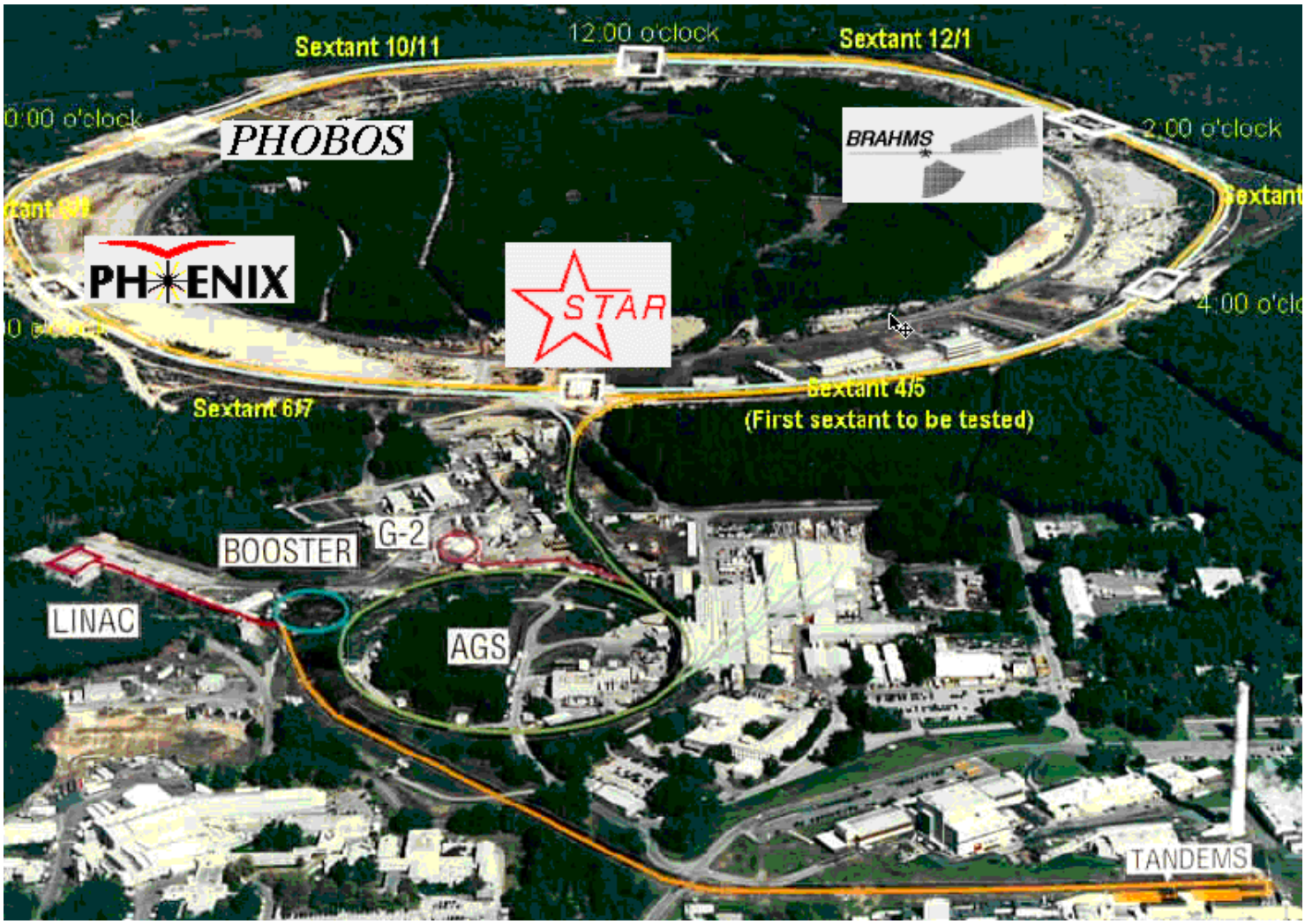
The Solenoidal Tracker at RHIC



Relativistic Heavy-Ion Collider (RHIC)

- Two concentric superconducting rings
- Ions from A~200 to polarized-p; also p+A
- Magnets look great, "Super Sunday" sextant test
- Completed Spring, 1999

	Au+Au	p+p
E_{beam} (max)	100 GeV/u	250 GeV
Luminosity	2×10^{26} /cm^2/s	1.4×10^{31} /cm^2/s

