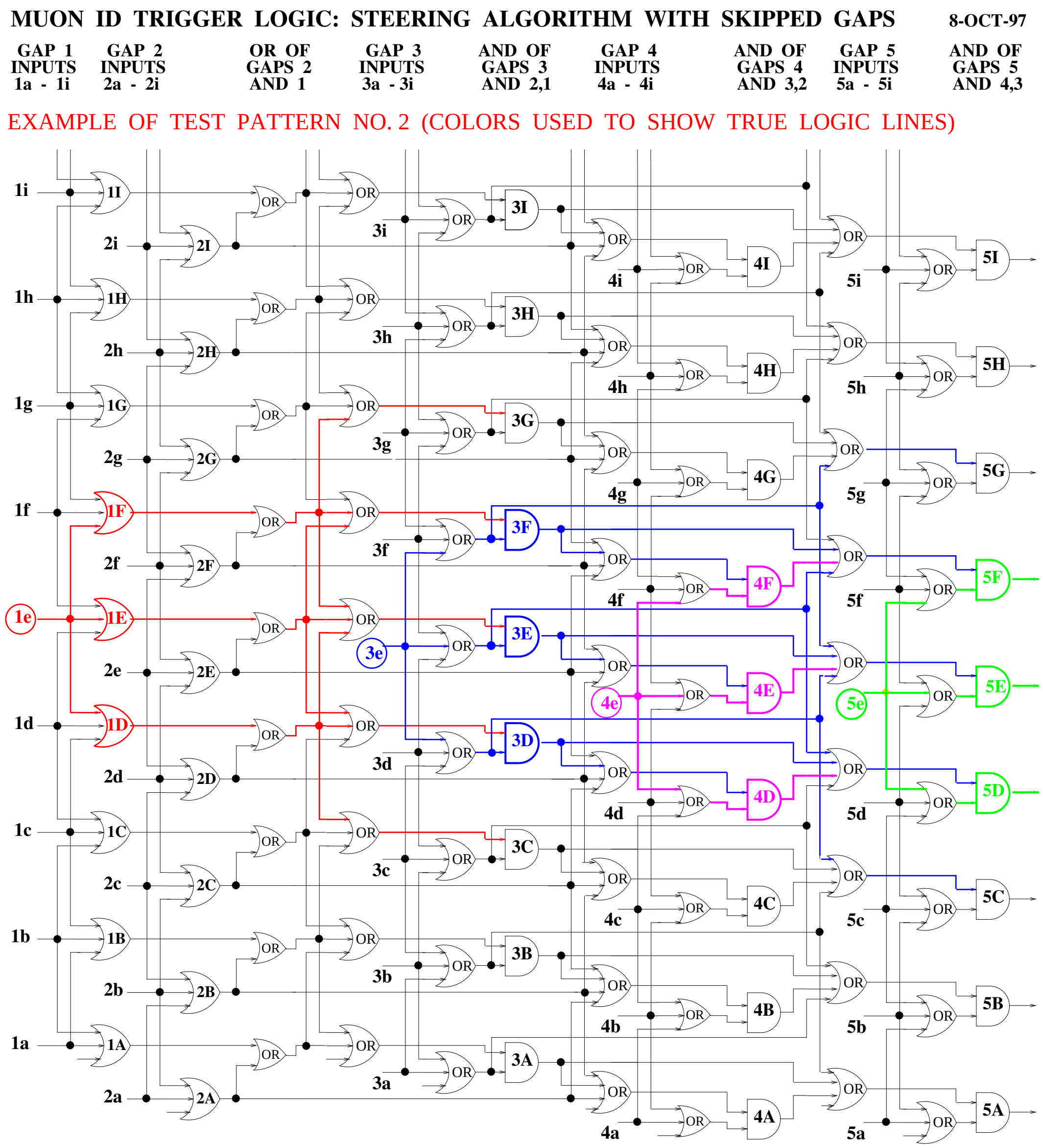
- 293 $\Upsilon$ per year with one muon in each arm (at $y = 0$ where perhaps the QGP "soup" is densest).

