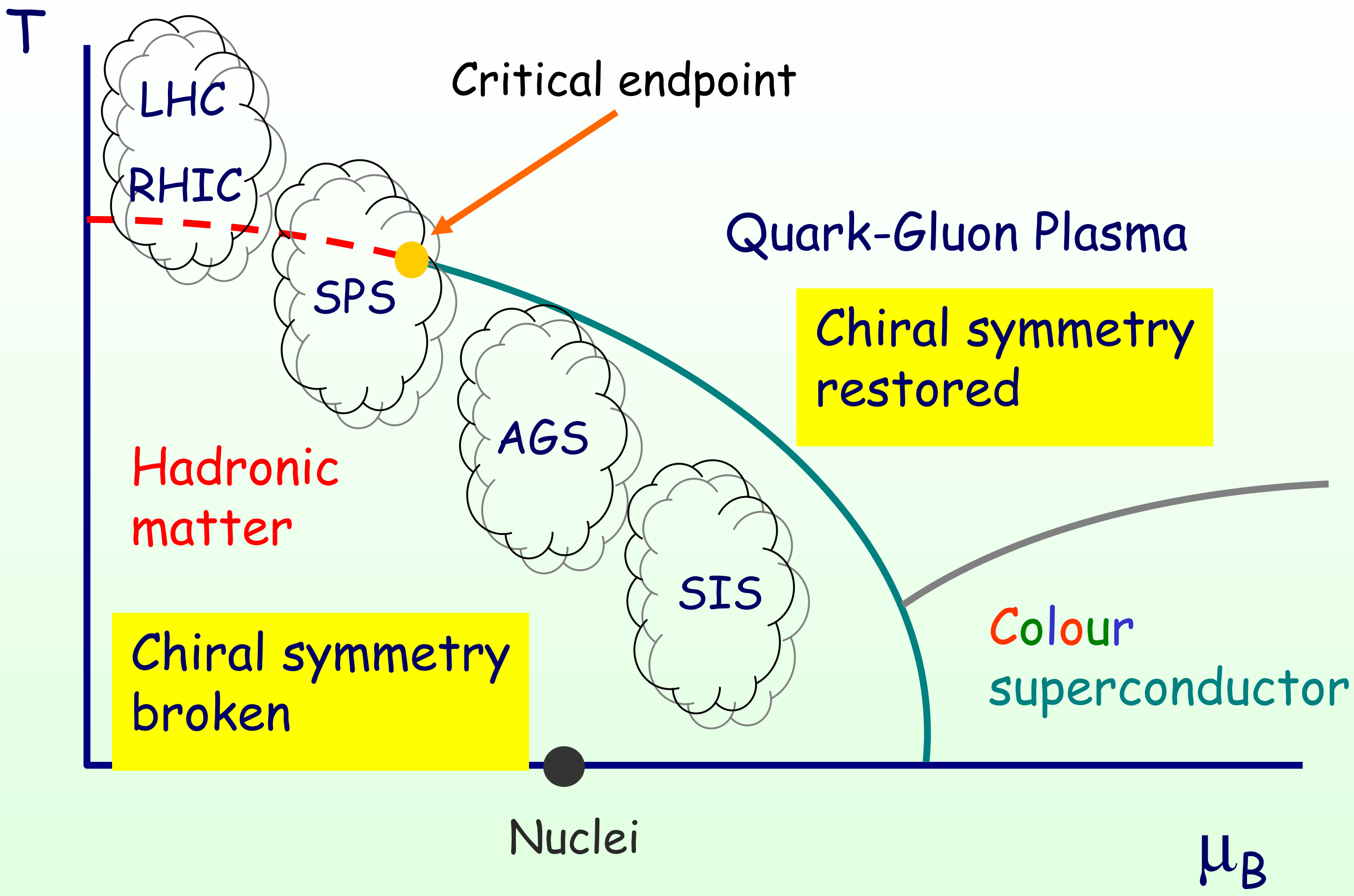
Fixed Target @ RHIC – The Pitch

- RHIC is a unique facility for understanding the physics of high energy density, low baryon density, strongly-interacting matter.
  - sQGP, CGC, scaling laws, etc, etc, etc.
- RHIC could simultaneously be a unique facility for exploring the physics of a larger range of the phase diagram of strongly-interacting matter.
- Both experimental and theoretical hints suggest that the additional regions of the QCD phase diagram may hold some intriguing new physics.

Motivation – I

- Good reason to think that high(est??) baryon densities are created in collisions of beams around 20–30 GeV on fixed targets.
  - See work of Busza and others on rapidity loss of leading baryon in p+A
- Theoretical situation is controversial and there are no unambiguous experimental probes of baryon density but there is clear reason to be interested in this beam energy range.
- AGS program also focused on high baryon density but may have had a tad too low beam energy.