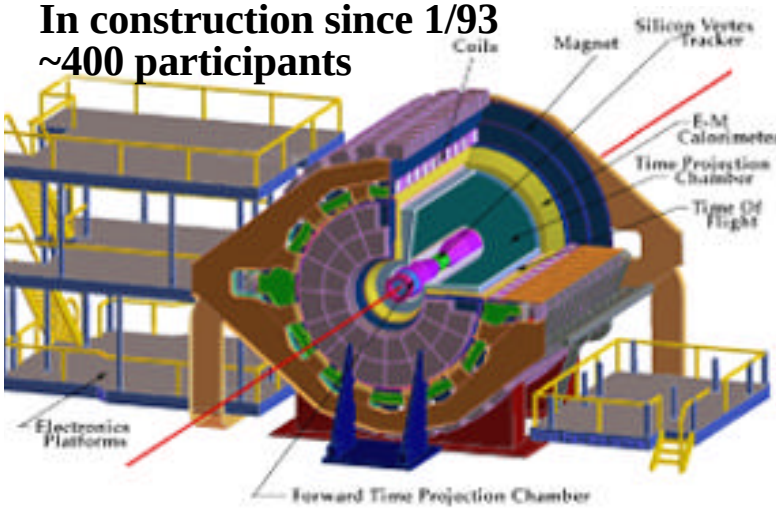
Nuclear matter under extreme conditions...
Search for, and studies of, the Quark Gluon Plasma...
Structure functions and other spin-dependent phenomena...

Outline:

W.J. Llope
Rice University

STAR

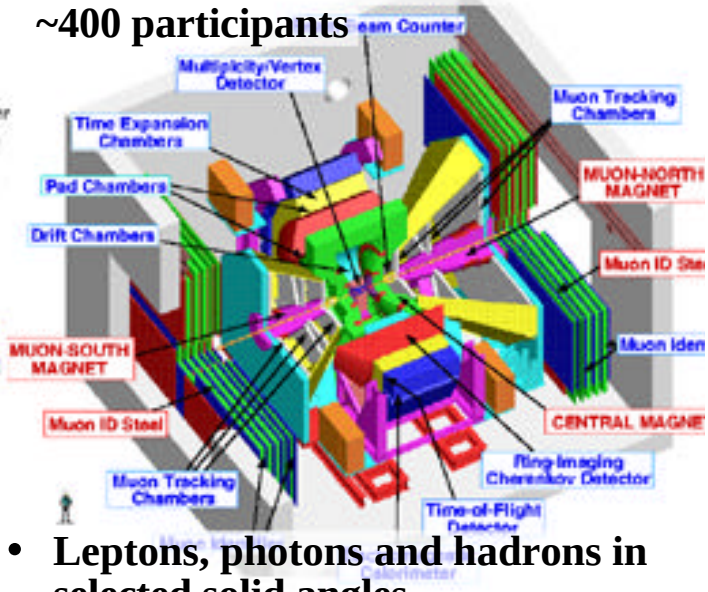
Solenoidal field
Large-Ω tracking
TPC, Si, Cal., TOF
In construction since 1/93
~400 participants



- **Measurements of hadronic observables with large acceptance**
- **Event-by-event analyses of hadrons and jets**

PHENIX

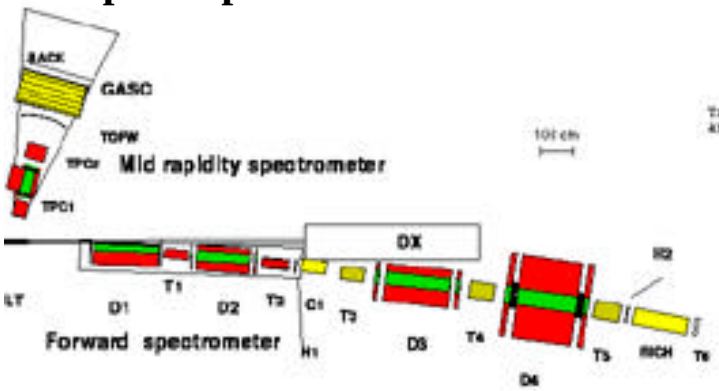
Axial field, high rates
2 central arms, 2 forward arms
TEC, RICH, Cal., Si, TOF, μ-ID
In construction since 3/94
~400 participants



- **Leptons, photons and hadrons in selected solid angles**
- **Simultaneous detection of various phase transition phenomena**

