The RHIC Upgrade Program

Axel Drees, Stony Brook University
January 13th, QM 2004, Oakland

Resent long range RHIC planning exercise at BNL

- **five year beam use proposals and decadal plans from all experiments**
- **Twenty year planning study for the RHIC facility**

Introduction: executive summary of plans for RHIC future

- **Schedule, projected luminosity development, detector upgrades**

Details of "near and medium term" detector upgrades

- **Particle identification for jet tomography (PHENIX, STAR)**
- **Dalitz pair rejection for electron pair continuum (PHENIX)**
- **Precision vertex tracking (PHENIX, STAR)**
- **Enhanced forward instrumentation (PHENIX)**

Longer term upgrades for RHIC II area

- **Upgrades of readout electronics, DAQ and triggers (STAR)**
- **Large acceptance micro TPC for fast tracking (PHENIX, STAR)**

Summary

documents can be found at http://www.bnl.gov/henp

Long Term RHIC Operation and Upgrade Plans

2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

RHIC operation at and beyond design luminosity

eRHIC
e-ion collider

RHIC II 40x design luminosity for Au-Au via electron cooling

RHIC baseline program
- Au-Au ~ 1 nb^{-1} at 200 GeV
- Species scan at 200 GeV
- Au-Au energy scan
- Polarized protons $\geq$ 150 nb^{-1}

Completion of
- BRAHMS & PHOBOS

Studies of dense nuclear matter
with rare probes: jet tomography, open flavor,
J/ψ, ψ', χc, $\Upsilon(1s)$, $\Upsilon(2s)$, $\Upsilon(3s)$
Polarized protons at 500 GeV
p-A physics

Near & medium term detector upgrades
of PHENIX and STAR
Proposals submitted or in preparation

New eRHIC experiment

Long term upgrades
of PHENIX and STAR
related to RHIC II

new RHIC experiments ?

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PHENIX

Physics Beyond Reach of Current RHIC Program

Provide key measurements so far inaccessible at RHIC in three broad areas:

- **Comprehensive study of QCD at high T with heavy ion, p-nucleus, and pp**
  - high p_T phenomena (identified particle, p_T>20 GeV/c and γ-jet)
  - electron pair continuum (low masses to Drell-Yan)
  - heavy flavor production (c- and b-physics)
  - charmonium spectroscopy (J/ψ, ψ' , χ_c and Υ(1s),Υ(2s),Υ(3s))

requires highest AA luminosity

- **Extended exploration of the spin structure of the nucleon**
  - gluon spin structure (ΔG/G) with heavy flavor and γ-jet correlations
  - quark spin structure (Δq/q) with W-production
  - Transversity

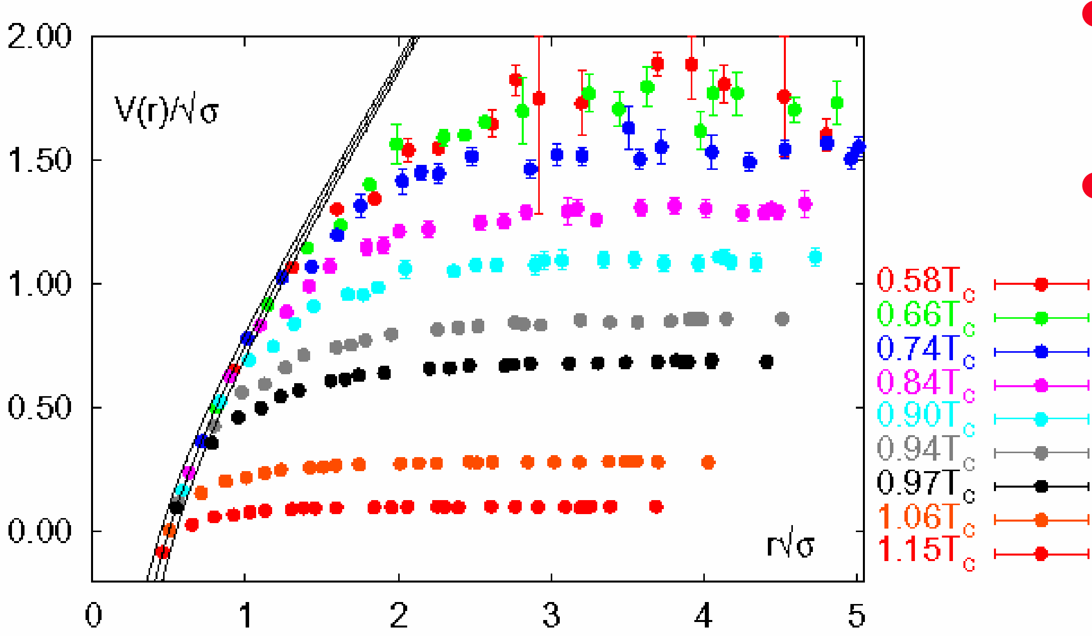
requires highest polarization and luminosity

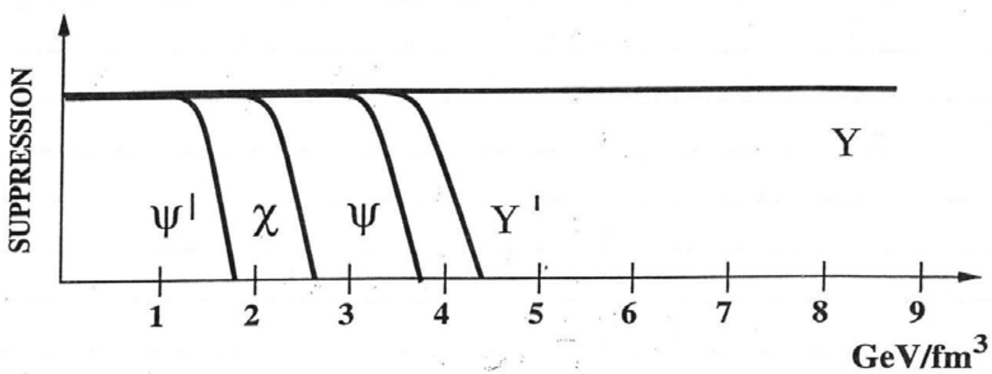
- **Exploration of the nucleon structure in nuclei**
  - A-, p_T-, x-dependence of the parton structure of nuclei
  - gluon saturation and the color glass condensate at low x

Requires not only upgrade of RHIC luminosity
But also of the experiments
Corresponding plans developed over the last 2 years

PHENIX

Quarkonium Spectroscopy





- **Map in-medium QCD potential with suite of quarkonium sates**
- **Requires highest luminosity i.e. RHIC II**
  - **> 10 nb^{-1} per AuAu run**
  - **PHENIX expectation:**

    J/ψ > 200000
    ψ' > 50000
    ϒ > 2500
    reconstructed
- **Detector upgrades:**
  - **PHENIX: mass resolution**
    Separate ϒ(1s) ϒ(2s) ϒ(3s)
  - **STAR: rate capability, trigger, electron ID**
    quarkonium program

