BRAHMS
Beam Use Proposal
Runs 4-6

F.Videbæk

For

The BRAHMS collaboration

The BRAHMS Collaboration

- 53 people from 12 institutions-

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Overview

- Introduction
- Accomplishments in RUN-2 & 3
  - Au-Au, d-Au, and pp data collected
  - Physics results
- Goals for RUN-4 and RUN-5+
  - Physics
  - Detailed request
  - Considerations
- Summary

Brahms Physics Goals

Probing and characterizing Hot and Dense Nuclear Matter
By studying:

- Particle Production
- Reaction Mechanisms and Dynamics
- Baryon Stopping
- Hard Processes (high p_t' spectra)

Through High Precision Measurements
of Identified Hadrons over wide range of

- Rapidity: $0 < y < 4$
  (Central and Fragmentation regions)
- Transverse momentum: $0.2 < p_t < 4$ GeV/*c*
  (with the current setup)

BRAHMS measurement capabilities (PID and momentum) at large y are unique in the RHIC Program. The PID capabilities at y~0,1 is at par or better than other exp.

The Program is well underway with the Au-Au data from RUN-2 and d-Au & pp data from Run-3

Au-Au Run-2

Data

- Initial survey of “soft” physics
- Selected high-p_t runs

Results (highlights)

- Charged particle multiplicity ($dN/d\eta$): PRL 88, 202301
- Rapidity dependent Particle ratios and statistical model analysis: PRL 90,102301
- Identified hadron spectra and yields at selected rapidities
  - Net-proton (Panic/QM02,in preparation)
  - dN/dy, slope vs. y for π,K,p (QM02, in preparation)
- High-p_t hadron yields and suppression in Au-Au An Au PRL 91,072305

Accomplishments in Run-3

d-Au at 200 GeV

– Brahms recorded ~ 65 nb^{-1} in the 12 weeks run, albeit most of the statistics came from the last 6 weeks after several background,and machine issue were resolved.

p-p at 200 GeV

– Brahms collected ~ 70 nb^{-1} in the ~4 weeks we took data.

	d-Au		p-p
MRS 90 40	9M 10M	MRS	5M
FS 4 12	4M 1.2M	FS	6M

Spectrometer triggers collected at selected angles.

d-Au Run-3

Data

- Survey of “soft” physics I.e. rapidity distributions for identified hadrons.
- Selected high-p_t runs at y~0,1,2,3

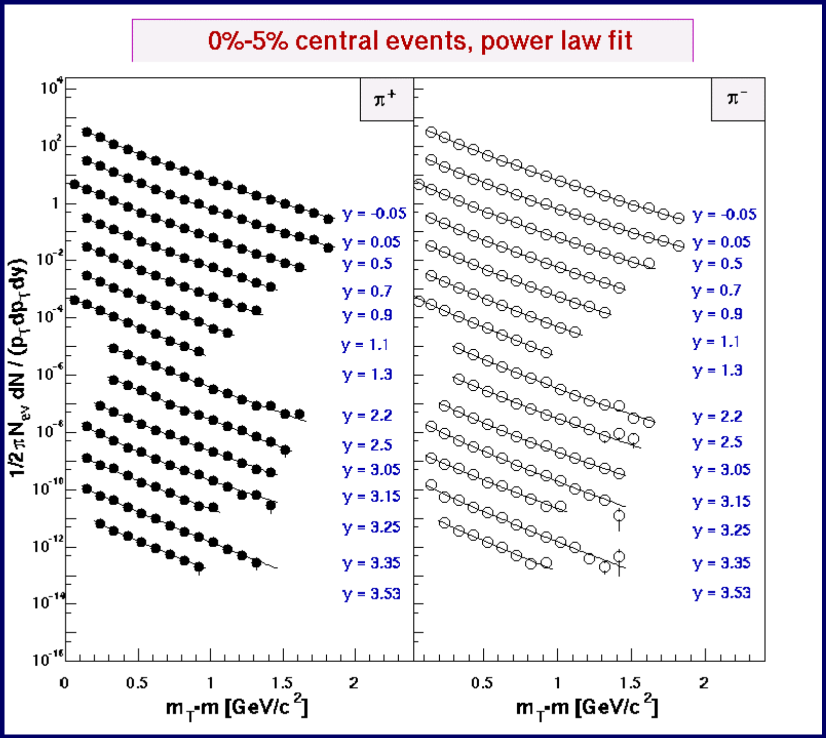
Results

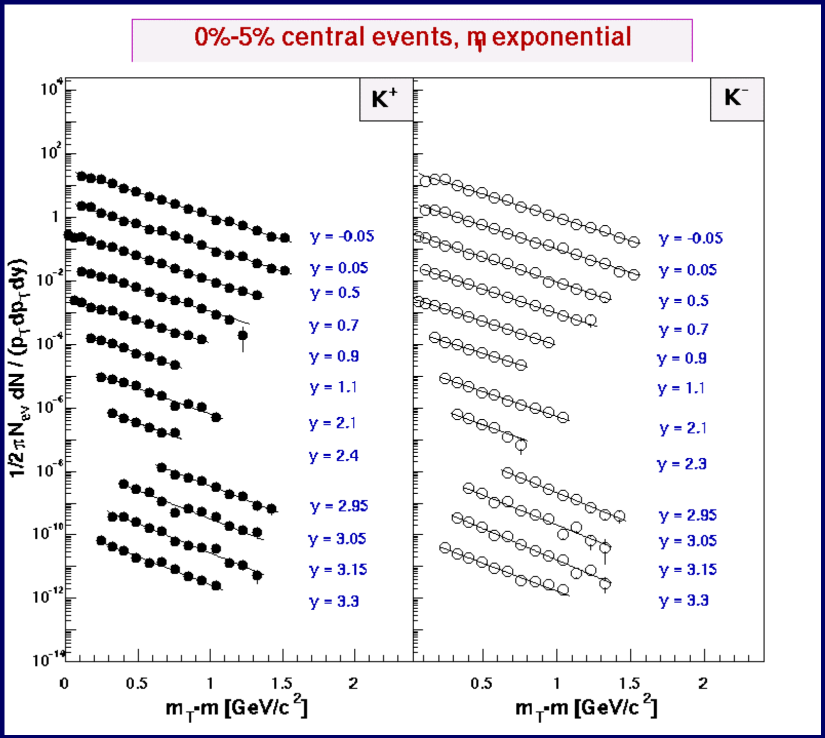
- High-p_t hadron yields, comparison to p-p; observation of no suppression in d-Au at rapidity y~0. PRL 91,072305

Some Ongoing analysis

- Charged particle multiplicity distributions
- High-p_t spectra for identified particles at several y.
- Spectra at large rapidities to compare with predictions of CGC.