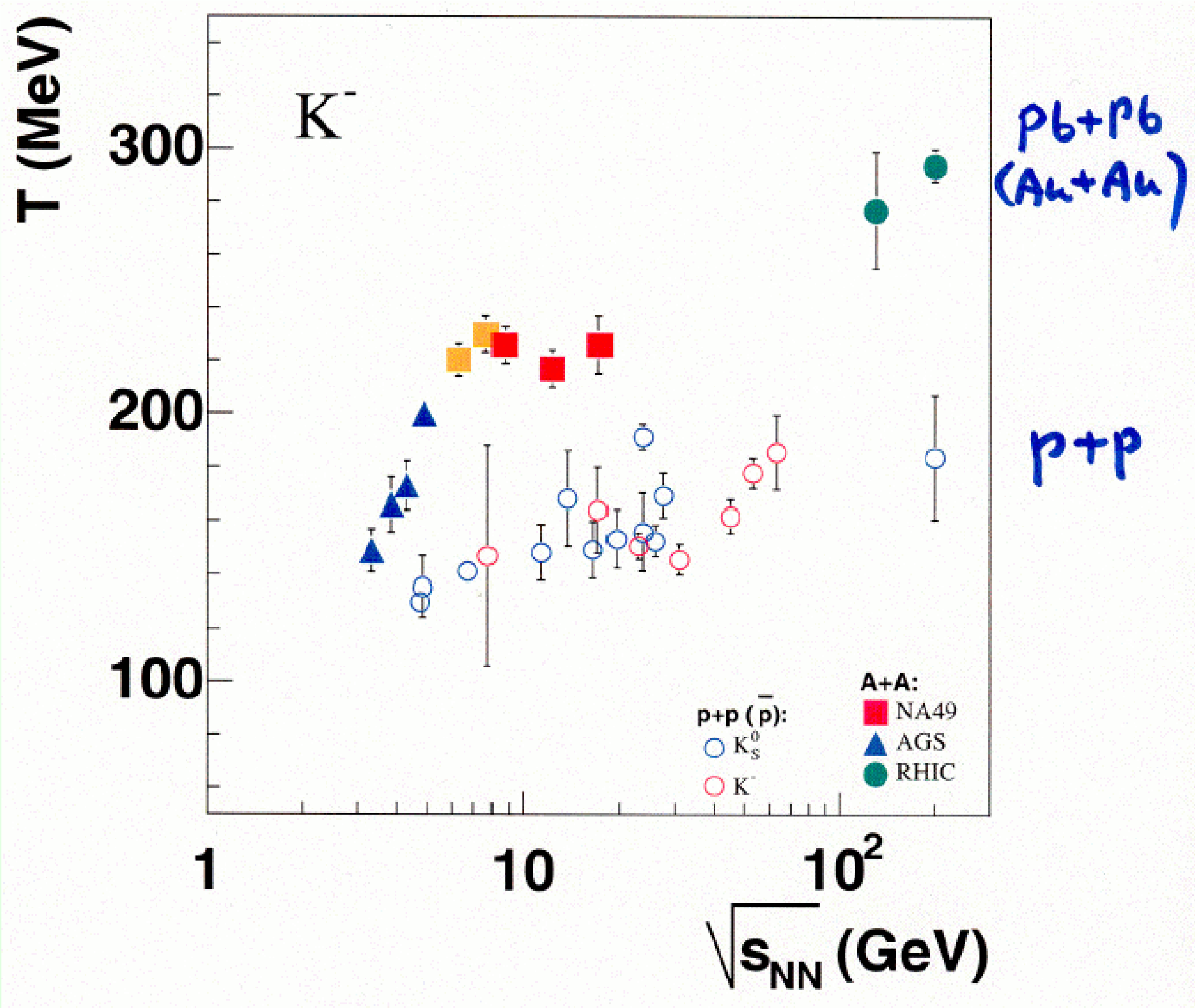
Motivation II – Friman QM04



QCD phase diagram may have interesting features in the region probed by 10–100 GeV beams on fixed targets.

Motivation III - Gazdzicki QM04

Several other observables show similar non-monotonic behavior.



