ESTIMATING AND REMOVING BACKGROUND COMPONENTS IN MEASURING INCLUSIVE SINGLE MUON PRODUCTION IN p+p COLLISIONS AT RHIC

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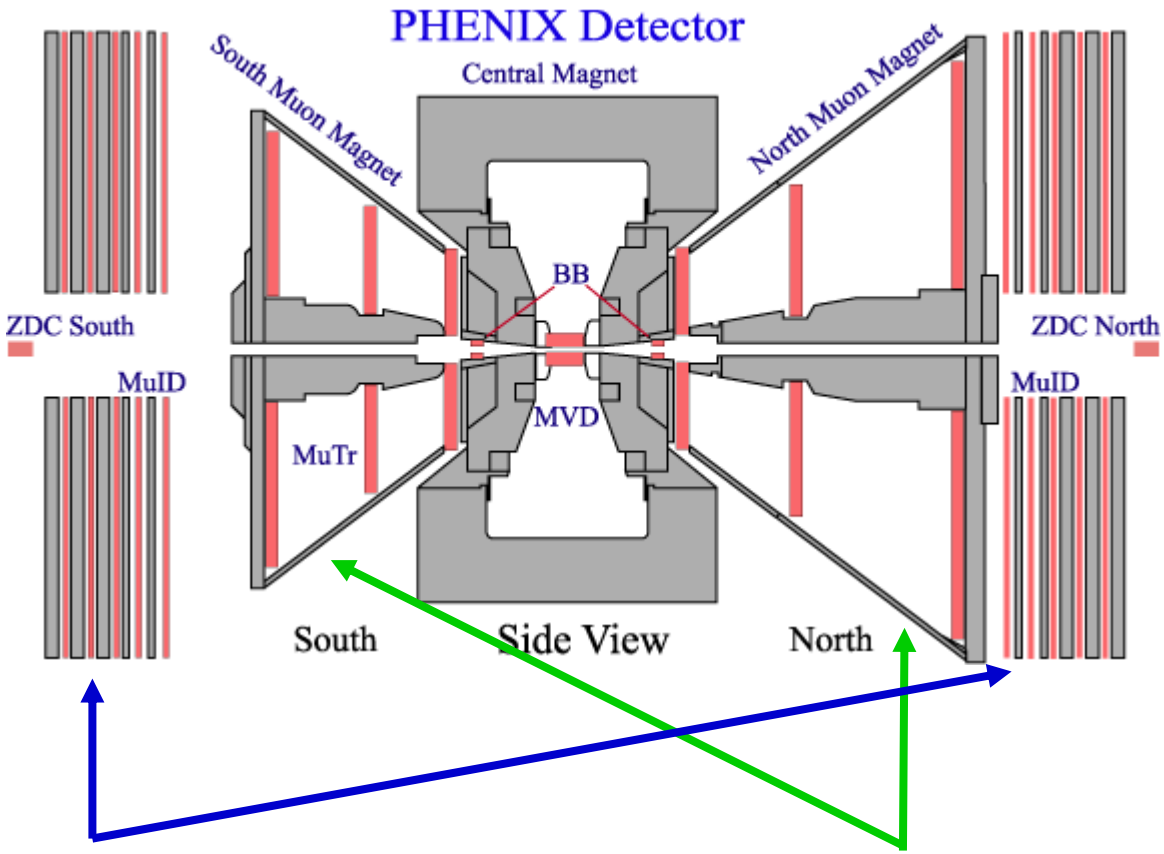
PHENIX SINGLE MUON PHYSICS BACKGROUNDS

PHENIX MUON ARMS



Muon Identifier (MuID)

5 gaps per arm filled with planes of transversely oriented Iarocci tubes

Muon Tracker (MuTR)