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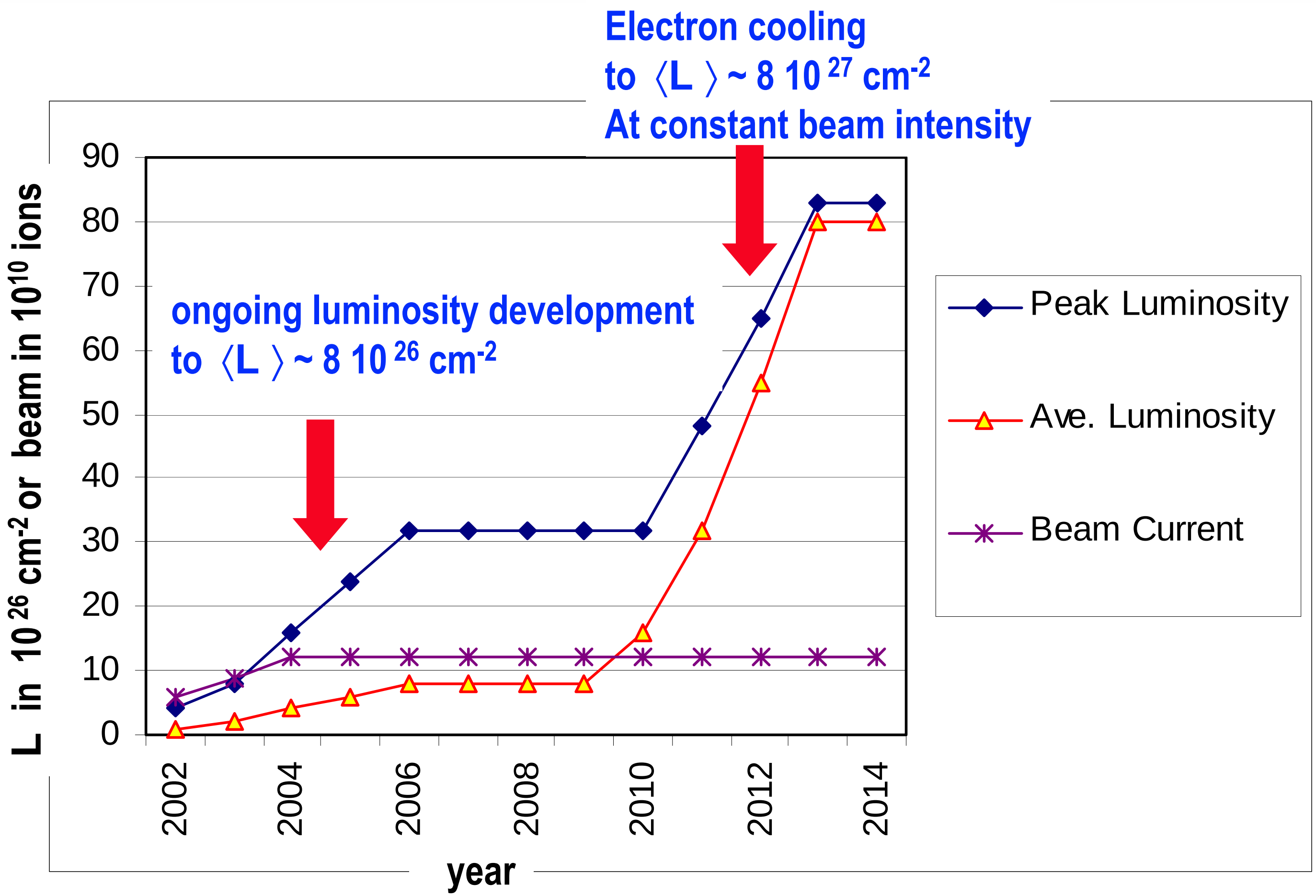
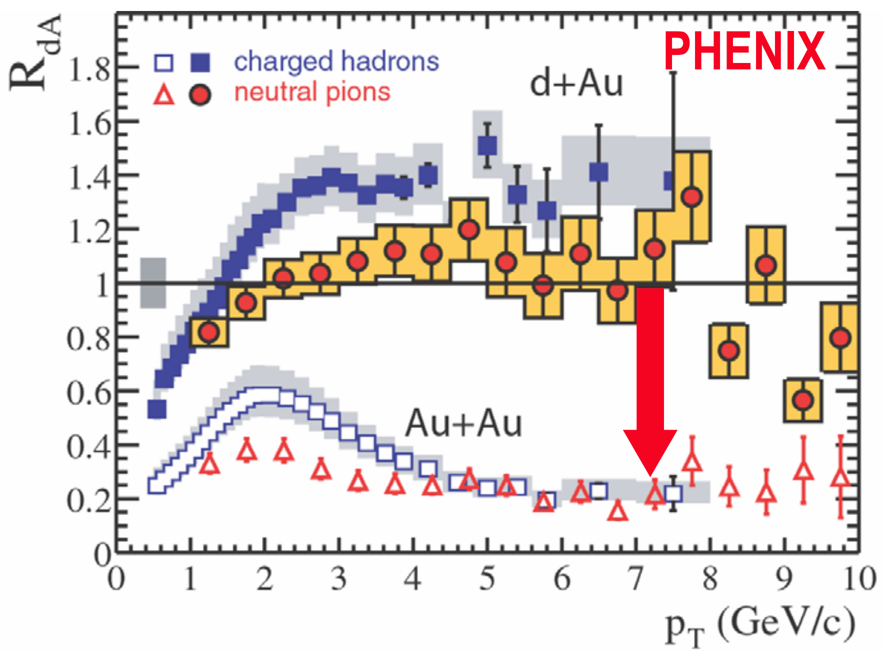
RHIC Au-Au Luminosity Development

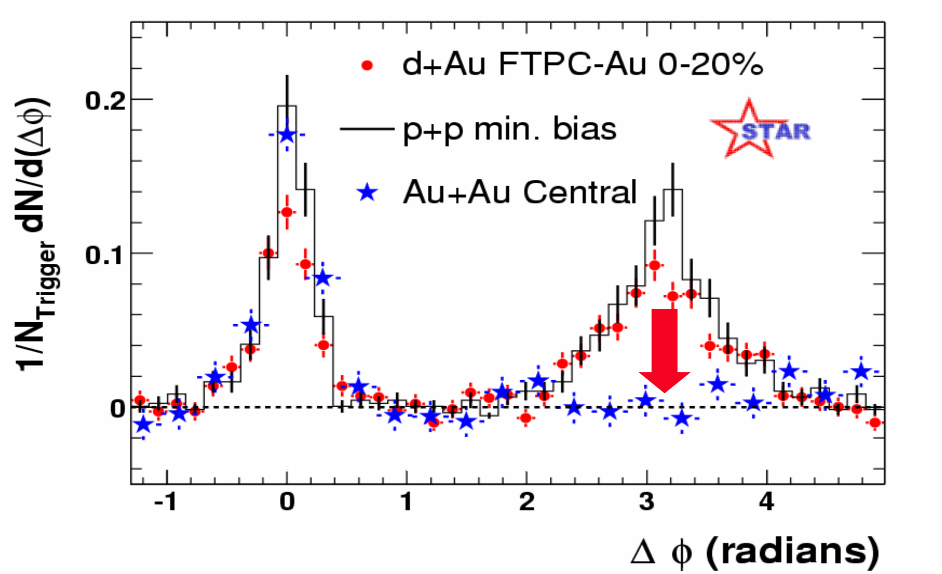


- **RHIC II Luminosity upgrade**
  - **Ongoing R&D for electron cooling**
  - **Hope for full implementation by 2010**
  - **Expect ramp up of luminosity over 3 years**
  - **Full Au-Au Luminosity by 2013**

High p_T Phenomena

Jet quenching: one of the most interesting discoveries at RHIC





Next steps require more detailed studies:

Near future: better PID

- Extend K, π, p p_T range to 10 GeV/c $\rightarrow$ PHENIX
- Large solid angle PID $\rightarrow$ STAR

Future steps: γ-jet tomography $\rightarrow$ RHIC II

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PHENIX High p_T Particle Identification

		Pion-Kaon separation	Kaon-Proton separation
TOF	σ~100 ps	0 - 2.5	- 5
RICH	n=1.00044 γth~34	5 - 17	17 -
Aerogel	n=1.01 γth~8.5	1 - 5	5 - 9

Combination of three PID detectors

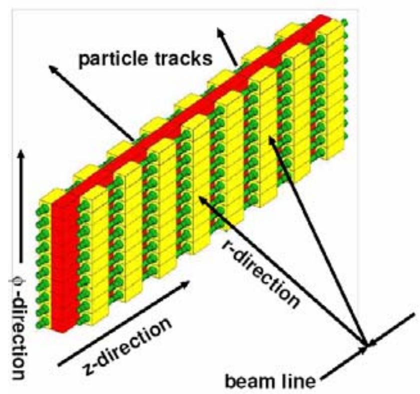
TOF σ ~ 100 ps

RICH with CO_2 γ_{th} ~ 34

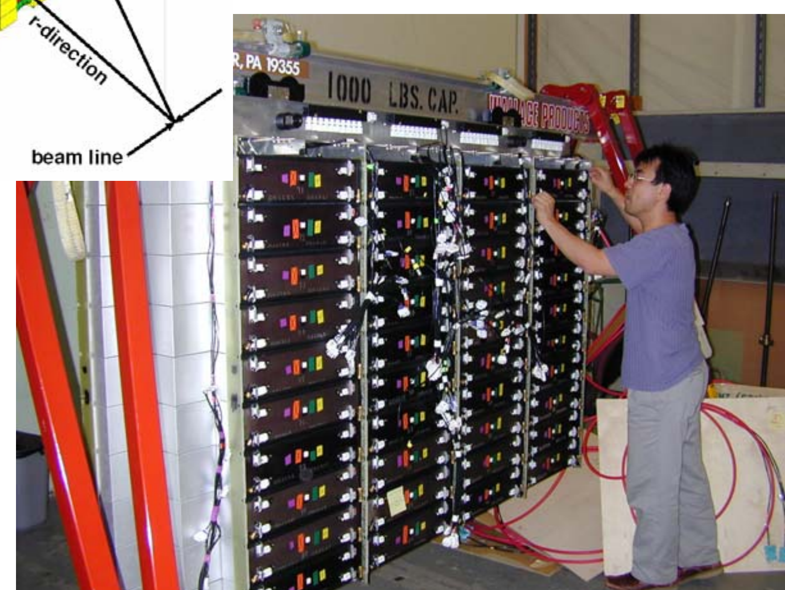
Aerogel Č, γ_{th} ~ 8.5

π, K, p separation out to ~ 10 GeV/c

coverage ~ 4-8 m^2 in west arm



- **2 m^2 Aerogel Cherenkov installed**
- **Future plans:**
  - **4 m^2 of aerogel detectors by 2005**
  - **Develop matching TOF detector based on RPC's**