## Momentum Resolution Spectra of Muon in North Arm @ 30 deg

## Studied with GEANT based simulation

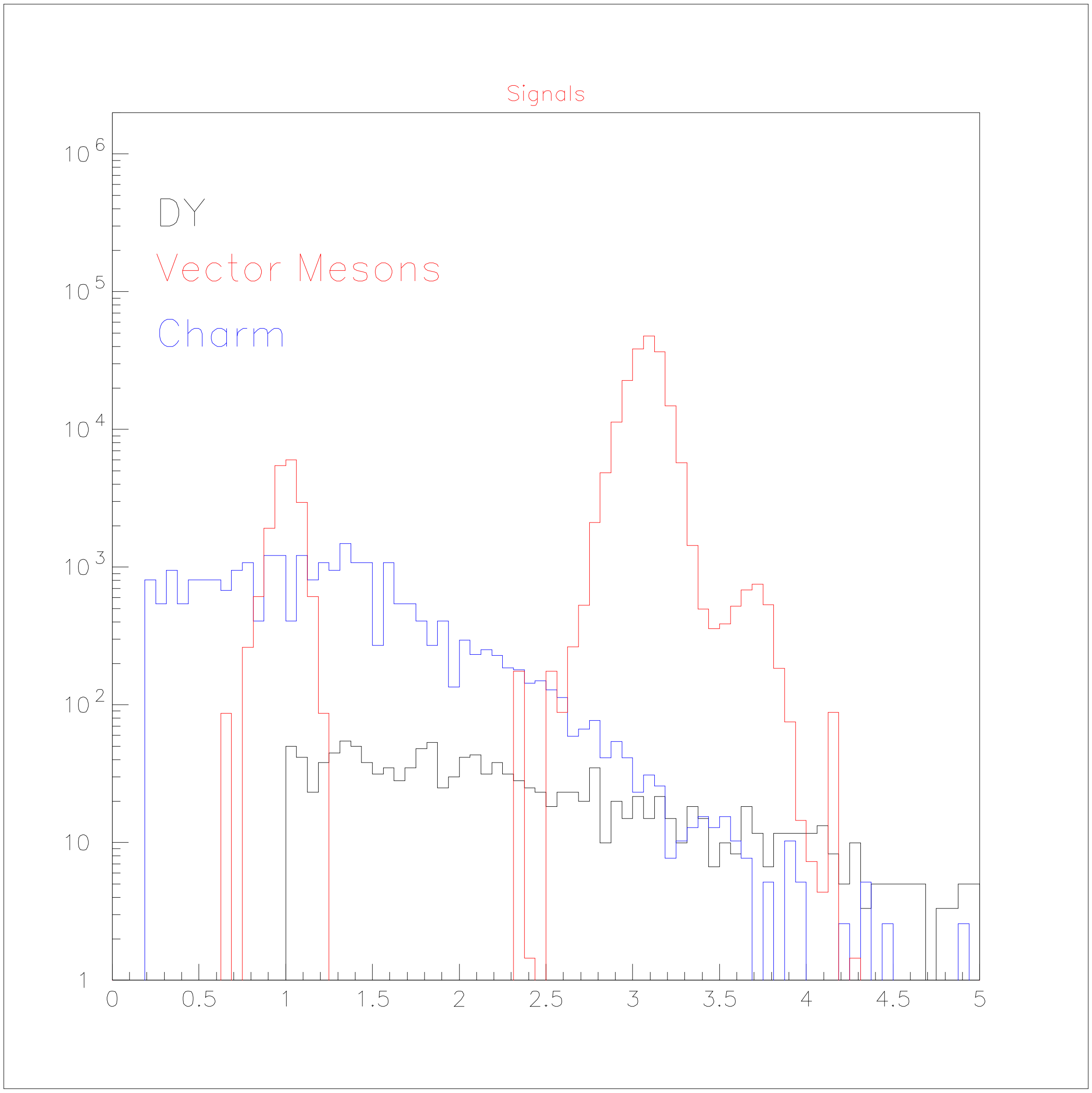


# LVL-1 Trigger Logic



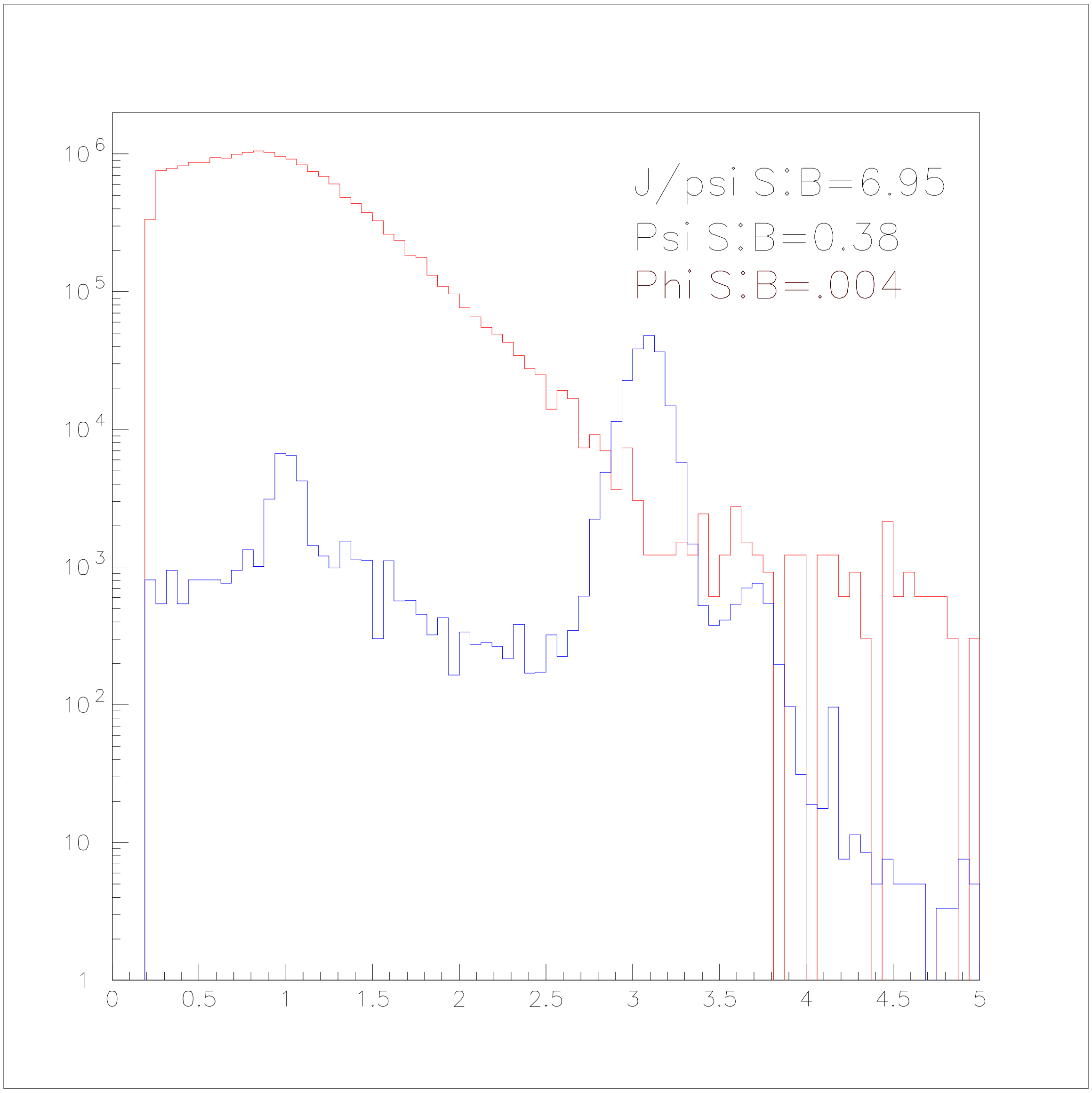

Example of electronic implementation of the muon identifier Level-1 trigger logic which allows for "steered" roads. Colors indicate example of true logic at each gap for a particular muon path.