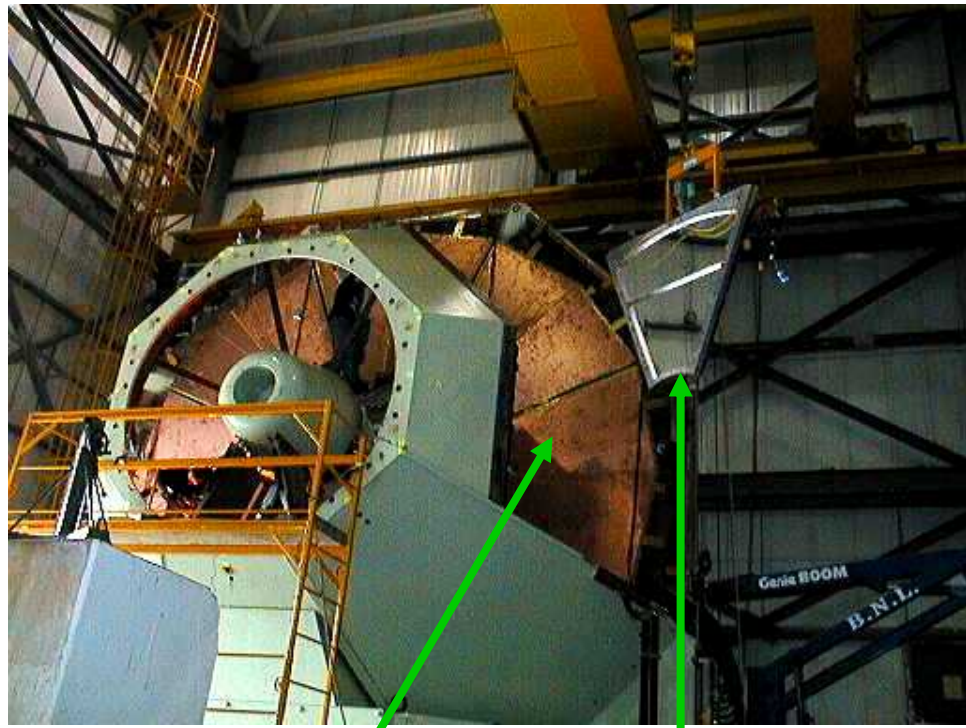
3 octagonal stations of cathode strip chambers per arm

PHENIX MUON ARMS

South Muon Identifier

One of 6 panels around the square hole for the beam pipe. These comprise one of the 5 gaps for the south MuID.

South Muon Tracker and Magnet

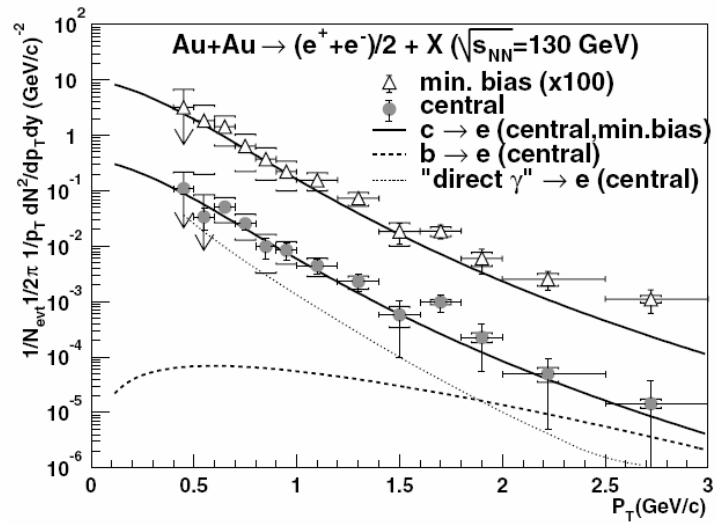


Installing a station 2 octant into the south muon arm.

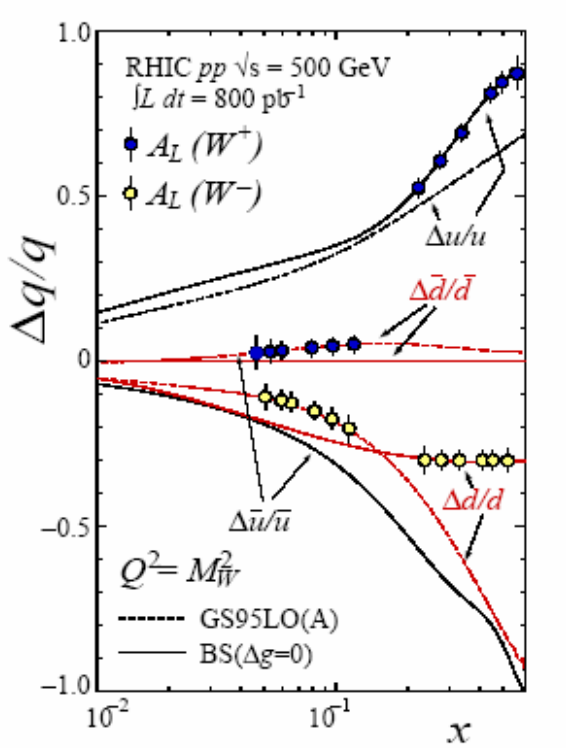
Station 3 already installed.