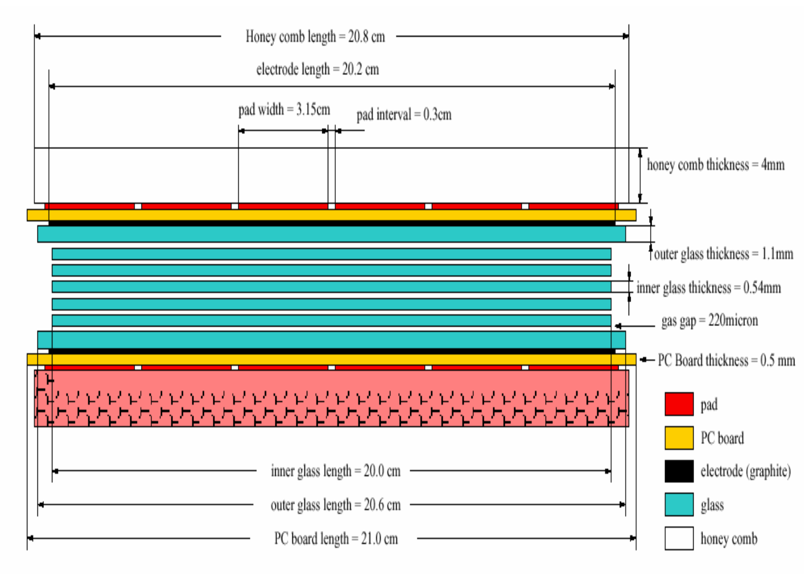


The STAR Barrel TOF with MRPC

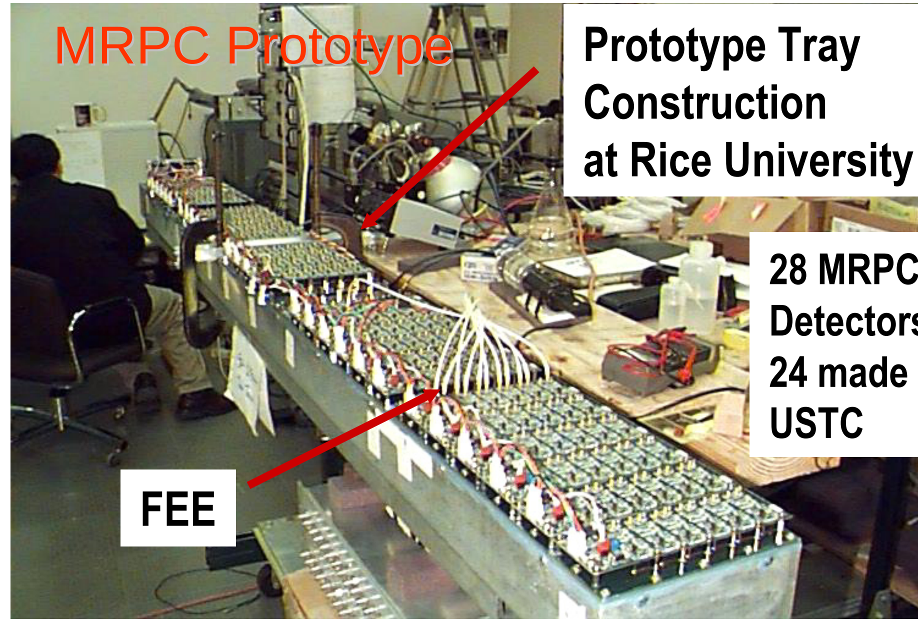
$\sigma \sim$ **70 ps, 2 meter path**

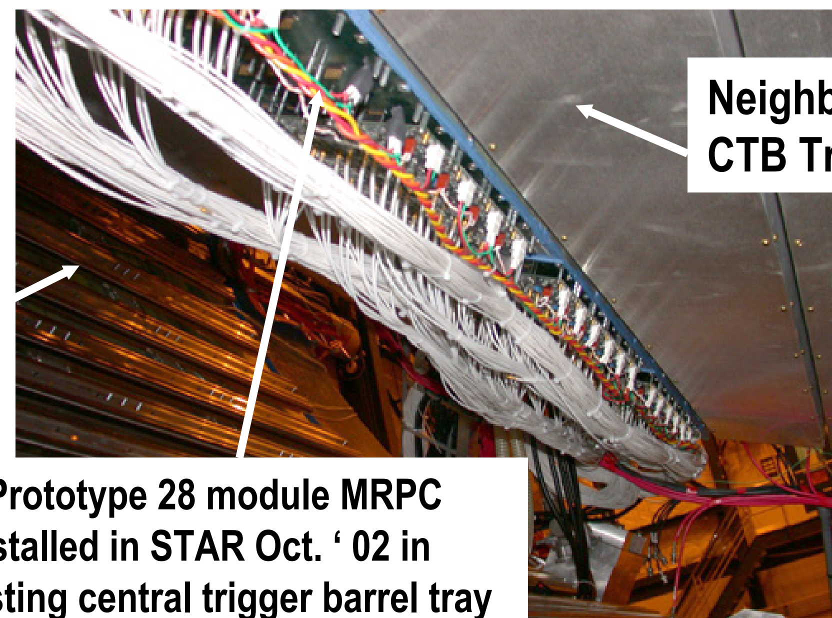
$\Delta\phi \sim 2\pi$

$-1 < \eta < 1$



MRPC design developed at CERN, built in China



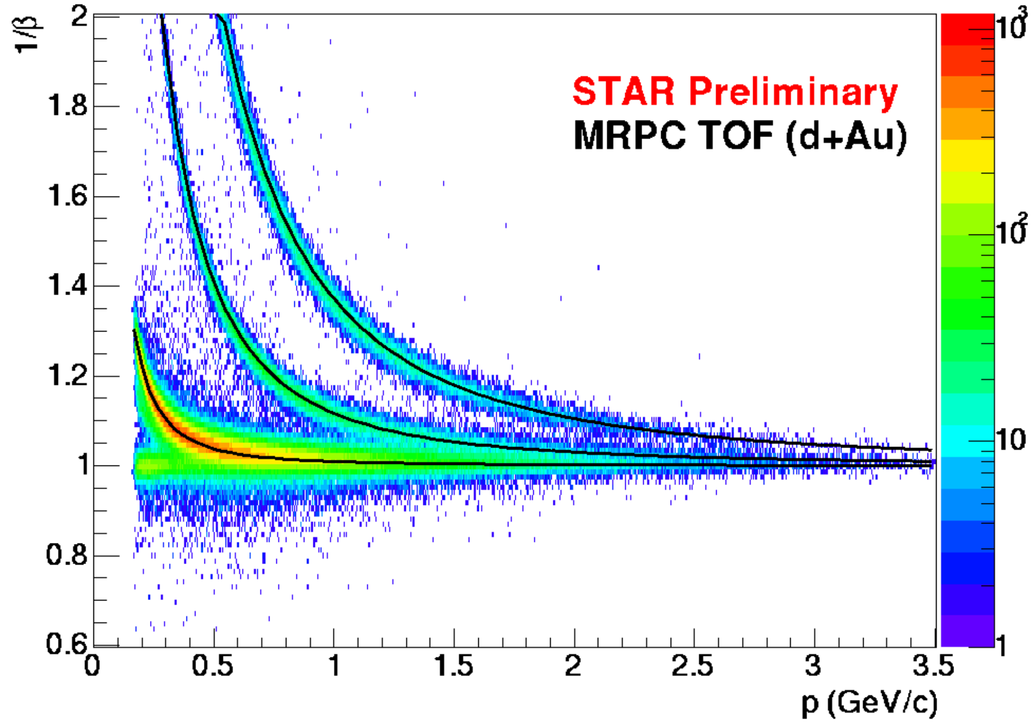


Completed Prototype 28 module MRPC TOF Tray installed in STAR Oct. ' 02 in place of existing central trigger barrel tray