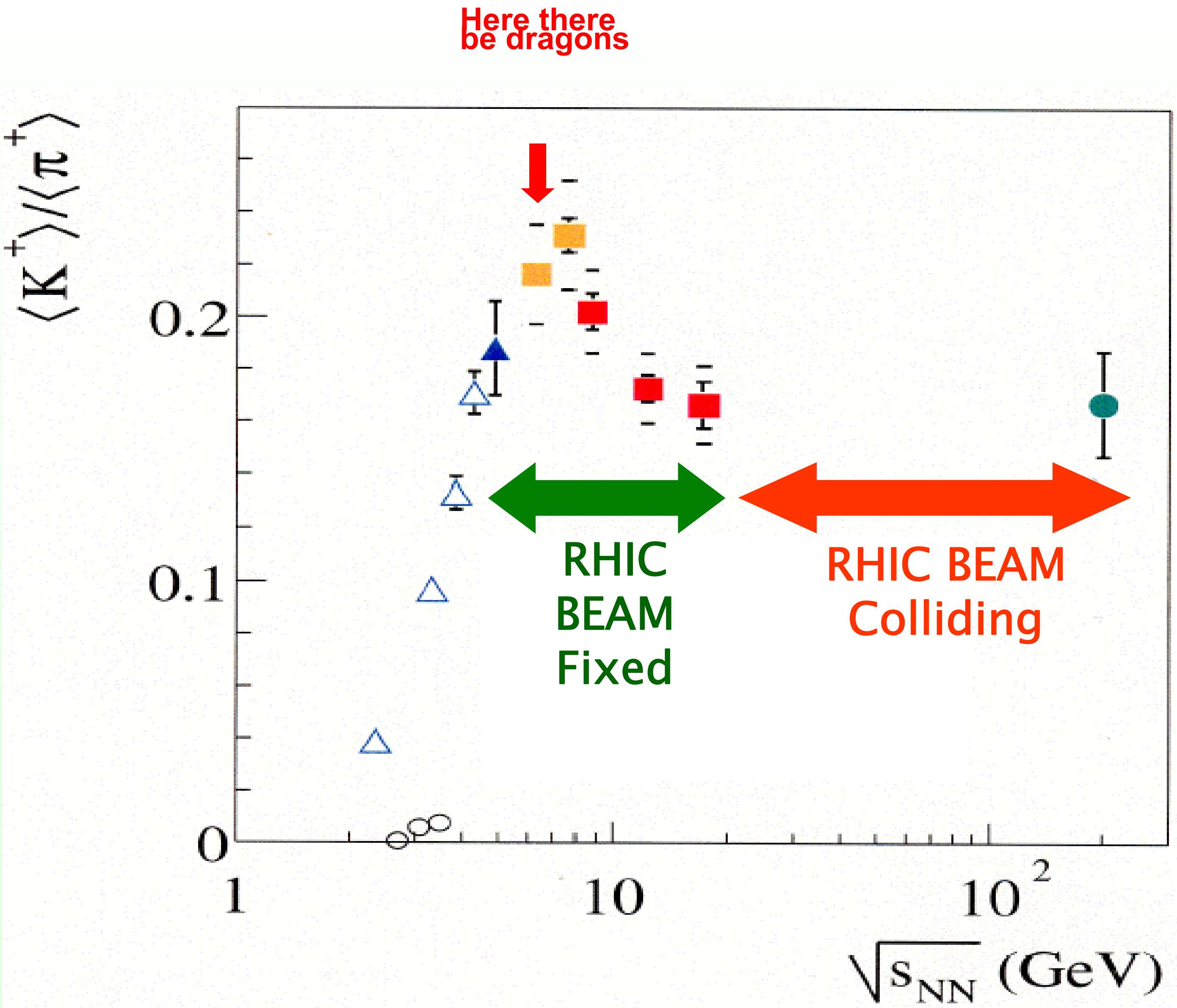
What does it mean?

- High baryon density leads to exotic new state.
  - Almost as exciting as recent RHIC results!?
- High baryon density leads to non-monotonic behavior but without creating exotic new state.
  - Very interesting QCD study in its own right!
- Perhaps an artifact of analysis or acceptance.
  - Independent verification is crucial!
  - Multiple experiments a great strength at RHIC.

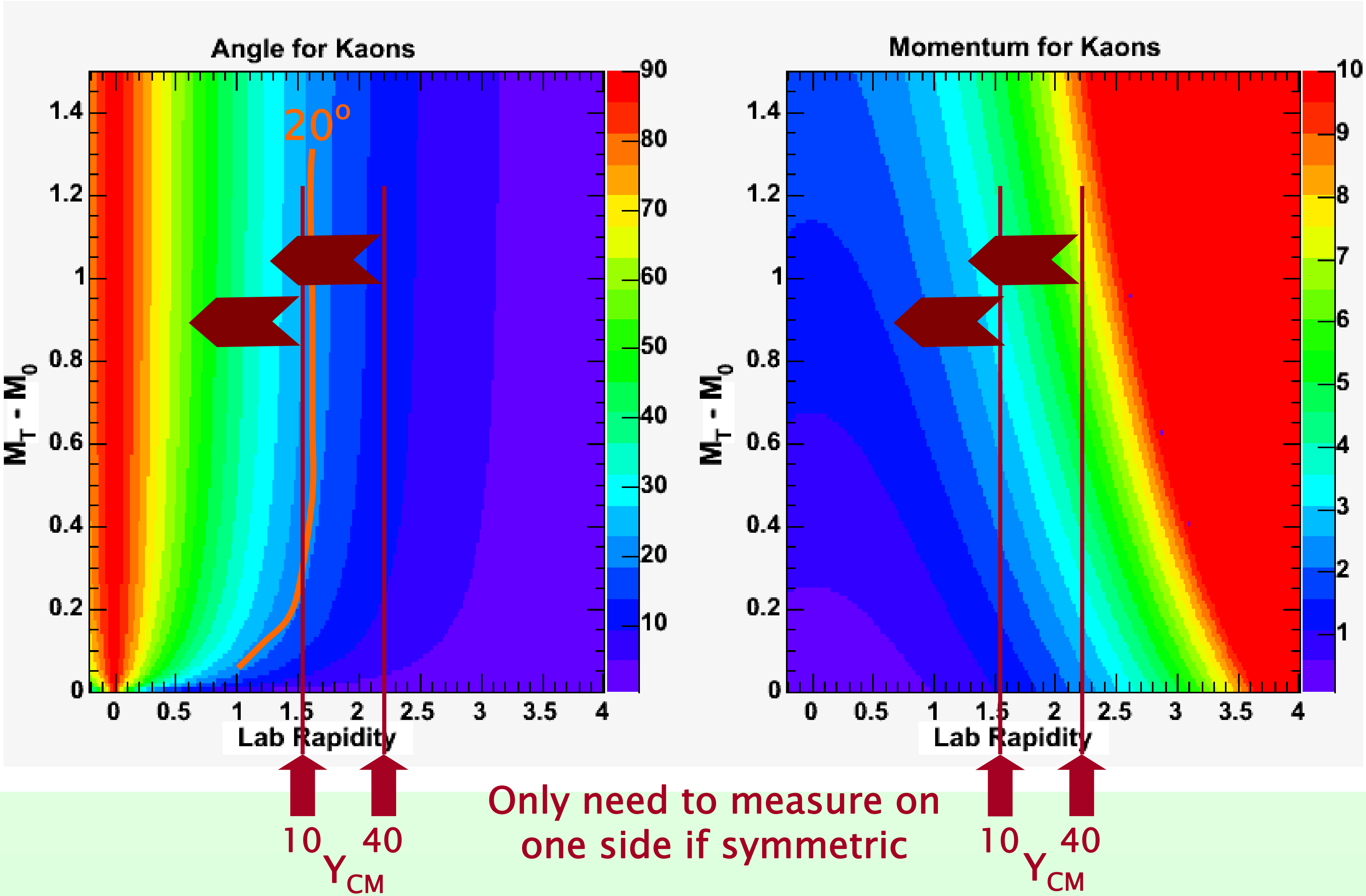
Am I jealous? You better believe it!