SINGLE MUON PHYSICS WITH PHENIX

- **Signal for open heavy flavor**
  - $c \rightarrow \mu$ and $b \rightarrow \mu$
  - Critical baseline for studying J/Ψ suppression.
- **Signal for W boson production**
  - $W \rightarrow \mu \nu$
- **To extract such signals from the measured inclusive single muon distribution, we must subtract the following background contributions.**



COMPARABLE SINGLE ELECTRON EXAMPLE: PHENIX Run 2 background-subtracted electron spectra for minimum bias (0%–92%) (scaled up by a factor of 100) and central (0%–10%) collisions compared with the expected contributions from open charm decays. Also shown, for central collisions only, are the expected contribution from bottom decays (dashed line) and the conversion electron spectrum from a direct photon prediction (dotted line). From Phys. Rev. Lett. 88, 192303 (2002).



ANOTHER EXAMPLE: Expected sensitivity for the flavor-decomposed quark and antiquark polarizations. Darker points with error bars refer to the sensitivity from $A_L(W^+)$ measurements, and lighter ones refer to $A_L(W^-)$. The curves represent different recent theoretical predictions for the parton densities. From "Prospects for Spin Physics at RHIC," G. Bunce, N. Saito, J. Soffer, W. Vogelsang, hep-ph/0007218.

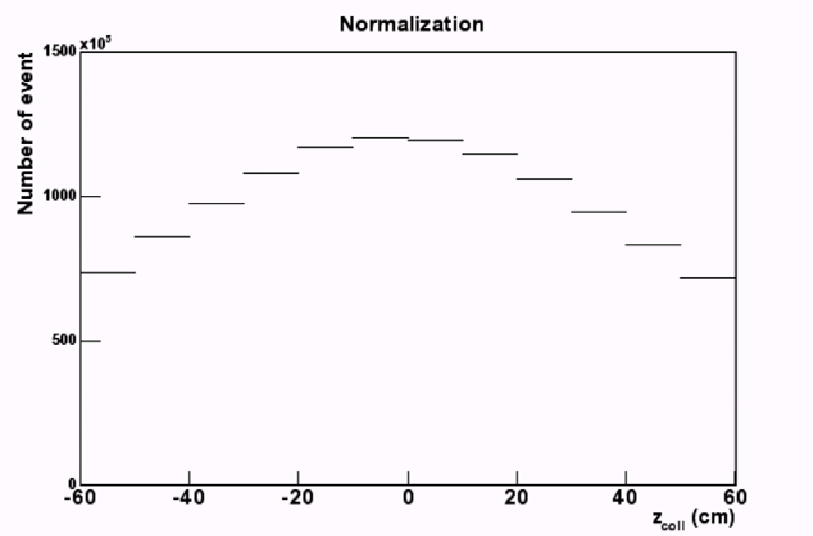
SINGLE MUON BACKGROUNDS

- **Decay muon background**
  - Muons from hadrons (primarily $\pi \rightarrow \mu \nu$ and $K \rightarrow \mu \nu$)
  - We separately discuss those that result from hadron decay in air before hitting the PHENIX nosecone ("free decays") and those from hadrons that decay within detector material.
  - Note: Decay muons or hadrons selected by depth – momentum matching can be used to measure light hadron production as a function of collision centrality, R_{cp}.
- **Punch-through background**
  - Hadrons or their shower remnants that penetrate through (much of) the muon identifier producing a false muon track
- **Background tracks**
  - Fake tracks, perhaps due to combining unrelated hits.
  - Beam related backgrounds.