PHENIX

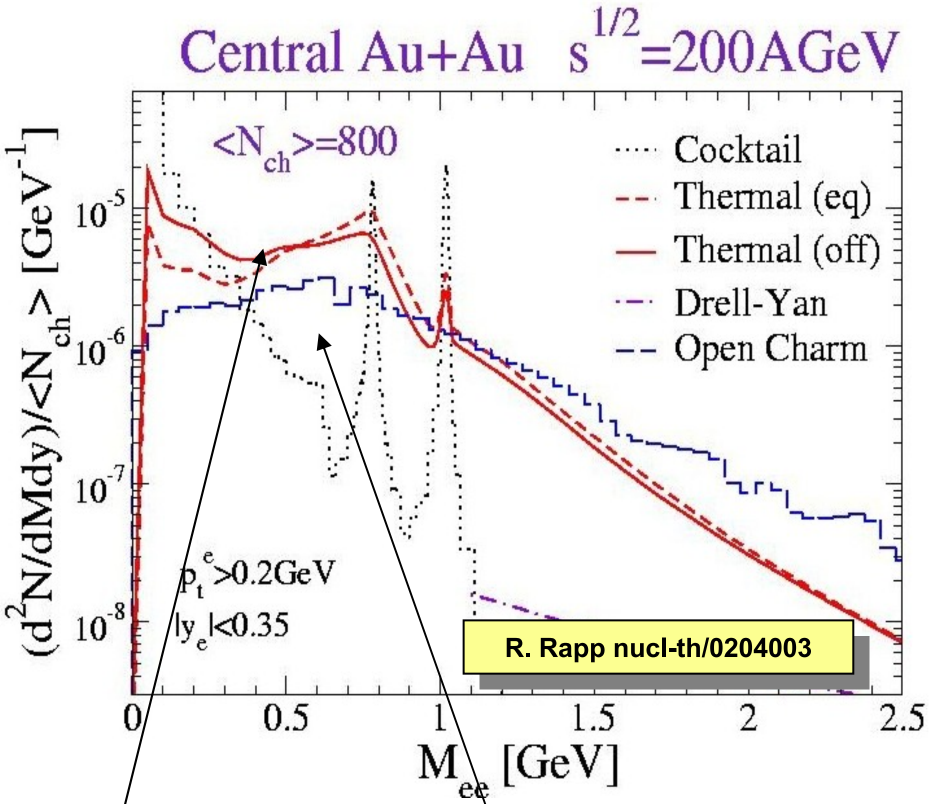
The STAR Barrel TOF

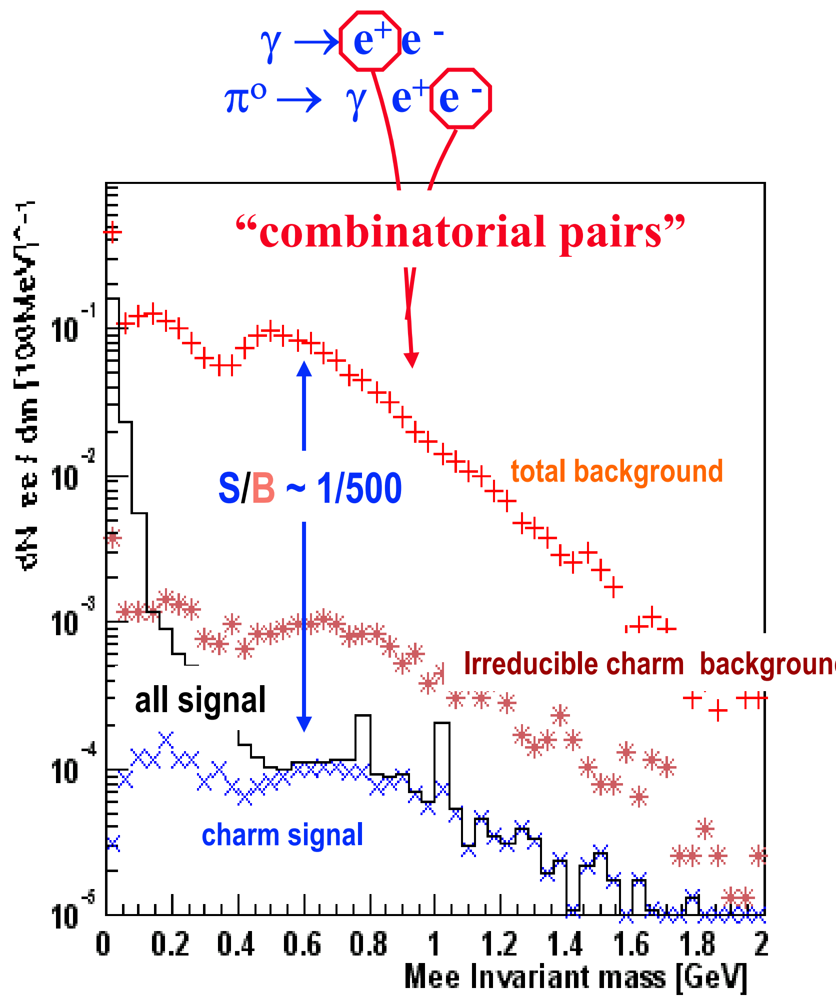
Prototype modules met all performance specs in the STAR environment and produced physics results in dAu



- Proposal submitted to BNL
  - Seek construction funding in FY05
  - Construction FY05 – FY07
  - 30 Trays (25% coverage) in FY06
  - Partial (and increasing) coverage (and physics capability) available during construction phase.

Low-Mass e^+e^- Pairs: Prospects at RHIC





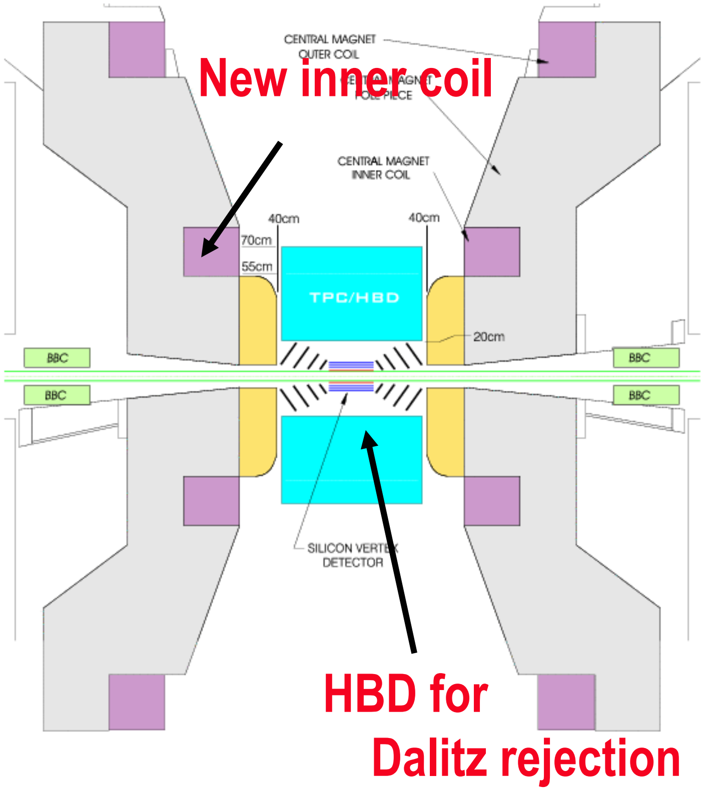
Strong enhancement of low-mass pairs persists at RHIC