BRAHMS

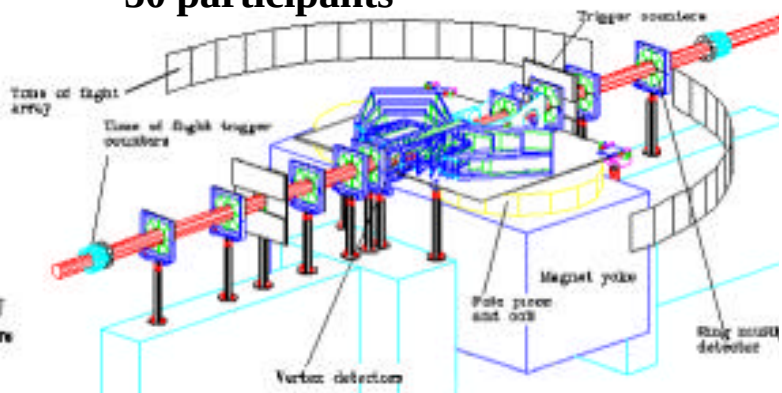
2 "conventional" spectrometers
Magnets, chambers, TOF, RICH
Variable settings
Baseline review in 1996
~40 participants



- **Inclusive particle production over full rapidity range**

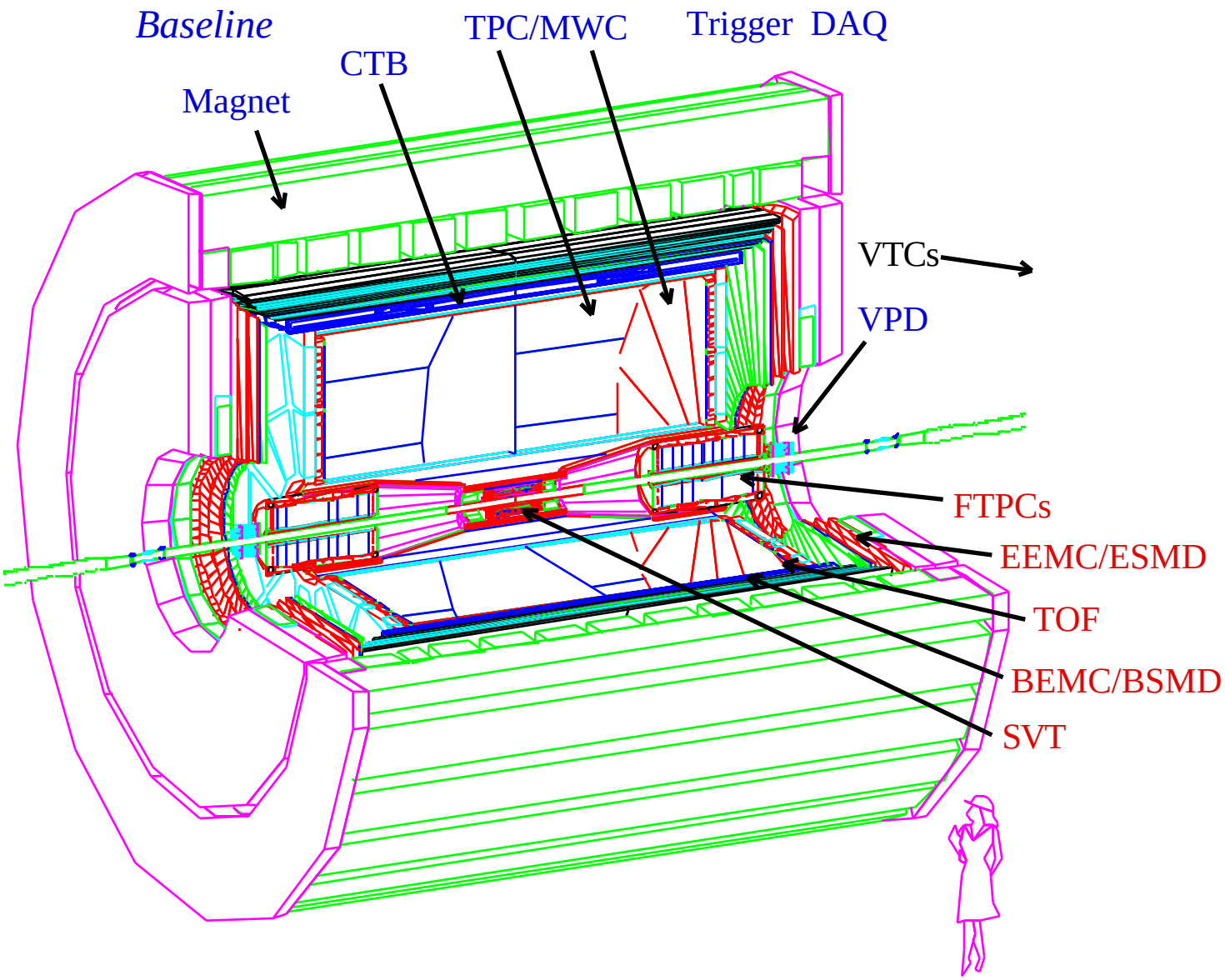
PHOBOS

"Table-top" 2 arm spectrometer
Si μ-strips, chambers, TOF
In construction since 1995
~50 participants