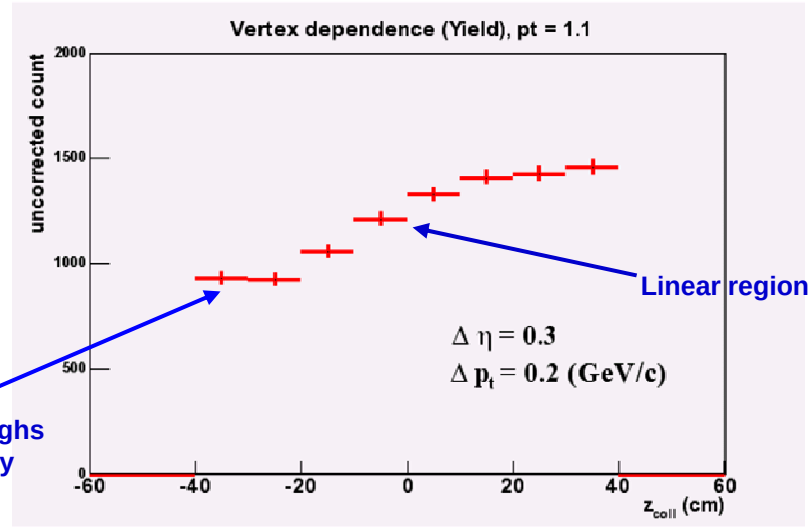
MEASURING THE DECAY MUON BACKGROUND

- Some of the previously mentioned backgrounds are suppressed by the detector design and reconstruction algorithms (depth/momentum cut, etc.).
- However, some backgrounds remain that must be subtracted statistically.
- We can measure the "free decay" background component within a limited range of p_T.
- $P_{decay}(L_Z, y, p_T) = 1 - \exp(-L_Z / \gamma c \tau \cos\theta)$
  - $L_Z < 60$ cm and $\lambda = 371$ cm for $K^{\pm}$ and 781 cm for $\pi^{\pm}$.
  - Since $L_Z << c\tau$, P_{decay} has a nearly linear dependence on L_Z. The other background components do not have this characteristic dependence on L_Z.

MEASURING THE DECAY MUON BACKGROUND



Minimum bias event z-vertex distribution used for normalization.



Uncorrected measured muon z-vertex distribution showing linear dependence on z.

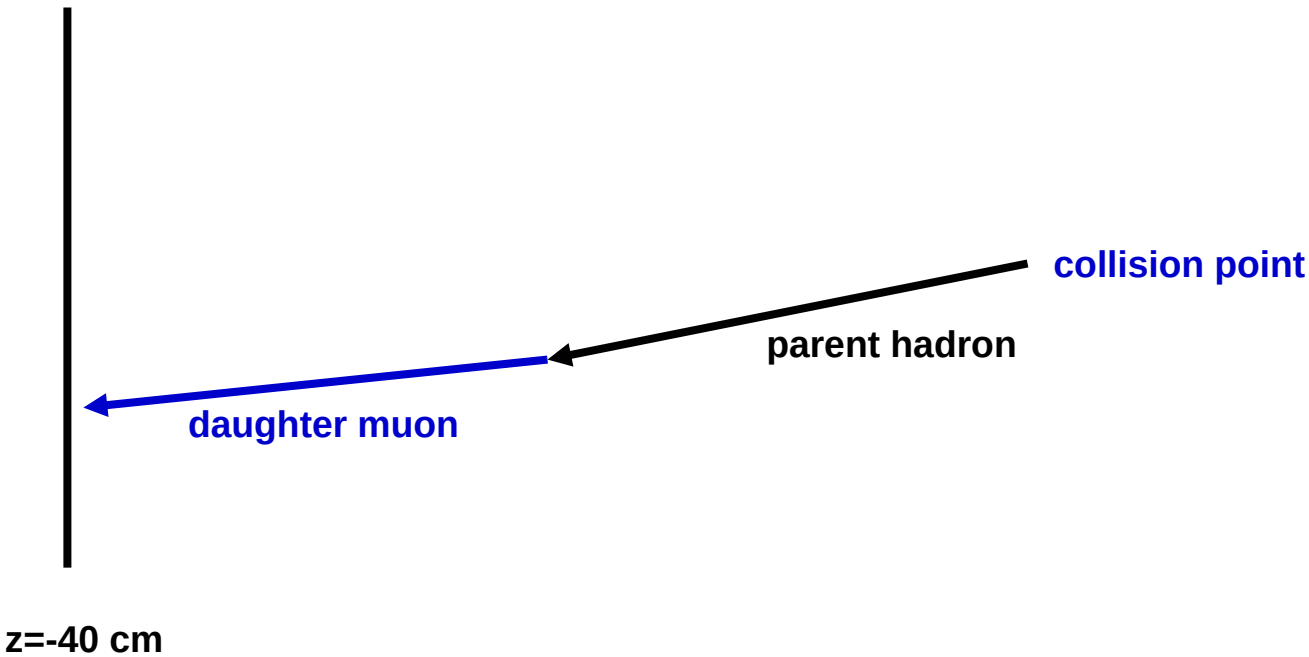
- **To measure decay muon component, we divide the measured inclusive single muon z-vertex distribution by the minimum bias z-vertex distribution.**
- **Then, we fit the normalized single muon z-vertex distribution with a term linear in z plus a constant (separately for different bins in p_T).**
- **For further details, see Poster Flavor 5 (Y. Kwon).**