Significant contribution from open charm

Need Dalitz rejection
& accurate charm measurement → PHENIX

PHENIX

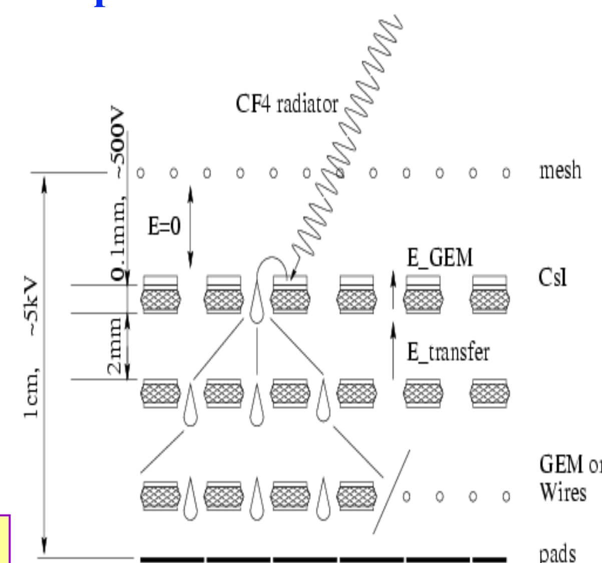
PHENIX Dalitz Rejection with a Hadron Blind Detector



- **Dalitz rejection via opening angle**
  - **Field free region to maintain opening angle**
  - **HBD for electron ID**

    Proximity focused RICH with 50 cm radiator

    Provides minimal signals for charged particle
- **HBD concept:**
  - **windowless Cherenkov detector**
  - **CF_4 as radiator and detector gas**
  - **Triple GEM with pad readout**
  - **CsI reflective photocathode**



R&D at Weizmann Institute

Bandwidth 6-11eV, $N_0 \approx 940\text{cm}^{-1}$ $N_{pe} \approx 40!$

No photon feedback

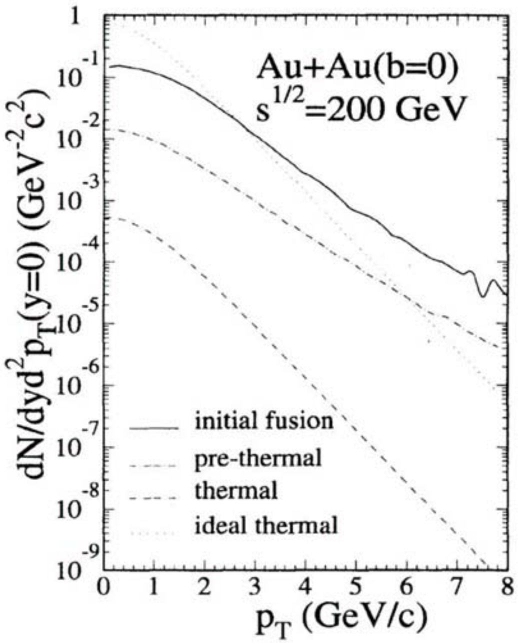
Low granularity, relatively low gain

Hadron blind

Proposal expected during 2004
Earliest implementation by 2006

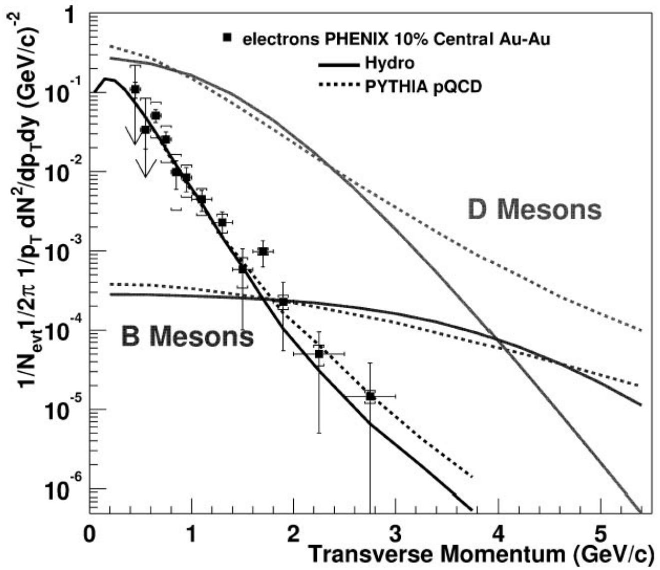
Physics from Precise Charm Measurements in Au-Au

Is there pre-thermal charm production?



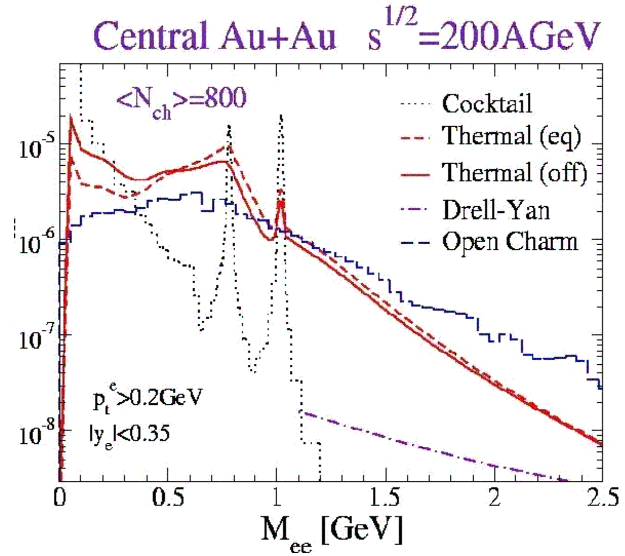
Precision measurement

Does charm flow? Does charm suffer energy loss?



Charm out to p_T > 4 GeV/c

Thermal dileptons from the QGP



Accurate measurement of correlated e+e- pairs

These measurements are not possible or very limited without micro vertex tracking

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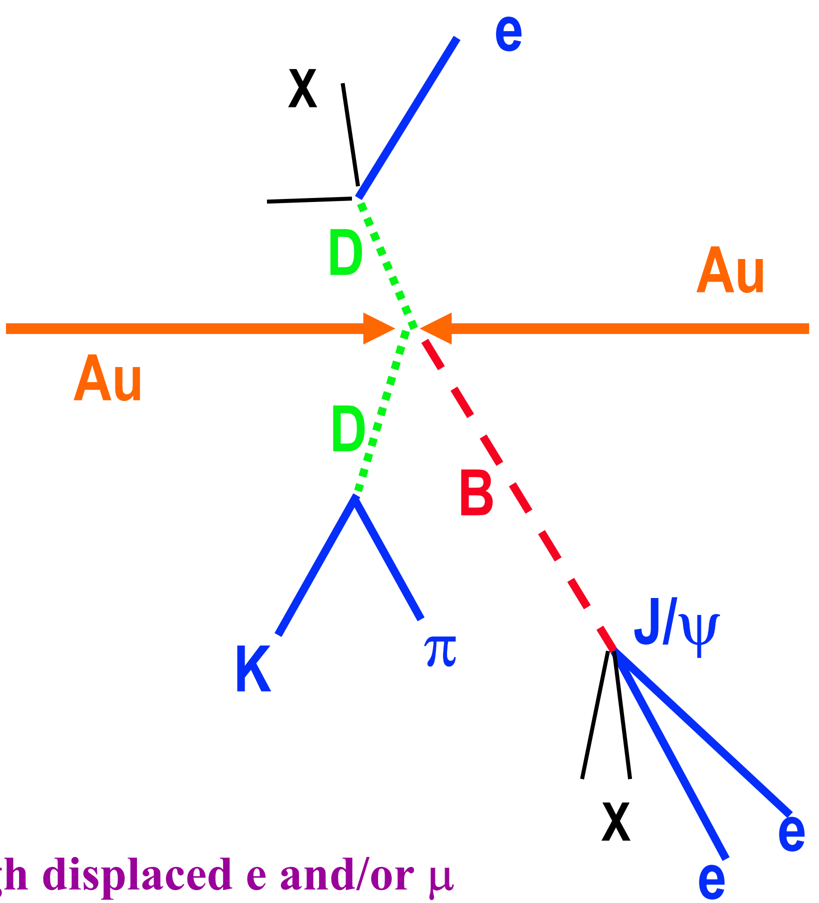
Direct Observation of Open Charm and Beauty

Detection of decay vertex will allow a clean identifications of charm and bottom decays

	m GeV	cτ μm
D^0	1865	125
$D^{\pm}$	1869	317
B^0	5279	464
$B^{\pm}$	5279	496



Detection options:

- Beauty and low p_T charm through displaced e and/or μ
- Beauty via displaced J/ψ
- High p_T charm through $D \to \pi K$