- If such a thing had been found at the AGS, there would be a fixed target program running today using the AGS between filling RHIC.
- On the other hand, I'm now very enthusiastic about adding a new dimension to RHIC physics.
- My interest is not motivated by one interesting result or a specific provocative theory.
- For me, intriguing results are candy, expanded exploration of the QCD phase diagram is the meal.

RHIC Beam Regions



Why Forward Physics?



Only need to measure on one side if symmetric

Low Energy Collider Mode??

- In principle, RHIC can circulate and collide beams at below the normal injection energies.
  - AGS has experience running at lower energies.
  - Decelerating the beam may even be a possibility.
  - Would use existing experiments most efficiently.

BUT…

Low Energy Collider Mode??

BUT…

- May require significant machine development.
- Certainly requires dedicated beam program.
- If luminosity drops like $1/(\text{Energy})^2$, the rate could be a serious issue, requiring a long program.
- ➲ Would still need “forward” angles. To get reasonable coverage of rapidity distributions requires $\theta < \sim 10\text{–}20^{\circ}$.

High Rapidity at RHIC– Same Physics??

- At lower SPS energies, $\bar{p}/p$ ~0.05 or less.
- At full RHIC Au+Au energies, $\bar{p}/p$ is still ~0.25 at rapidity as large as 3.
- So, technically very challenging!

but similar physics??

High Rapidity at RHIC– Same Physics??

BUT…

- Protons rising and antiprotons dropping fast so conditions are not stable over a broad region.
- Out on the tails of the rapidity distributions where kinematics have a big effect.
  - K^+ and K^- deviate already around rapidity of 2.
- CGC may strongly impact particle production.
- So, very interesting region to investigate but perhaps (probably??) not the same physics as midrapidity at $\sqrt{s_{NN}}$~4–10 GeV.

Beam & Machine Issues

- Effective beam current is frighteningly high.
  - 0.7×10^{9} ions/bunch $\Rightarrow$ $\approx3\times10^{15}$ ions/second!
- Beam loss cross sections are comparable to nuclear interaction cross sections so particle losses are of the same order as the data rate.
- Only a very narrow beam region near 20 GeV is inaccessible to machine due to transition.
  - Some data near transition obtainable during ramp.

Target Options

- Foil target: Would anything survive the beam?
- Wire: Could be moving or located in halo.
- Gas jet: Fairly standard technology but need to be careful about RHIC vacuum and choice of target material somewhat limited.
- Ion beam: Might be possible due to huge effective beam current. Many advantages of control, choice of targets, local expertise.

- ➲ Biggest design issue ($$$?) may be beam pipe.