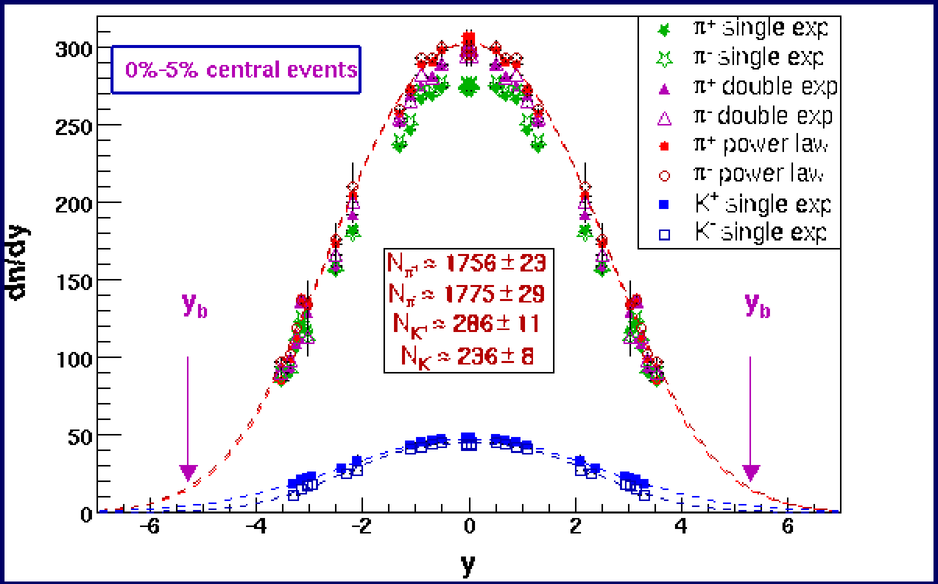
Meson Distributions

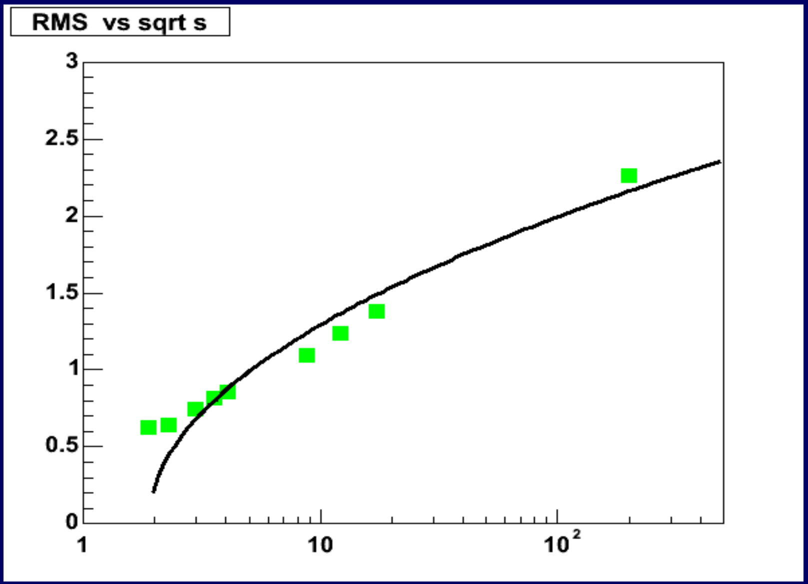




The large dynamic range of the Brahms spectrometers yields coverage from y~0-3.
Data shown for 0-5% centrality.