Need secondary vertex resolution < 50 μm

Beauty and high p_T charm will require high luminosity

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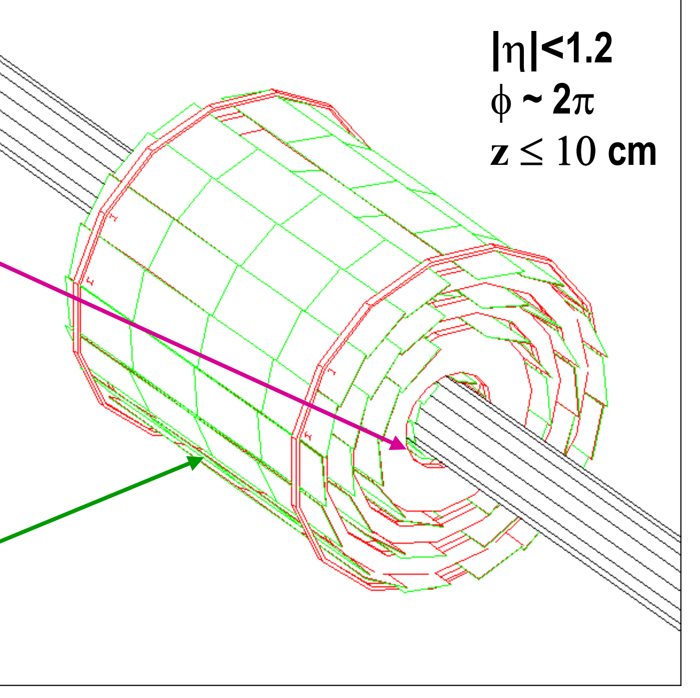
PHENIX Barrel VTX Detector Proposal

- **Proposal submitted to BNL**
  - **Detector system based on established technology**
  - **Extensive ongoing R&D program**
  - **Seek construction funds FY05 through FY07**

Barrel detector
(GEANT model)



Inner layer:
Hybrid Pixel Detector (50 μm x 425 μm) at R ~ 2.5 cm
Alice hybrid pixel technology:

32 x 256 channels / chip
bump bonded to pixel sensor

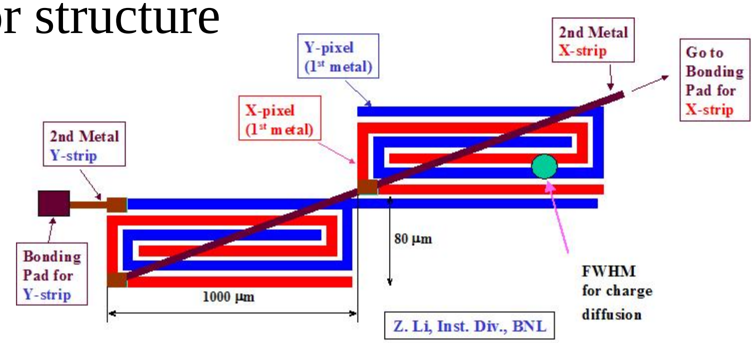
talks by V.Manzari and A.David

Three outer layers:
Strip Detectors (80 μm x 3 cm) at R ~ 6, 8, 10 cm
novel strip sensors with FNAL SVX4 readout
details on next slide

PHENIX Silicon Strips Detectors

- **Sensor technology choice:**
  - **Single sided, two dimensional read-out sensor developed by Z. Li of BNL Inst. Division**
  - **80 µ x 3 cm strip**
  - **X/U stereo read-out**

Sensor structure



- **Readout chip technology choice:**
  - **SVX4 chip developed by FNAL/LBNL**
  - **128 ch/chip**

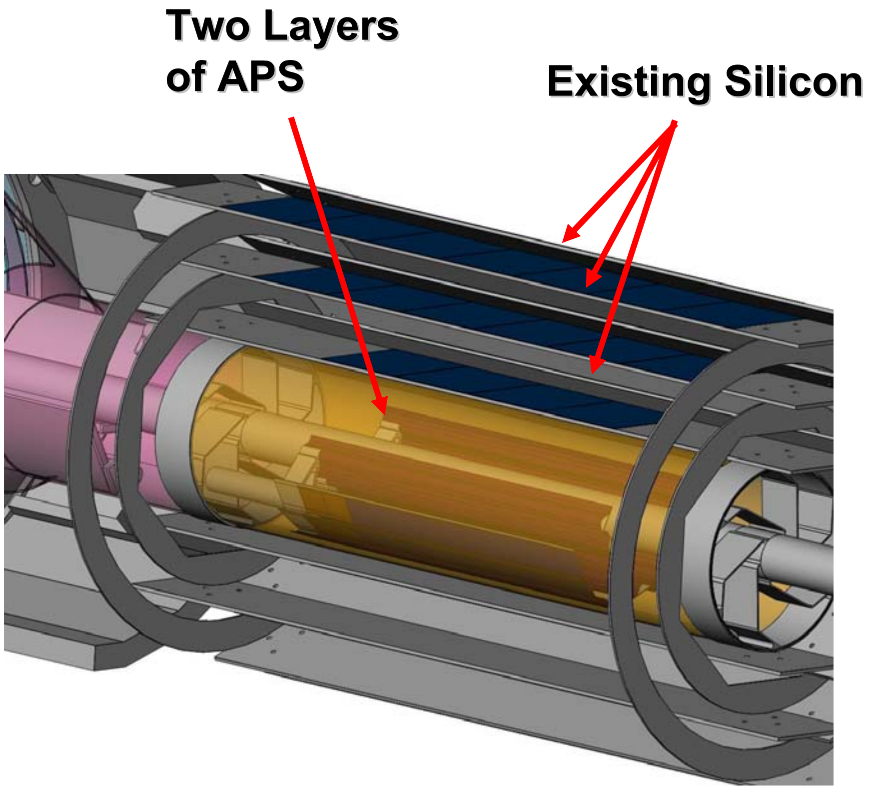
SVX4 chip

- **Ongoing R&D**
  - **Prototypes sensors tested in beam at KEK**
  - **2nd generation prototype in production**
  - **Will be tested with SVX4 readout**
  - **Plan to purchase SVX4 from FNAL**

STAR Micro-Vertex Detector

- **High resolution inner vertex detector:**
  - **< 20 μm track resolution at vertex**
  - **2 layers of CMOS Active Pixel Sensors**
  - **Inner radius ~1.8 cm**
  - **Active length 20 cm**
  - **Readout speed 20 ms (generation 1)**
  - **Number of pixels 130 M**

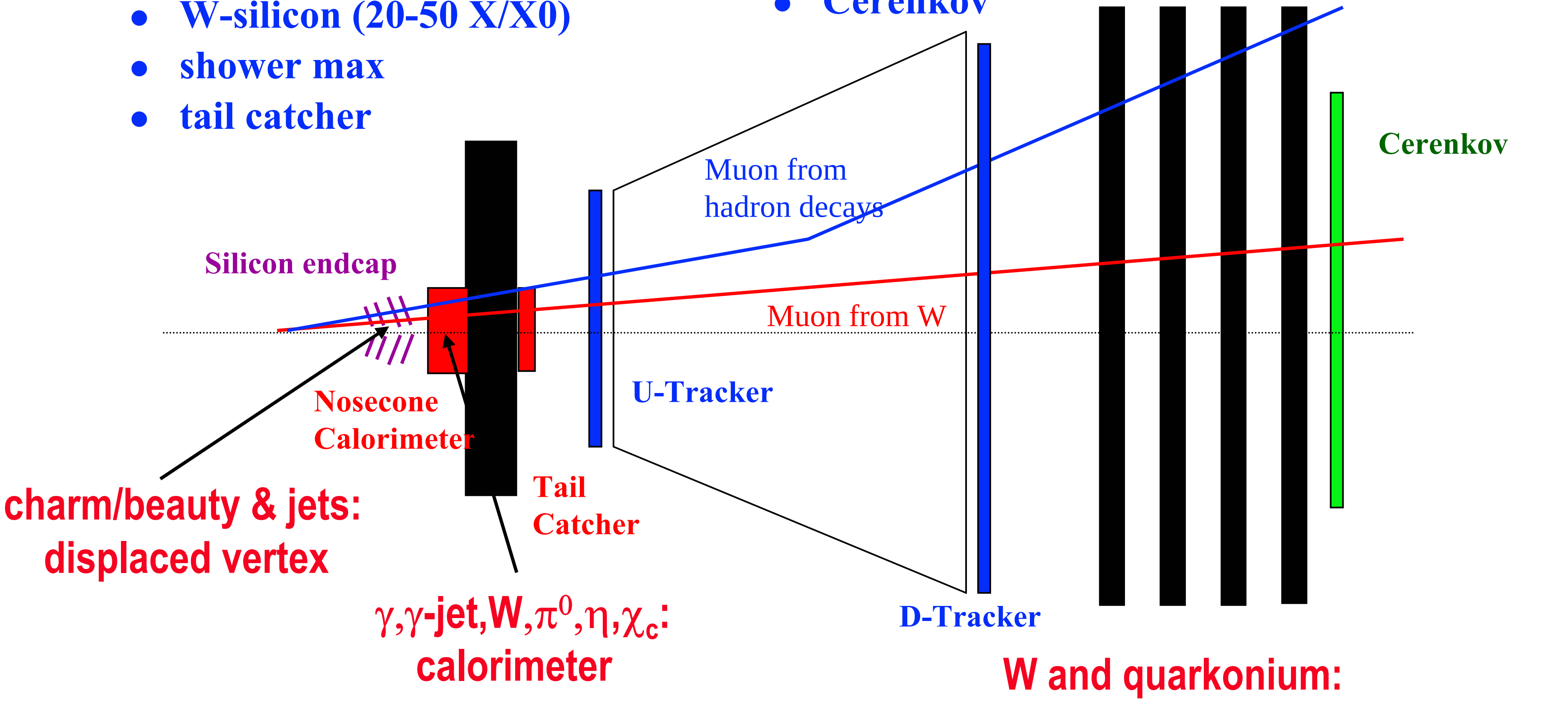
Proposal expected during 2004
Earliest implementation by 2007