EFFICIENCY FOR THE FREE DECAY BACKGROUND

- Need to know the efficiency for reconstructing a muon created in each bin in z, η, and p_T.
- Need to be able to check our measured free-decay spectra and extend it to higher p_T, so that we can obtain the input momentum spectrum needed to correctly simulate non-free decays and punch-throughs.
- Since only ~ 1 out of 10^3 hadrons from the vertex results in a muon passing through the MuID, using a full simulation requires millions of events to be simulated and reconstructed in order to obtain sufficient statistics for each bin in particle ID, z, η, and p_T.
- We describe an approach to greatly reduce the number of events to pass on to the full PHENIX simulation by first using a special single particle Monte Carlo event generator.

SIMULATING THE FREE DECAY BACKGROUND

- **Event generator**
  - For each bin in particle ID (π or K), z-vertex, η, and p_T, throw a fixed large number (~300 M) of single particle decays.
  - Allow them to decay based on their decay length in air. For those that decay before the nose cone, write to a file the x, y, z, and 3-momentum of the daughter muon.

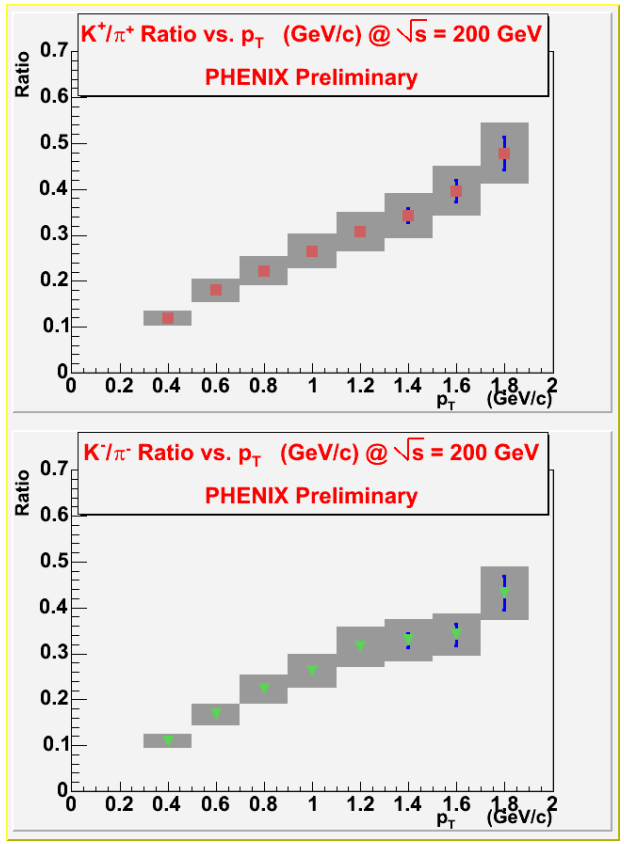


SIMULATING THE FREE DECAY BACKGROUND

- **Pass the file of muons that is generated on to the full PHENIX simulation and reconstruction.**
- **Weight the z distribution according to the minimum bias z-vertex distribution.**
- **Weight the momentum spectrum and impose the K / π ratio using measurements from the PHENIX central arms.**