Meson rapidity distributions



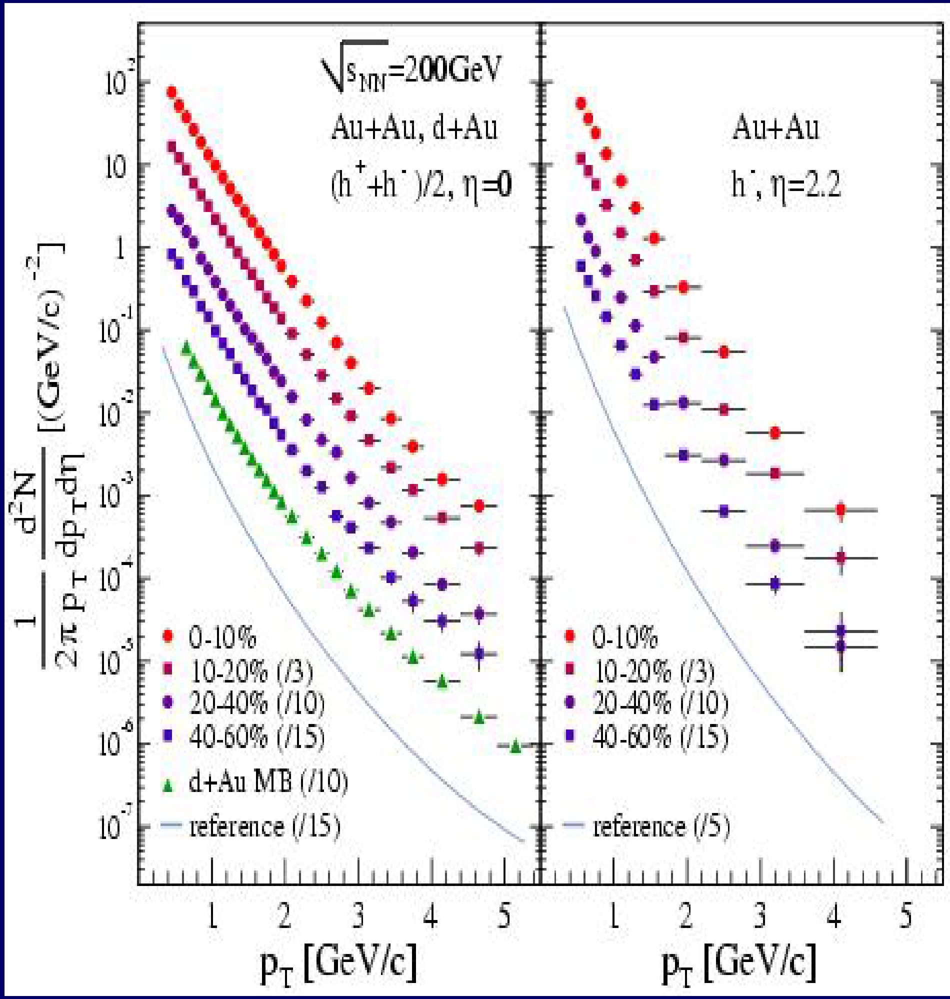


No wide "plateau" observed in rapidity for identified mesons. Close to a Gaussian shape ($\sigma(\pi+) = 2.35 \sim \sigma(k+) = 2.39$)

Total yield in agreement with published $dN/d\eta$ measurements from multiplicity sub-system.

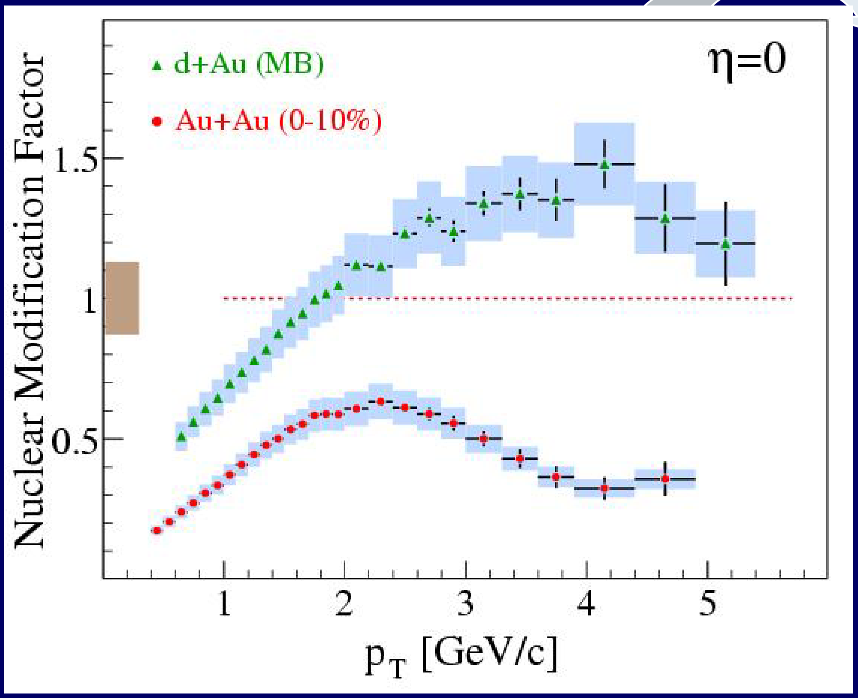
The RMS of π distributions from low energy to RHIC is close to prediction of Landau Hydro model (Caruthers)

High-p_t spectra



High-p_t studies have emerged as significant probe of the dense medium. Brahms can contribute significantly to these studies through rapidity dependence of identified hadrons up to p_t of ~4-5 GeV/c.