- **Develop second generation**
  - **High readout speed**
  - **LEPSI/IReS, and LBNL+UC Irvine**

PHENIX Forward Upgrade Components

- **Endcap Vertex Tracker**
  - silicon pixel detectors
- **Nosecone EM Calorimeter**
  - W-silicon (20-50 X/X0)
  - shower max
  - tail catcher
- **Muon trigger**
  - U-tracker (MuTr or new)
  - D-tracker (timing with RPC's?)
  - Cerenkov



Proposal expected in 2004
Staged implementation 2005++

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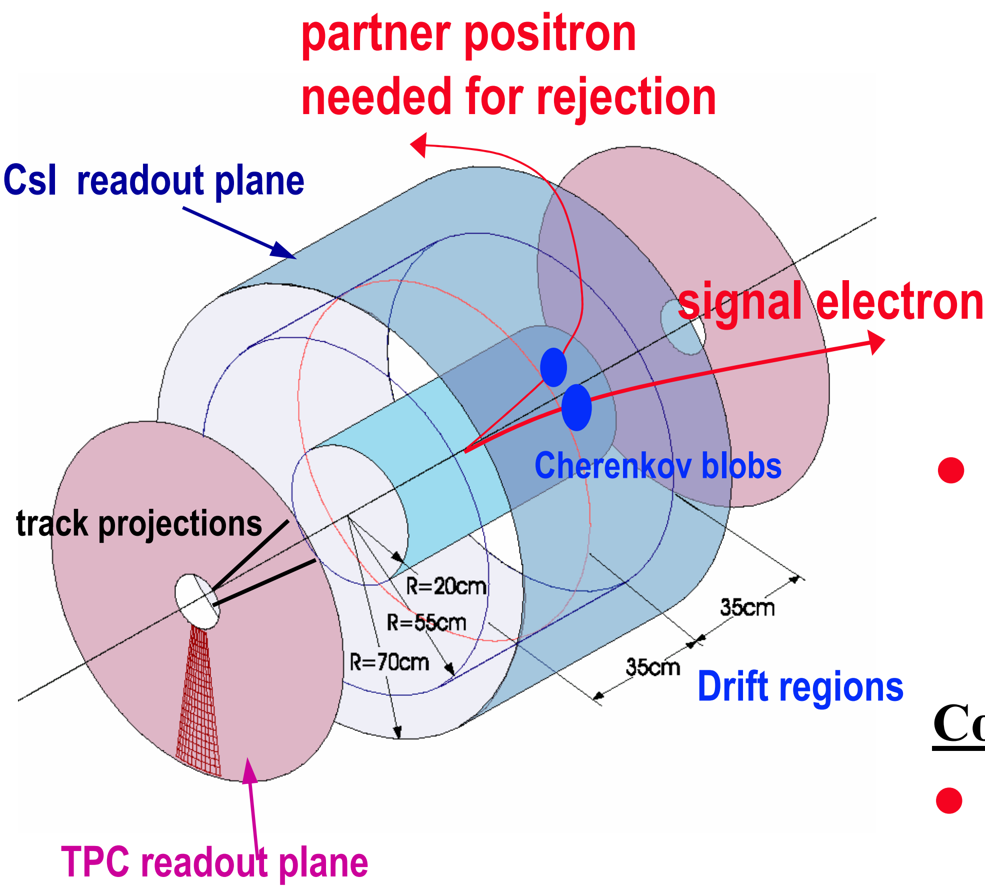
Large Acceptance Tracker (TPC)



GEMs are used for both TPC and HBD

- **Inner tracker with fast, compact TPC**
  - **Provides large acceptance to PHENIX**
    $\Delta\phi \sim 2\pi, \ |\eta| < 1.0$
  - **Fast tracking detector for STAR to handle RHIC II luminosities**
  - **Central tracking detector for future RHIC experiment**
- **R&D status:**
  - **Joined R&D with STAR and LEGS**
  - **Working drift cell with CF_4 and GEM's**

Combination with HBD:

- **Backup for PHENIX Dalitz rejection**
  - **Adds tracking and charge information**
  - **More robust rejection**
  - **Both detectors in one gas volume**
  - **Independent R&D promising**

Other STAR Upgrades

- **DAQ 1000 upgrade for RHIC II:**

  increase STAR's rate capability to equivalent of 1 kHz

  - **Implementation:**

    Replace TPC FEE with version based on ALICE ALTRO chip

    Replace TPC DAQ system with one storing only cluster information extracted in fast hardware

    Upgrade EMC level 2 receiver boards and use for other subsystems

    Staged implementation starting FY04

- **Forward upgrades under discussion**

  - **Improved tracking** $\eta > 1$

    Charge identification for W-physics

  - **Forward hadron calorimeter** $2.4 < \eta < 4$

    Probing gluon saturation and spin physics with forward jet production

  - **Roman pots** $\eta \sim 6.5$

    Access to a variety of diffractive phenomena in p-p scattering

A New Heavy Ion Experiment for RHIC II?

Letter of interest by: R. Bellwied, J.W. Harris, N. Smirnov, P. Steinberg, B. Surrow, and T. Ullrich

Statement of Interest document at http://star.physics.yale.edu/users/harris

- **Compelling Physics with RHIC II**
  - tomography of the QGP
  - initial conditions

    saturation / color glass condensate
  - structure and dynamics of proton

    rare processes: sea polarization, parity-violating processes

Large overlap with physics program proposed for PHENIX and STAR upgrades

- **Utilize Hard Probes**
  - jets γ-high-p_T correlations
  - high-p_T PID particles
  - J/ψ, Υ

Also punch line of PHENIX and STAR upgrades

"ideal hadron collider detector"

- **Detector Requirements**
  - ~4π EM + hadronic calorimetry
  - high resolution tracking (large $\int B{\cdot}dl$)
  - PID to p ~ 20-30 GeV/c (flavor tagging)
  - high rate DAQ and specialized triggering