Kaon Yields

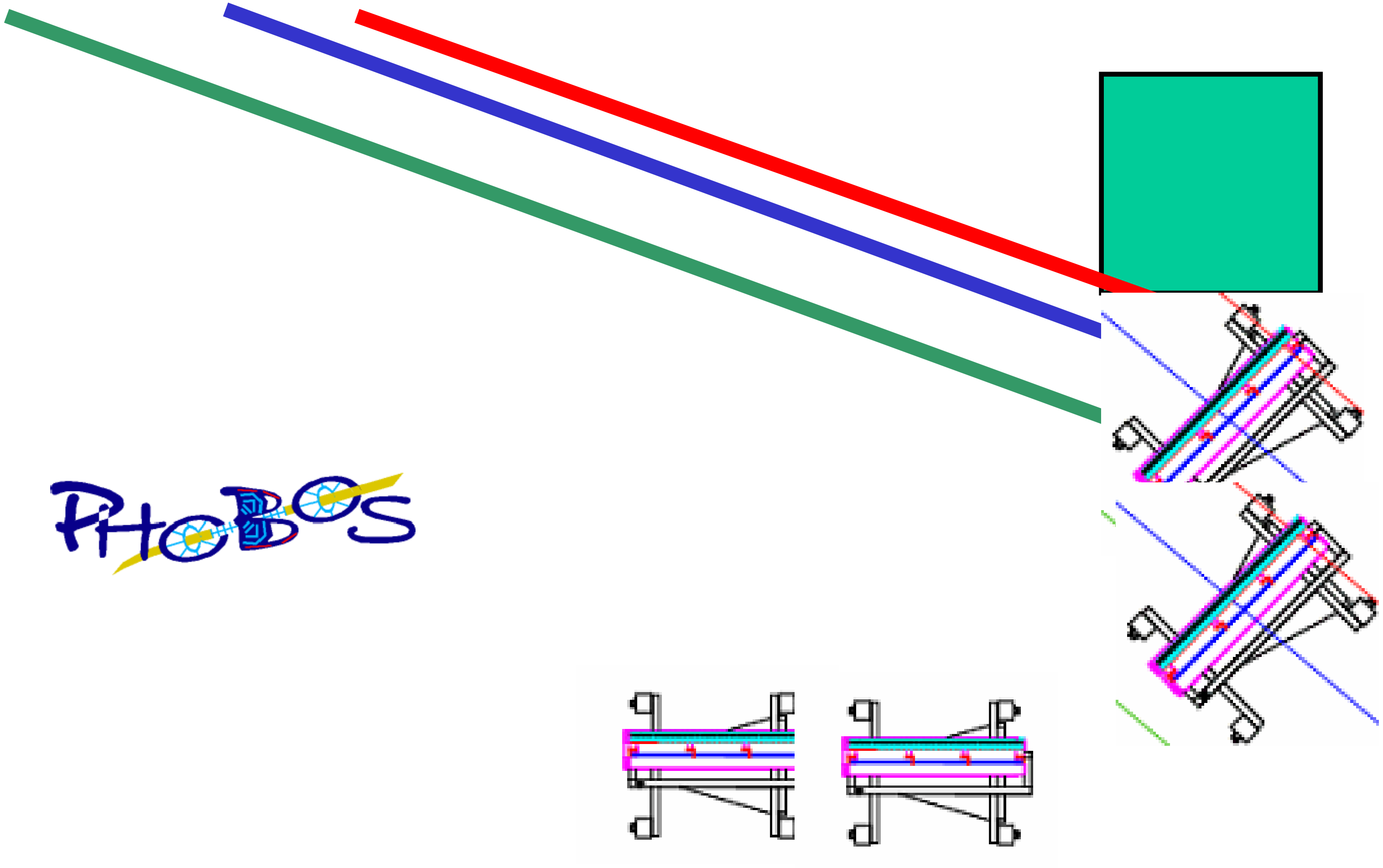
- Kaon data samples
  - Typical dN/dy values are 1-100. At the lowest beam energies away from y=0, K^- yield might be as low as 0.1
  - With 1 million events, you don't need much acceptance to get enough kaons to accurately determine the yield and slope.
    - Detailed yield estimates of the capabilities for Phobos, Brahms, or some combination of detectors yet to be done.

Possible Running Modes

- Dedicated running
  - With only 100 Hz DAQ, 1 million events takes <3 hours. For 3 energies (10, 25, 40) and 8 spectrometer settings per energy(4 angles, 2 polarities), you need ~3 days.
- Taking survey data during ramp
  - RHIC ramps 90 GeV in ≈5 min, so each ramp gives 17 seconds per 5 GeV bin in beam energy.
  - With 6 ramps per day, 200 Hz DAQ rate, and 6 weeks, data sample is almost 1 million events in each 5 GeV bin.
  - Early proof-of-principle run mode?

Fixed Target in PHOBOS ??

- Beam pipe (maybe) being removed next year.
- Opportunity to put something in?
- Sadly, probably not worth it, too bad.



Fixed Target in BRAHMS ??

- Angular range and PID clearly not a problem!
- Acceptance Issues
  - Did a (very) rough calculation of BRAHMS yield.
  - For fixed target running, the FS is used near midrapidity where yields are higher!
  - If I did my numbers right, the $\Delta\eta(\Delta\phi/2\pi)$ for FS and MRS are comparable and of the order of 0.5–1.5×10^{-3}.
  - Even for dN/dy ~0.1, 1M events gives 100 particles.
    - Note: Does not include momentum acceptance!
  - Modest data samples are probably adequate.
    - More realistic calculation clearly required.