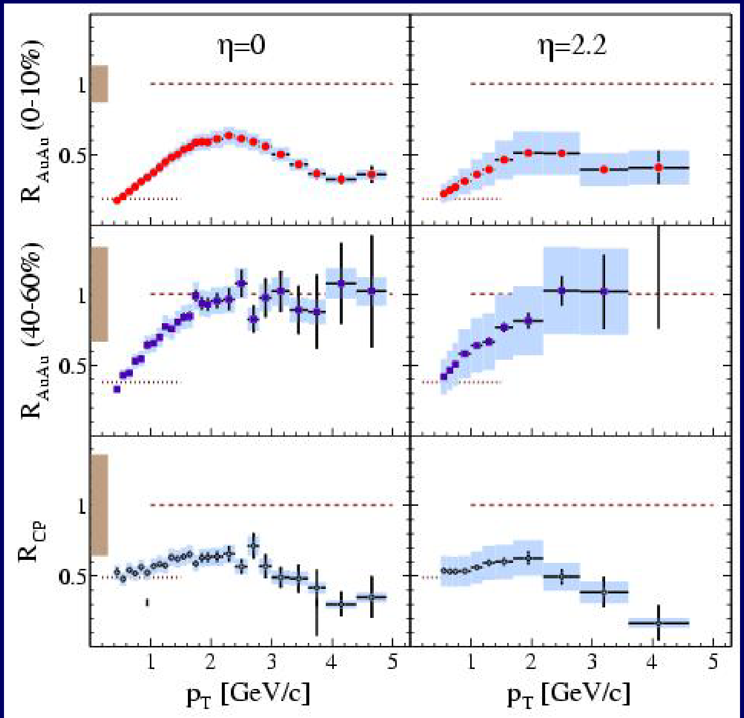
d+Au Nuclear Modification η =0

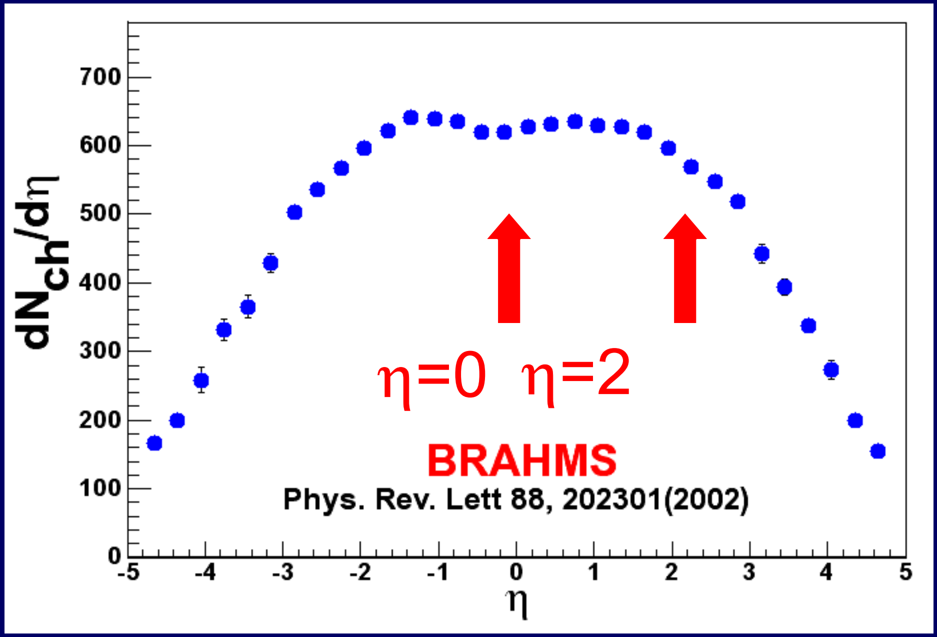


High p_T enhancement observed in d+Au collisions at $\sqrt{s_{NN}}$=200 GeV.

Comparing Au+Au to d+Au
$\Rightarrow$ strong effect of dense nuclear medium

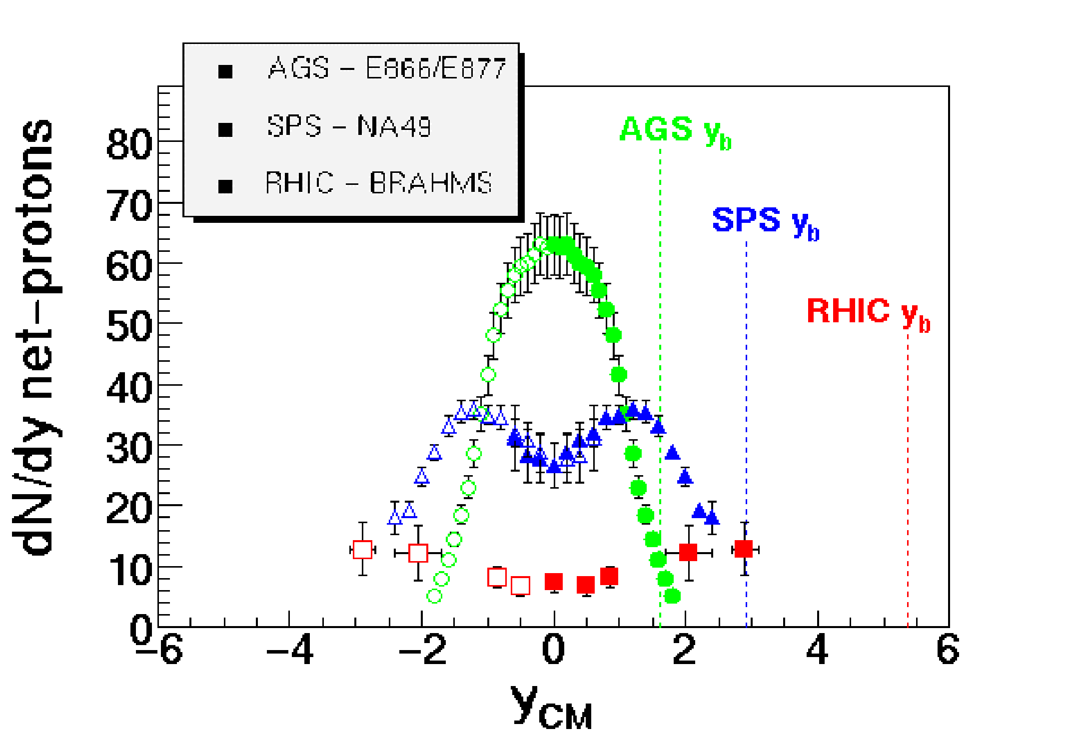
Rapidity Dependent Suppression





The rapidity coverage enables us to study the suppression vs. density w/o changing centrality.
The Au-AU data from run-2 show similar size effects at η~0 and η~ 2

Baryon-stopping (transport)