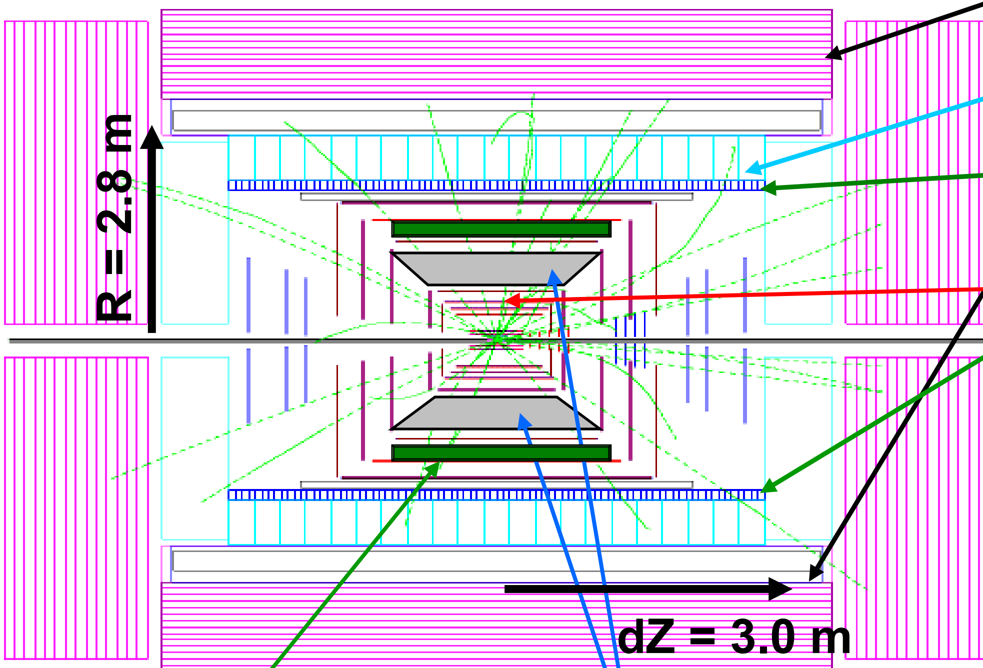
Addresses short comings of STAR (rate, resolution, PID ..) and PHENIX (acceptance)

and adds hadron calorimetry

PHENIX

Principle Design Study for Future RHIC Experiment

SLD magnet, hadronic cal. + μ-chambers |η| < 3
(depth = 15 x (5 + 5) cm, rϕ = 0.3 cm, Δz = 3 cm)

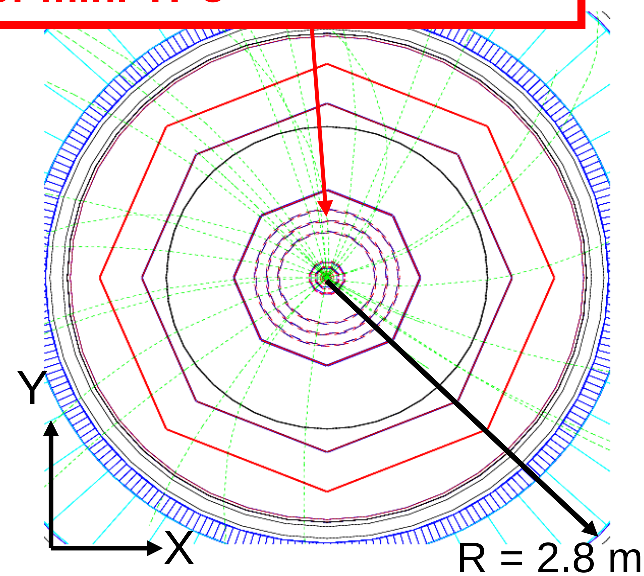


SC Magnet Coil, 1.5 T

EMC: Crystals + Fe(Pb)/Sc
(accordion type, projective)
or LAr 6x6 mrad towers

ToF RPC's

3-6 layers Si-strip detectors
or mini-TPC



π/K/p (1-30 GeV/c) PID:
Gas RICH (C5F12) with Spherical Mirror
Read-out: CsI pads sensitive to UV and MIP

AeroGel Cherenkov Detectors with two values of N

Additional Tracking: Si Vertex,
4 Pad Detectors in Barrel
and End Caps (μ-pattern)
Si + Pad Detectors Forward

PHENIX

Principle Design Study for Future RHIC Experiment

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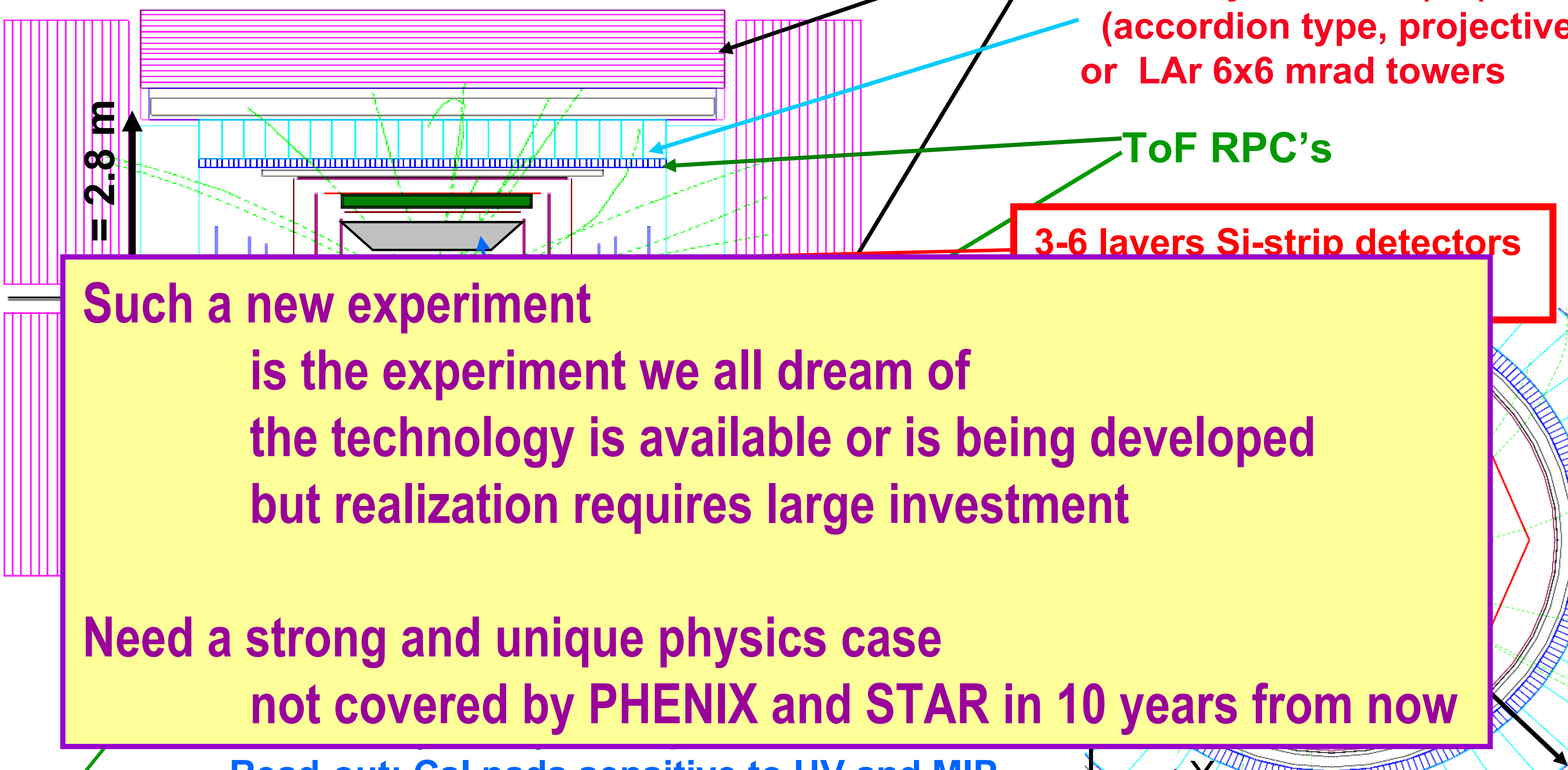

Such a new experiment

is the experiment we all dream of

the technology is available or is being developed

but realization requires large investment

Need a strong and unique physics case

not covered by PHENIX and STAR in 10 years from now

Additional Tracking: Si Vertex,
4 Pad Detectors in Barrel
and End Caps (μ-pattern)
Si + Pad Detectors Forward

PHENIX

Long Term RHIC Operation and Upgrade Plans

2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018

RHIC operation at and beyond design luminosity

eRHIC
e-ion collider

RHIC II 40x design luminosity for Au-Au via electron cooling

RHIC baseline program
- Au-Au ~ 1 nb^{-1} at 200 GeV
- Species scan at 200 GeV
- Au-Au energy scan
- Polarized protons $\geq$ 150 mb^{-1}

Completion of
- BRAHMS & PHOBOS

Studies of dense nuclear matter
with rare probes: jet tomography, open flavor,
J/ψ, ψ', χc, $\Upsilon(1s)$, $\Upsilon(2s)$, $\Upsilon(3s)$
Polarized protons at 500 GeV
p-A physics

Near & medium term detector upgrades of PHENIX and STAR
Proposals submitted or in preparation

New eRHIC experiment

Medium term upgrades of PHENIX and STAR related to RHIC II

new RHIC experiments ?

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PHENIX