Closing Thoughts / Open Questions

- Enormous potential exists to expand the RHIC program into a whole new regime.
- A first survey program could be done with a modest investment of time and money.
  - Most (all?) of the early data could be taken by running during normal collider operations.
- How & when can this be incorporated into the continuation of the collider physics programs?

Backup Slides

What do others think?

- SPS may try to restart this program in a few years but the 900lb gorilla of LHC may eat all the available resources.
  - +Large investment in existing experiment(s)
  - ×Non-trivial effort to do many beam energies

- Europeans (mostly Germany) are building a RHIC-scale machine partly justified by interest in this physics.

Target Numbers

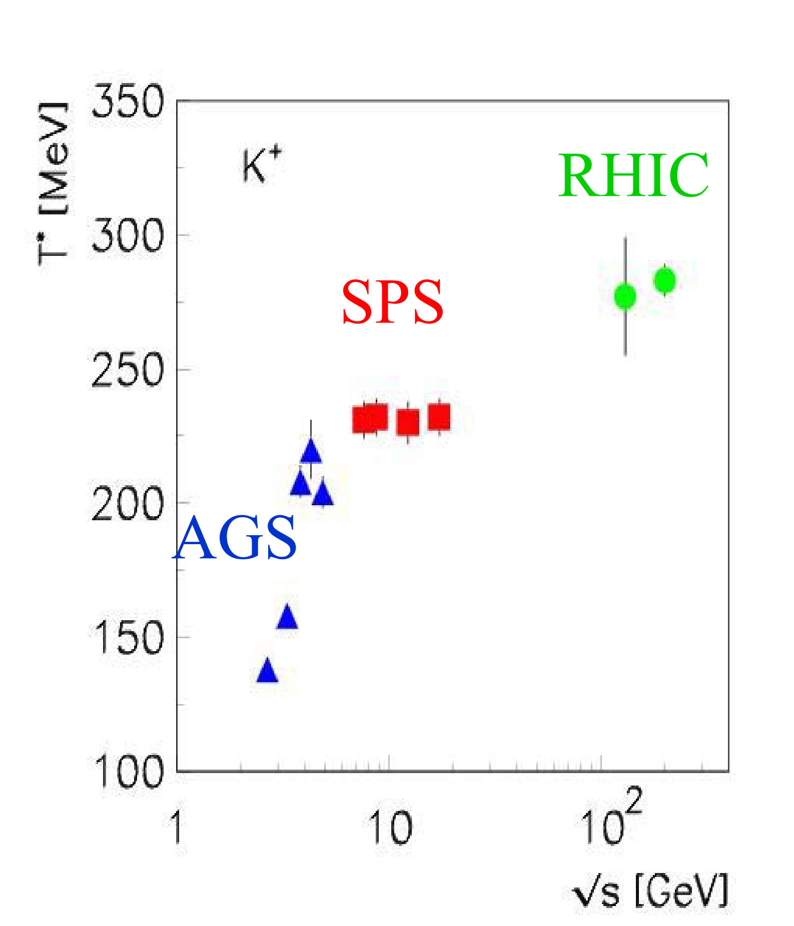
- Required target thickness
  - With 3×10^{15} ions/s and 6b cross section for Au+Au, 1 kHz event rate requires only $\approx5\times10^{10}$ ions/cm^2 or $\approx2\times10^{-11}$ gm/cm^2 for Au
- Gas jet target "vacuum"
  - If jet is 2 mm thick in beam direction, the pressure in the target is only $\approx7\times10^{-6}$ torr
  - This is equivalent to $\approx1\times10^{-9}$ torr averaged over the 12 m total length of the IP beam pipe
- Ion beam current
  - 1 milliamp of Au at 10 keV is $\approx6\times10^{8}$ ions/cm. If beam is 2 mm wide, this is $\approx3\times10^{9}$ ions/ cm^2.