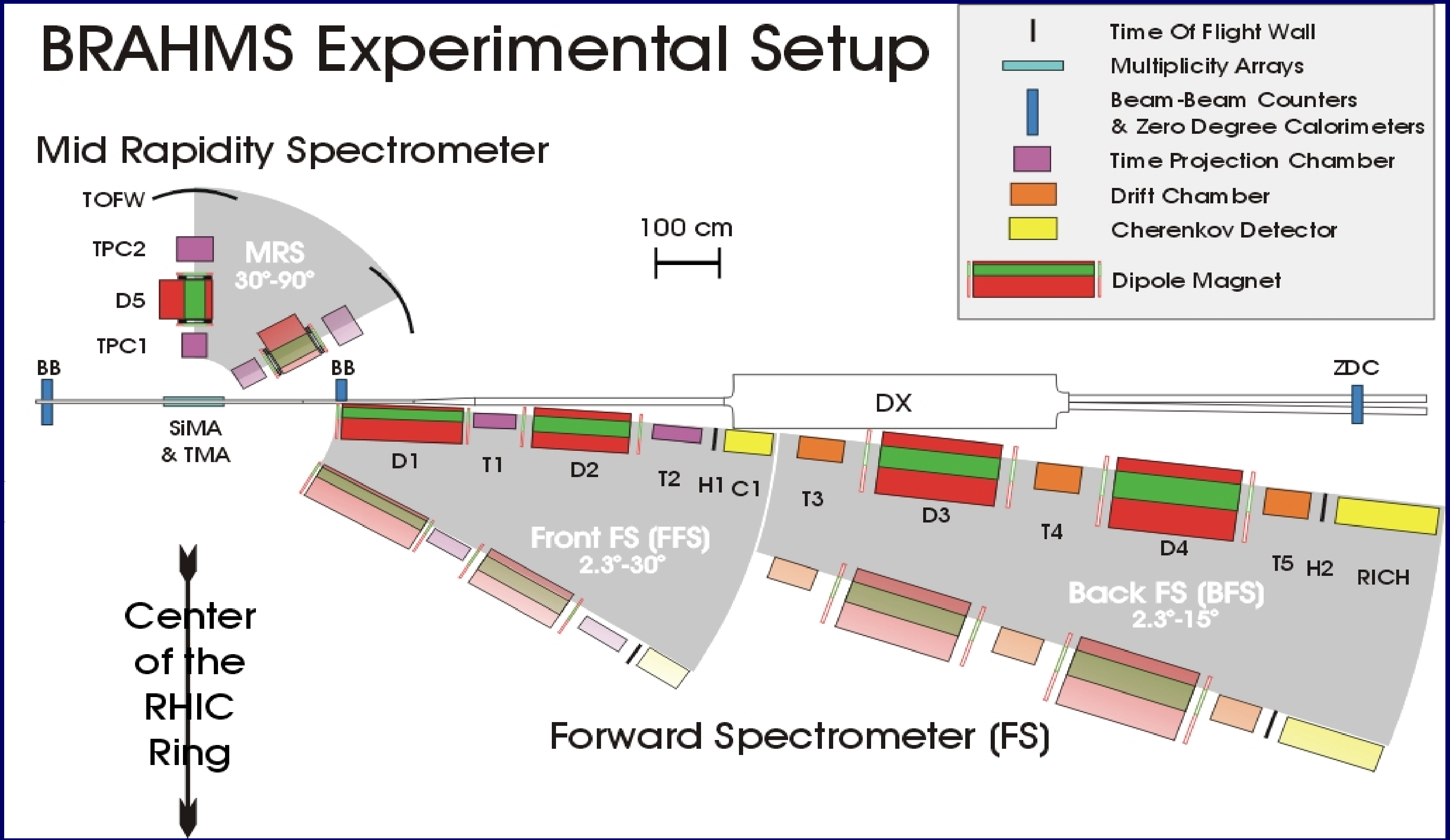
- AGS->RHIC : Stopping -> Transparency
- Net proton peak must be at > y ~ 2
- Estimated rapidity loss at 200 GeV is 2.3

Summary of 200 GeV results I

- p_T spectra of pions and kaons (0<y<4)
  - Systematic decrease in inverse slopes with increasing y
  - Rapidity distributions are near Gaussian.
  - K^+/K^- at high rapidity a problem for models
  - $\sqrt{s_{NN}}$ dependence of K/π (AGS-SPS-RHIC)
- Thermal expansion fits to π, K, p
  - Increasing radial expansion with centrality (y=0)
  - Decreasing freeze-out temperature with centrality (y=0)
  - Radial flow evident to rapidity 3

Summary of 200 GeV results II

- Net proton Yields
  - Flat for $0<y<1.5$ dn/dy=7.3±0.5 at y = 0
  - Rises for y>2 dn/dy=12.9±0.4 at y=3
  - The rapidity loss of protons is estimated to be in the range of 2.0 to 2.4 for central collisions
- High p_T suppression
  - Au+Au high p_t suppression at $\eta=0$ and $\eta=2$
  - d+Au do not see suppression at $\eta=0$ consistent with Cronin effect.
- p-p Running
  - Reference data analysis in progress
  - Commissioned spin physics program



BRAHMS Experimental Setup
Mid Rapidity Spectrometer
Time Of Flight Wall
Multiplicity Arrays
Beam-Beam Counters
& Zero Degree Calorimeters
Time Projection Chamber
Drift Chamber
Cherenkov Detector
Dipole Magnet
TOFW
TPC2
D5
TPC1
MRS
30°-90°
100 cm
BB
BB
SiMA
& TMA
DX
ZDC
D1
T1
D2
T2
H1
C1
T3
D3
T4
D4
T5
H2
RICH
Front FS (FFS)
2.3°-30°
Back FS (BFS)
2.3°-15°
Center
of the
RHIC
Ring
Forward Spectrometer (FS)

Run-4 Upgrades

- Heavy Ion running
  - MRS & FS spectrometer trigger counters
    - Increase efficiency
    - Increase peripheral data sample
  - Rearrange Si-Multiplicity array to attempt Flow Measurement
  - In addition to Baseline configuration a Cherenkov C4 was added to MRS together with additional TOF elements at larger flight path for parts of Run-3. This will enhance PID capabilities for pions in particular.
- Possible additions in Run-5 of subset of ALICE Si-detectors (FMD, ITS) to enhance physics capabilities (forward Mult, vertexing in small $d\Omega$

Physics program for next RHIC runs.

Completion of Baseline program and follow-up on opportunities in high-pt studies, and spin physics.