Dimuon Invariant Mass Distribution

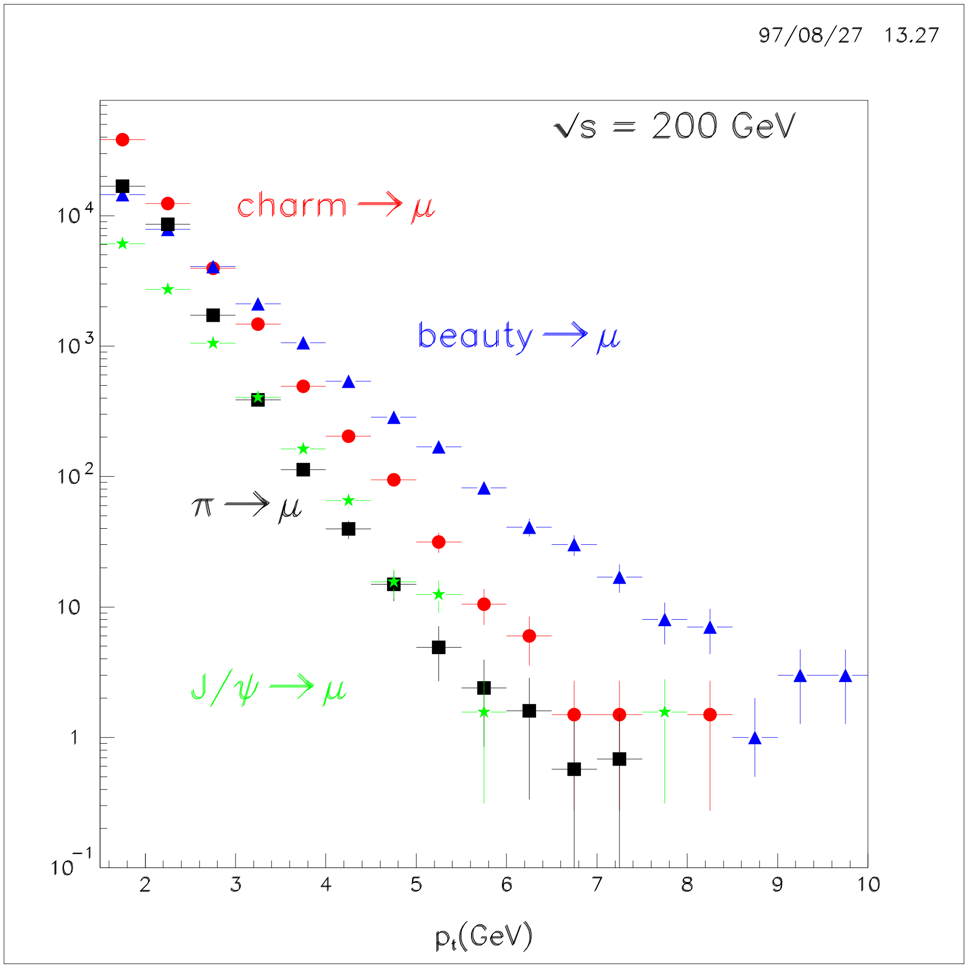



Contributions due to Drell-Yan production (black), vector mesons (red), and uncorrelated charm decays (blue). Distribution corresponds to one RHIC-year of $Au + Au$ minimum bias collisions at design luminosity of $2 \times 10^{26}$ cm$^{-2}$s$^{-1}$.

Dimuon Invariant Mass Distribution




Contribution due to (preceding) combined signals (blue) and including backgrounds as well (red). Distribution corresponds to one RHIC-year of $Au + Au$ minimum bias collisions at design luminosity of $2 \times 10^{26}$ cm$^{-2}$s$^{-1}$.




Single muon transverse momentum distribution due to heavy flavor decay signals and backgrounds. Distribution corresponds to 12 days of continuous running at luminosity $10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ (10% of design luminosity) for $pp$ collisions. Similar distributions for $p + Au$ and $Au + Au$ collisions allow this analysis to be performed with heavy ion data, too.

- Gluon fusion $gg \to (b\bar{b}$ or $c\bar{c})$ followed by $(b$ or $c) \to \mu X$.
- Heavy flavor production dominates single muon $p_t$ spectrum for $p_t > 4$ GeV/c. (This analysis does not distinguish $c$ from $b$ decays.)
- Measure open heavy flavor production to study gluon shadowing factor. Year-1 luminosity sufficient.

# SPIN PHYSICS PROGRAM

- Goal is to understand the contributions of the spin of sea quarks and the polarization of gluons to the total nucleon spin and help explain deviation of past experimental data from the Ellis-Jaffe sum rule.