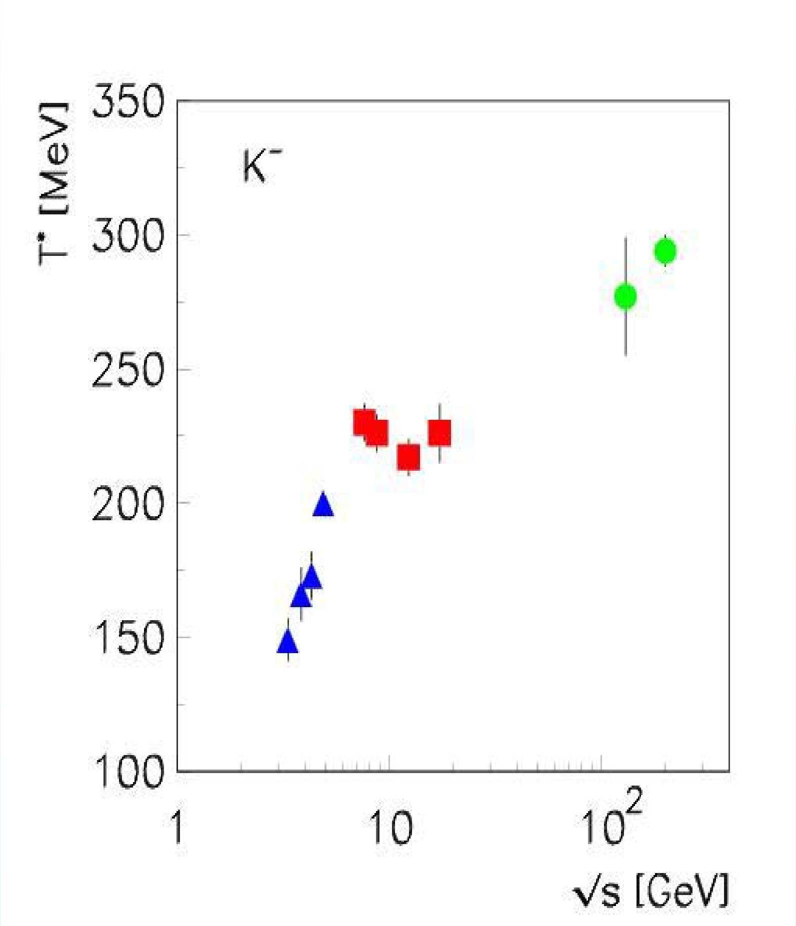
Beam Loss Numbers

- Beam loss examples: Energies near 20 GeV
  - Radiative electron capture ≈9 b
  - Non-radiative capture ≈3 b
  - Vacuum electron capture ≈11 b
  - First two scale like $(1/\gamma)$, last rises like $\ln(\gamma)$
  - Beam emittance growth is acceptable
  - Worst case scenario: Loss rate due to target is 100 times event rate which is 1000 Hz, then beam lifetime is still greater than 100 hours