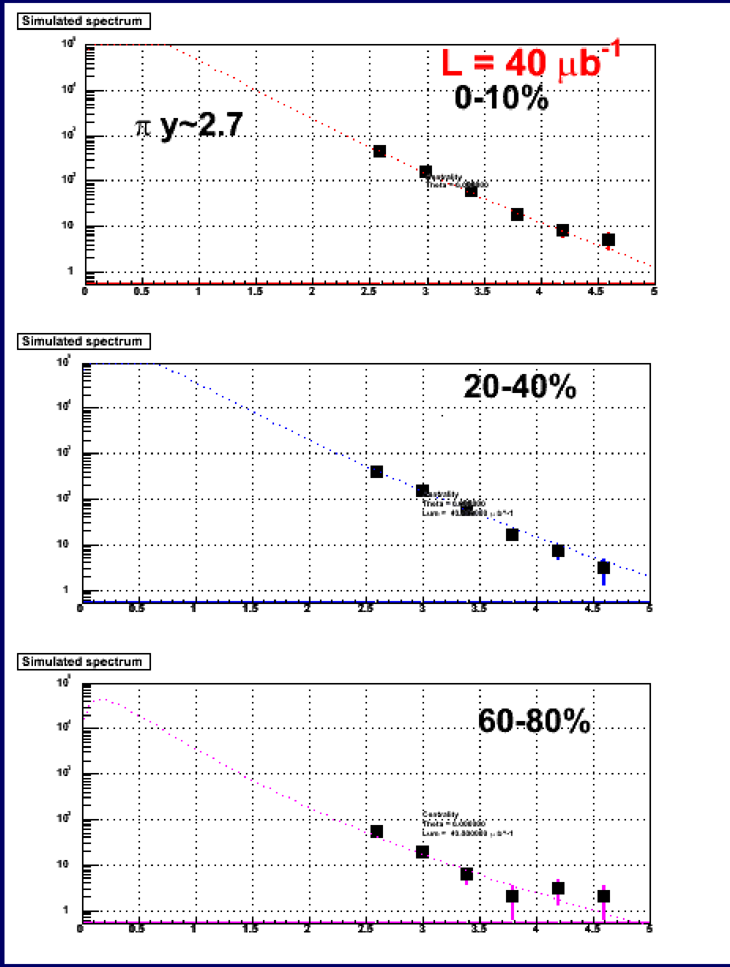
- Systematics of high-p_t suppression
- Longitudinal collision dynamics via rapidity distributions.
- Collective effects
  - Transverse flow
  - Source sizes (coalescence)
  - Elliptic flow
- Centrality, System size and energy dependence
- Dedicated spin program (An)

High-p_t studies.

- Suppression observed in Au-Au relative to pp and d-Au.
- The suppression effect is thought to be ~ ρ.L
- Interplay of partonic energy loss, Cronin and possible CGC.
- Controlled experiments with systematic change of this via change in system (L), density (rapidity, centrality) and $\sqrt{S_{NN}}$.
- Suppression depends on hadron type.
- P_t dependence of π, p different. P/ π >= 1 at large p_t.

High p_t at forward rapidities

Initial measurement at y~2.2 for identified pions. Obtained with ~ 4 μb^{-1} ,but for central events only. Need >*10 statistics to get high quality peripheral data. Measurements can also be done at somewhat higher y (~3) where the dN(π)/dy has dropped to ~ ½ the value at y~0.