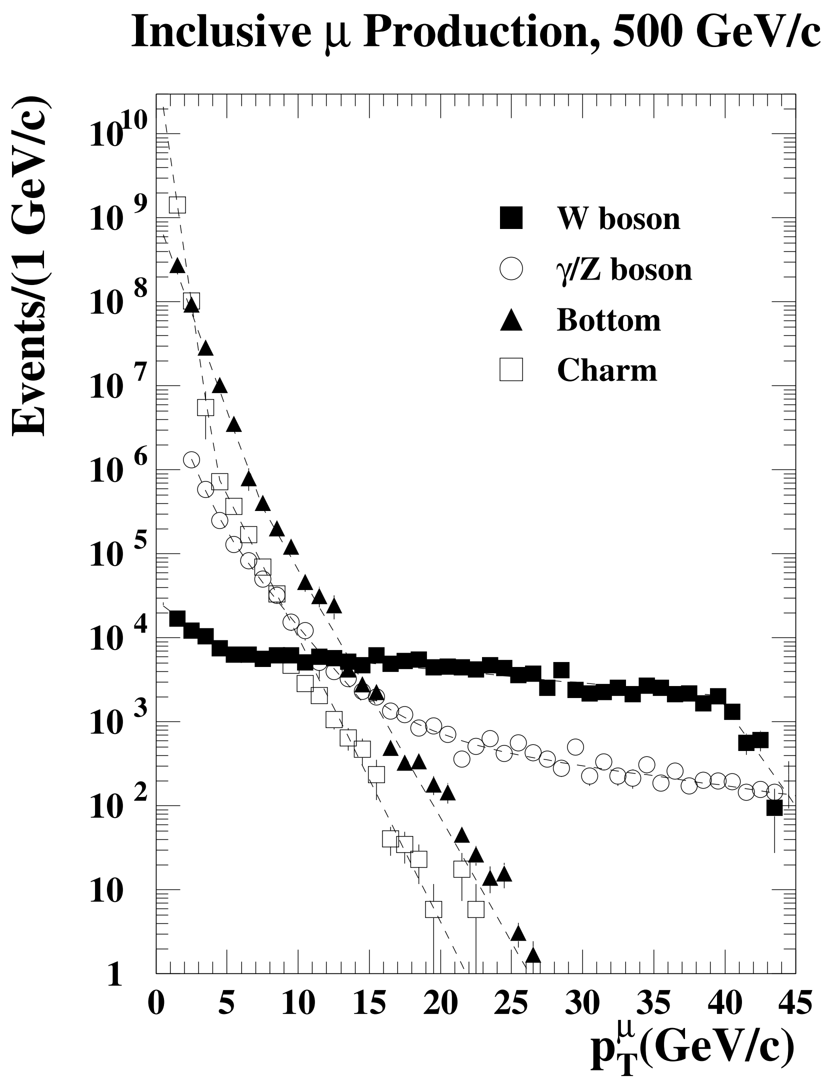
- Longitudinally or transversely polarized $p + p$ collisions at $\sqrt{s}$ from 50 to 500 GeV are to be analyzed to measure the helicity distributions of quarks and anti-quarks and gluon polarization in the nucleon.

- Dimuons and high $p_t$ single muons are detected to measure helicity dependent cross sections (beam proton spins aligned or anti-aligned) such as the polarized Drell-Yan process, vector boson production, and polarized gluon fusion.

- Antiquark structure function measurements rely on analyzing Drell-Yan and vector boson production data.

- Gluon polarization measurements rely on analyzing heavy quark, $J/\psi$, and prompt photon data.

- Muon spectrometer with two arms has a greatly enhanced detection capability for large $M/\sqrt{s}$ muon pairs, where polarization effects are likely to be maximal.




Single muon transverse momentum distribution due to various decay processes. Distribution corresponds to an integrated luminosity of $2 \times 10^{39}\mathrm{cm}^{-2}$ (one year of running at design luminosity) of $pp$ collisions at $\sqrt{s} = 500$ GeV.

- Very high $p_t$ single muon spectrum dominated by vector boson decay with low background.

As an example of part of the spin physics program, consider the Drell-Yan process

$$q(x_1) + \overline{q}(x_2) \rightarrow \gamma^* \rightarrow \mu^+\mu^-$$

for which the longitudinal spin asymmetry is given by:

$$A_{LL}^{DY}(x_1, x_2) = \frac{\Sigma_a\, e_a^2 \Delta q_a(x_1) \Delta \overline{q}_a(x_2) + (2 \leftrightarrow 1)}{\Sigma_a\, e_a^2 q_a(x_1) \overline{q}_a(x_2) + (2 \leftrightarrow 1)}$$

where $\Delta q_a \equiv q_a^+ - q_a^-$, where $q_a$ are the quark momentum fraction distribution functions. The superscripts refer to parton spin projections parallel (+) or antiparallel (−) to the parent hadron's spin projection.

# CONSTRUCTION HIGHLIGHTS

- Construction project is underway.
- Assembly factories ramping up at BNL and Japan.
- Install first muon identifier panel this February!
- Install last panel by 9/30/98.
- Ready to take data in summer 1999.
- Expected performance should enable PHENIX to address the heavy ion and spin physics goals.

# PHOTO CAPTIONS

(Left to right:)

1. Muon tracker station 2 prototype under construction.

2. Muon tracker station 3 honeycomb panel for prototype construction.

3. Muon identifier full-scale prototype under construction.

4. Muon identifier prototype internal amplifiers.