SIMULATING THE FREE DECAY BACKGROUND

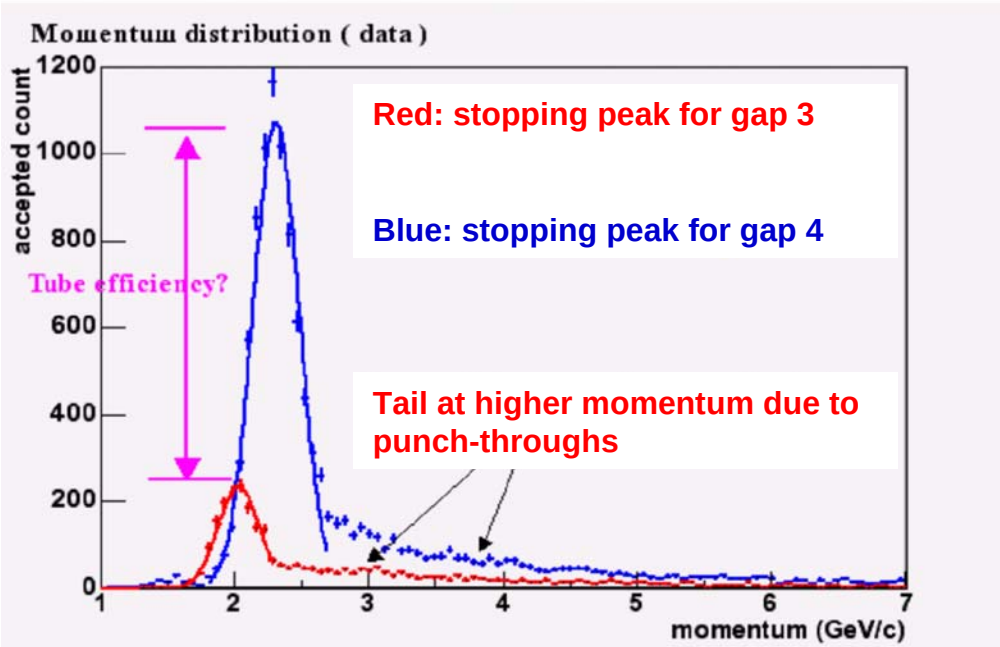
- To get the parent hadron momentum spectrum, we can use spectra measured in the PHENIX central arms adjusted for the difference in rapidities.
- This approach should be acceptable for the purposes of this simulation, with the assignment of an appropriate systematic error.
- Both PYTHIA and results from BRAHMS Au+Au data support this approach.
- For further details concerning the identified spectra from the PHENIX central arms, please see Poster Spectra 8 (M. Harvey) and a talk in the Thursday am plenary session (J. Velkovska).



Measured K/π ratio from PHENIX central arms for Run 2 p+p collisions at 200 GeV

ESTIMATING THE PUNCH-THROUGH BACKGROUND

- Shown below are the momentum distributions for muon candidates that stop at gap 3 (red) and gap 4 (blue) of the MuID.
- We can use distributions such as these to measure the punch-through contamination in intermediate gaps. However, we need a simulation to estimate the punch-through contamination in the last gap and to correct for the effect of detector inefficiencies using this approach.



ESTIMATING THE PUNCH-THROUGH BACKGROUND

- **Simulation is a necessary element of this study**
  - Efficiency
  - Shower profile details
  - Decay in flight
  - Hadronic interaction cross sections
- **A hybrid data-driven model is being developed.**
  - The simulation is sensitive to the hadronic interaction model used: FLUKA, GHEISHA, …. (Exponentially sensitive to the difference in such packages.)
  - Use data to check the predictions for intermediate gaps.
- **Excellent μ/π separation of the PHENIX Muon Identifier means that less than 1 in ~10^3 simulated hadrons will punch through the MuID.**
- **Millions of events must be simulated, and reconstructed in order to obtain sufficient statistics for each bin in z and p_T.**

OUTLOOK

- **The PHENIX muon arms are performing well and will significantly increase statistics during Run 4. Stay tuned for exciting physics!**
- **See related PHENIX posters prepared by**
  - **D. Silvermyr, Poster Flavor 2**
  - **Y. Kwon, Poster Flavor 5**
  - **A. Glenn, Poster Flavor 6**
  - **C. Zhang and A. Purwar, Poster Flavor 13**
  - **V. Dzordzhadze, Poster Intrumentation 5**
- **Hear related PHENIX talks from**
  - **S. Kelly, "Charm production …", Parallel Session 2, Thursday afternoon**
  - **M.-X. Liu, "Muon production …", Parallel Session 2, Thursday afternoon**
  - **M. Brooks, "J/psi and Open Charm", Plenary Session, 9 am Friday**
  - **R. G. de Cassagnac, "J/psi production …", Parallel Session 3, Friday afternoon**
- **For more information, see www.phenix.bnl.gov.**