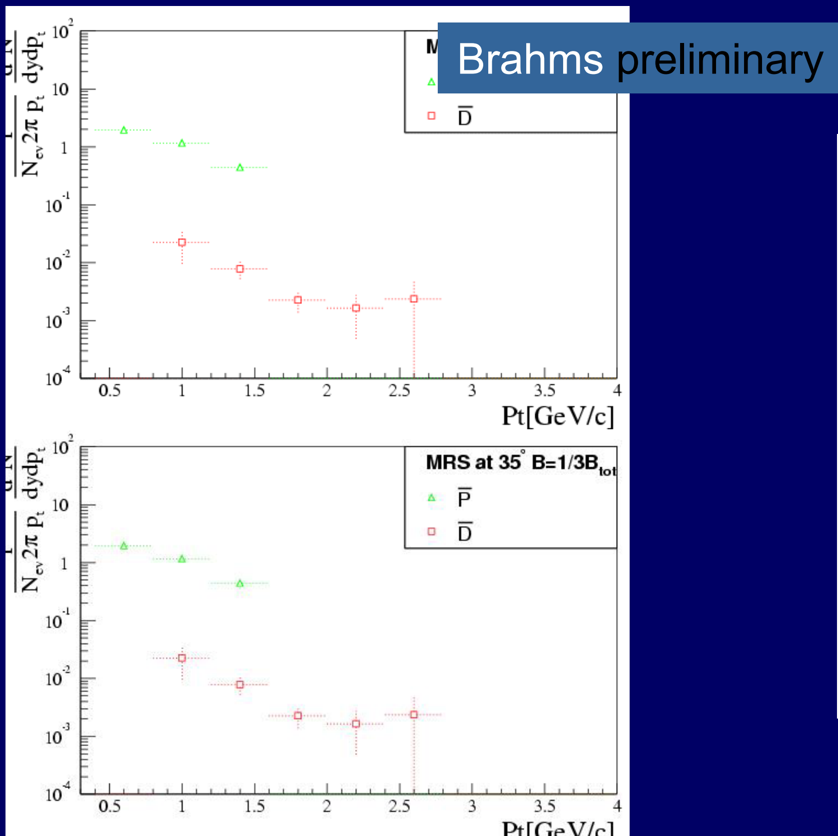


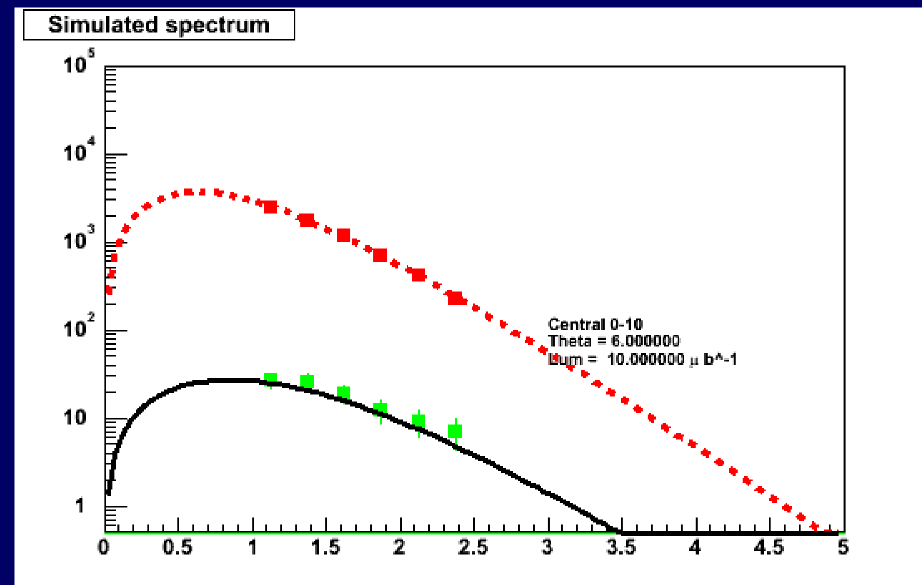
Estimated π spectrum at y~2.7, with 40 μb^{-1}.
Lower p_t range requires ~ 10 μb^{-1}

Bulk and Collective Properties - longitudinal dynamics

- Development of stopping
  - Projectile and energy dependence
- ~4π identified hadron yields
- Collective flow (transverse & elliptic)
  - $<p_t>$ vs. centrality and rapidity
- Correlation measurements
  - Coalescence (anti) deuterons.
  - HBT
- Explore particle production at low # $N_{collision}$, and N_{part} (10-100) by utilizing light projectile

Coalescence Measurements





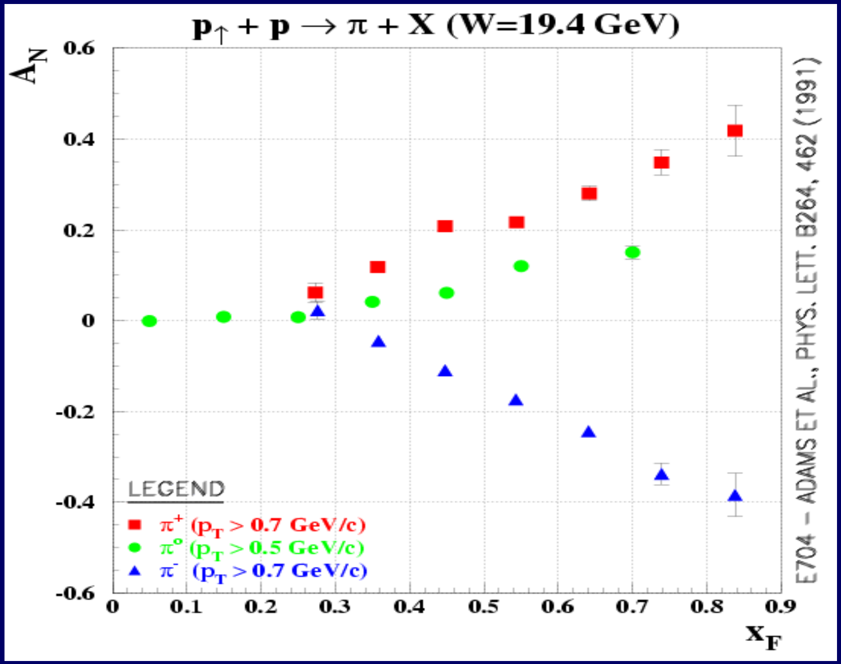
Data from mid-rapidity y~0,1
$B_2 \sim 10^{-3}$. Au-Au.

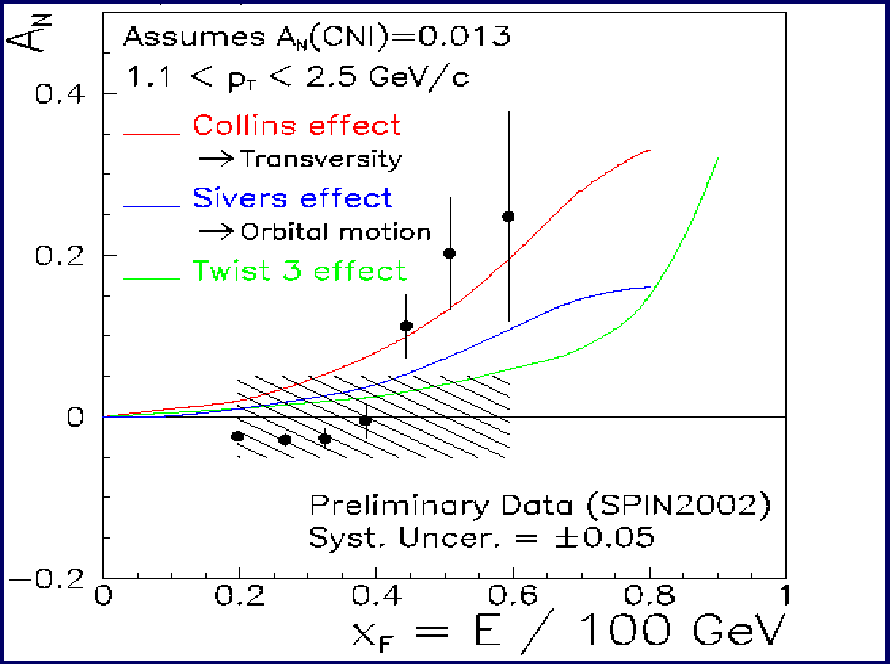
Expected d–bar statistics at y~2.5 for 10 μb^{-1}.

p-p measurements

- Transverse Spin asymmetry measurements at moderately large X_F.
- Completion of reference data; In particular high p_t spectra for identified hadrons at y~2 and 3.

Transverse Spin





Low energy data (AGS) show clear differences between pi+-0. At higher energies the models used to describe the data differ.