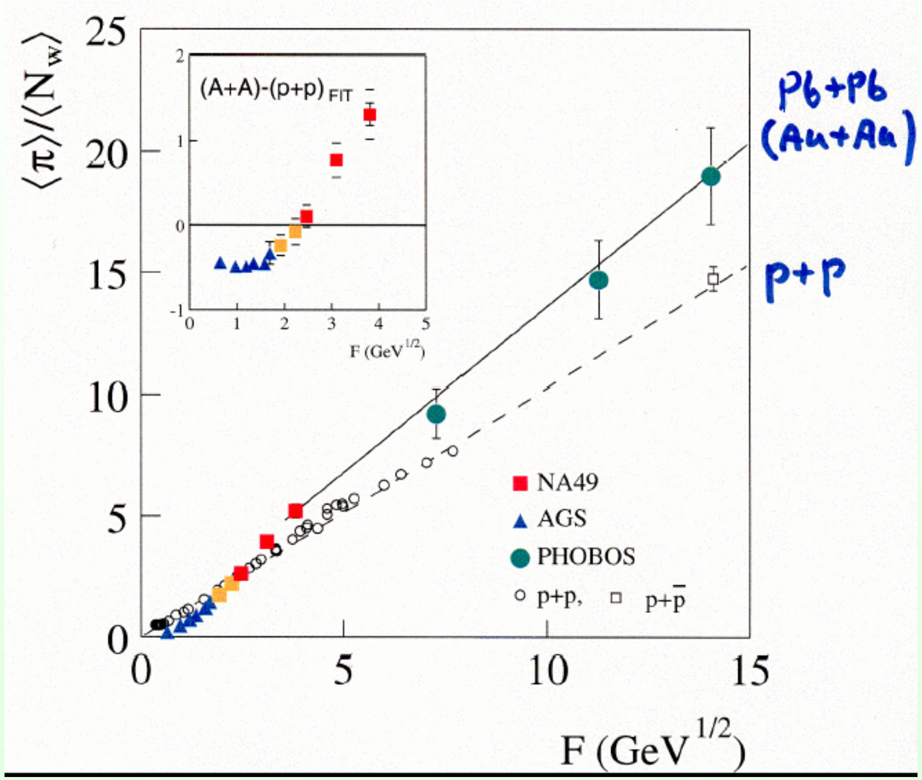
Motivation - IIa

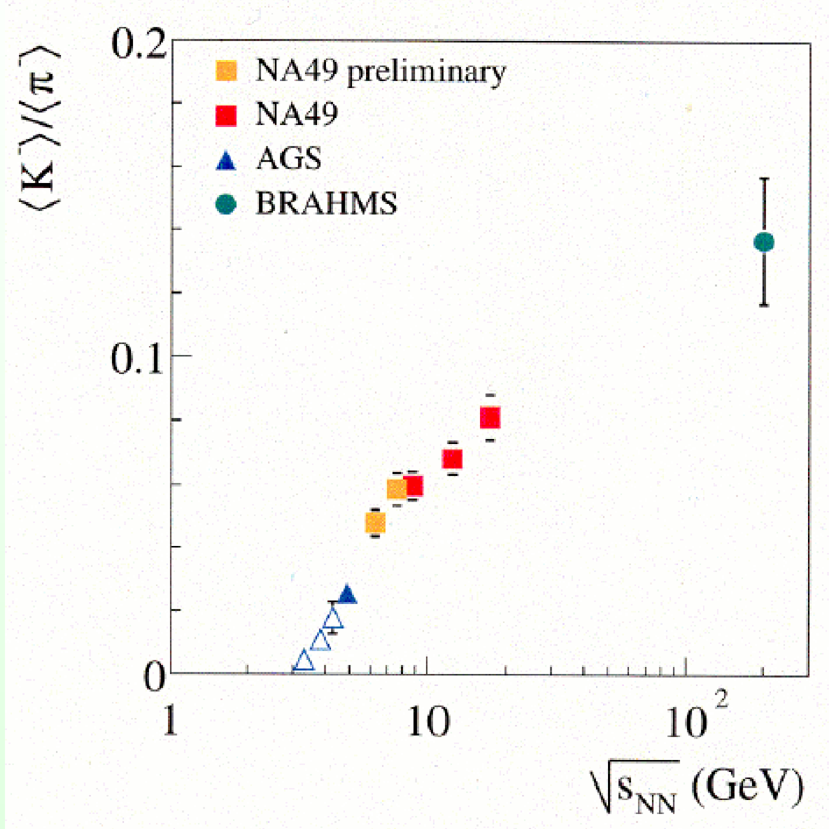
➲ Recent intriguing SPS data from NA49





Motivation Update QM2004





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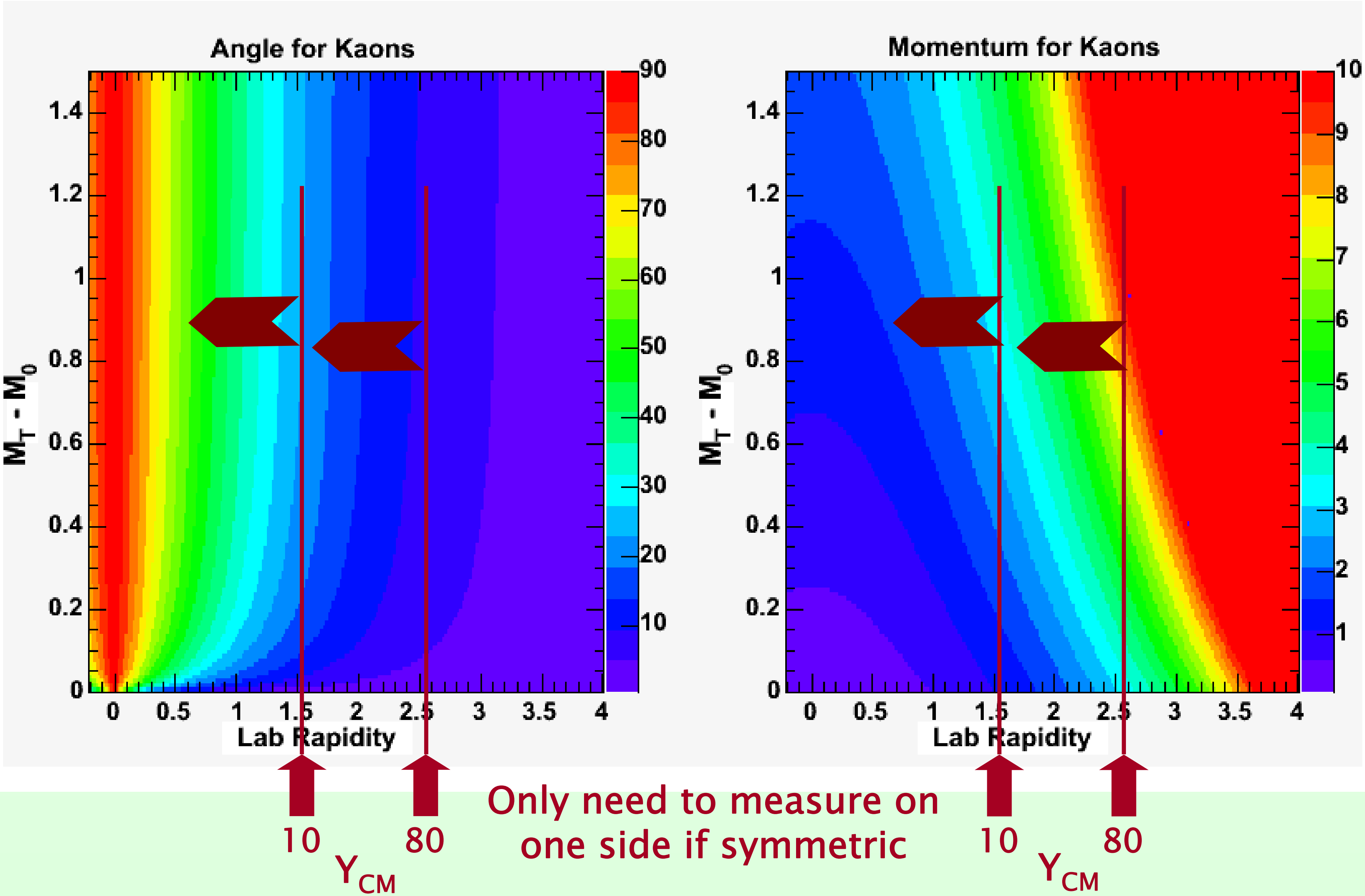

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