Large spin effects reported by STAR for $\sqrt{s}$ = 200 GeV *pp* collisions

This makes it an appealing measurement within the RHIC spin program, and has been discussed within the RHIC spin group.

Transverse Spin in BRAHMS

Charged pions at x_f~0.2-0.4

Expect asymmetry of 1-5% for π^+

Requires good control of systematic error (< 0.3% with 40% beam polarization.)

- Run-3 measurement ~0.15%

Under Run-3 Conditions, 2 weeks to make a significant first measurement.

Prefer to do program in two phases

- π^{+}, π^{-} at x_f ~0.25 (requires ~ 0.6 pb^{-1})
- Extend to higher Xf ~ 0.3-0.4 (longer measurement)

Considerations for request

- Assumed β*=3 for RUN-4; β *=2 in subsequent years
- Assumed the Au-Au at full energy likely to achieve better than minimum projection. (was reached at end of run-2)
- There was no Fe projection at time of writing of BUP. The estimate given later is slightly smaller than our projection from Si/Au estimates. To reach 1.2 like 12 weeks is needed at β * of 2. Tables following updated to reflect this change for 27/37 week request for Run-5

Au-Au at 200 GeV

The Au-Au program for 200 GeV, which we would like to see done in Run IV, is tabulated below. The measurements at y~1 can be performed in parallel with those of the forward spectrometer(high rapidity) which sets the length of the request.

1. Collect high statistics for high-p_t spectra at y~2.5 and y~3.5 for both charge states. (100 + 40 μb^{-1})
2. Flow (v2-measurements up to about p_t~2 vs. centrality) p_t~3 overall. (40 μb^{-1})
3. Supplement existing lower p_t data where needed. (40 μb^{-1})
4. Perform simultaneous coalescence measurements at y~2.5. Part of this will be done under 1, but requires additional settings. (20 μb^{-1})
5. Centrality dependence of p,K,p in 0.2-6 GeV/c at y~1, and 0.

Fe-Fe at 200 GeV

- The focus will be on measuring the higher p_t region of identified particle at y~1 and y~2.5. This will help in disentangling the importance of medium size vs. energy density experimentally, leading to a greater understanding of the phenomena observed with Au-Au at 200 and 130 GeV. (R_{Fe} ~ 2/3R_{Au})

- Identified charged hadrons at y~1 and 2.5. (0.9 nb^{-1})
- Complete rapidity distribution for net-protons (baryons), particle composition, and strangeness production vs. rapidity. (0.3 nb^{-1})

Au-Au at 63 GeV

- The reduced expected luminosities (~9 times less than at full energy) implies that only a few focused measurements will be performed for the high-p_t measurements due to the solid angles of the BRAHMS spectrometers. Complete rapidity distributions for soft physics particle production will be obtained. The main request is for two simultaneous measurements of

1. High-p_t measurement at y~1. (10 μb^{-1}) (MRS)
2. Survey of net-proton, kaon and π distributions utilizing the FS. (10 μb^{-1})

Summary of Total request for Run 4-6

Species	Energy	Luminosity	Weeks (approximate)
Au-Au	200	240 μb^{-1}	19
Fe-Fe	200	1.2 nb^{-1}	8->10
Au-Au	63	10 μb^{-1}	10
p-p	200	1.2 pb^{-1}	6-> 10

Table 1. Summary of requested species and luminosities.

Request and CA-D Guidance.

Species	Weeks	Int. Lum.	request
Au-Au 200 GeV	19 14	[120-320] [70-180]	240 μb^{-1} 240
Fe-Fe 200 GeV	8 10	[0.5-1.5] [.9-2.0]	1.2 nb^{-1}
Au-Au 63 GeV	6 8	[4-7] [6-10]	10 μb^{-1}
pp 200 GeV	8	[.9-1.3]	3 pb^{-1}

The β^* is 3 for 200 GeV Au; 2 otherwise

The pp estimate did not have the *2 loss for additional IR's running (working point issue)

Requests per year

- Priorities, considerations
  - The experiments were requested to propose a run plan under assumptions of 27 and 37 weeks.
  - The greatest advantage of the longer running time is the reduction of risk I.e. being able to achieve the physics goals laid out in the next 3 years
- Comments

The numbers are different than in submitted proposal adjusted to reflect better our understanding of luminosity (particular pp and Fe).

27 Week run plan

RUN 4	Au-Au 200 GeV	19 weeks
RUN 5	Fe-Fe 200 GeV pp	10 weeks 4 weeks
RUN 6	Au-Au 63 GeV pp 200 GeV (Au-Au 200 GeV)	10 weeks 4 weeks **(as needed)**
RUN 7	Depends on progress in IV-VI	

*** In case of a pp commissioning period we wish to perform a first An transverse asymmetry measurement in the order of 1 week.**

37 Week Run Plan

RUN 4	Au-Au 200 GeV Au-Au 63 GeV	19 weeks 8 weeks
RUN 5	Fe-Fe 200 GeV pp	12 weeks 10 weeks
RUN 6	Au-Au 200 GeV pp 200 GeV	as needed 4 weeks

The major advantage of longer runs than 27 weeks is that the risks in not achieving the luminosity goals is much reduced, and high statistics sample can be reached, and that the two-modes requests yields much more physics.

Summary

- The highest priority is a high statistics Au-Au run at full energy to study in detail high-p_t suppression at larger rapidities for identified hadrons.
  - This is in good agreement with requests from other experiments.
- Subsequent heavy-ions runs should be for 200 GeV Fe, and a lower energy Au run, preferentially at 63 GeV.
- The collaboration also puts importance to a measurement of the transverse spin asymmetries at large x_F for identified pions within the next 3 year period, preferentially split over two periods.
- Additional Au at full energy may be warranted, pending outcome of Run-4 and lessons learned.

Backup An systematic error

Systematic error estimated from variation in bunch Luminosity measurement using ZDC, INEL and BB Detector systems.