- **Charged hadrons and leptons in selected solid angles**

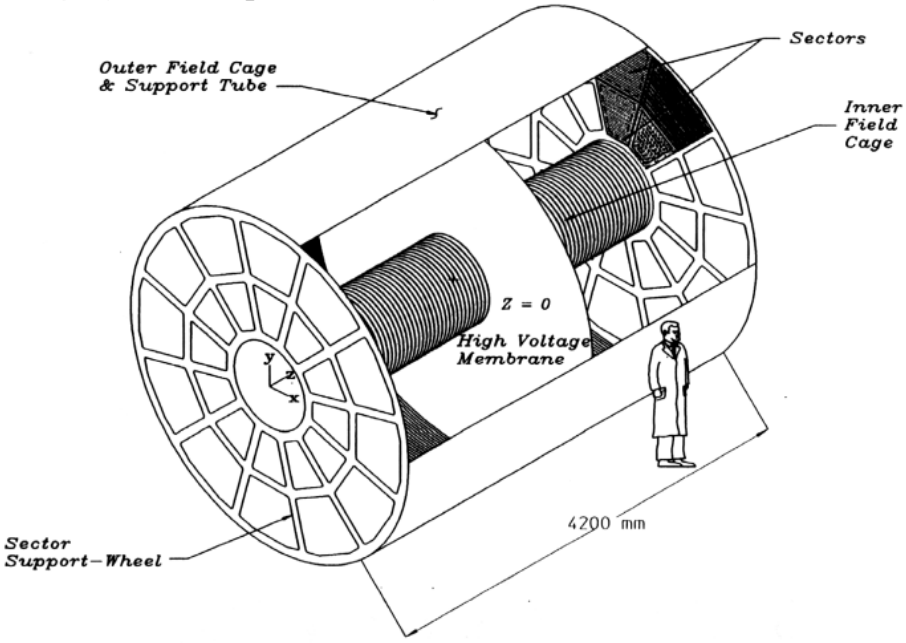
Solenoidal Tracker at RHIC



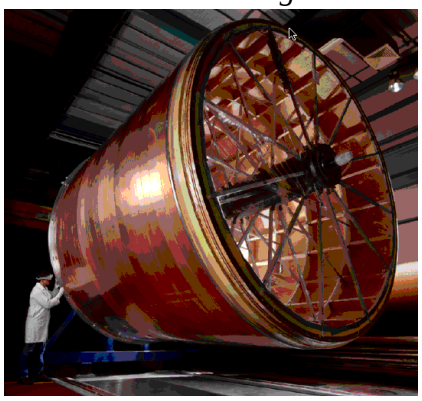
Additional Experimental Equipment (AEE) or proposed...

TPC

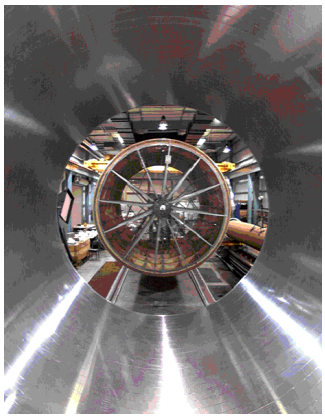
- Tracking, p-reconstruction for 4000 charged particles with $|\eta|<1.8$
  136,000 pads, 512 samples → ~70,000,000 pixels in 3D
- $p/p<1.5\%$ for $p>150$ MeV/c (~3% for p~10 GeV/c)
- Particle ID via dE/dx



Outer Field Cage



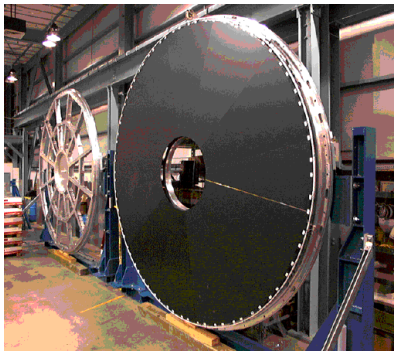
Gas Vessel and OFC



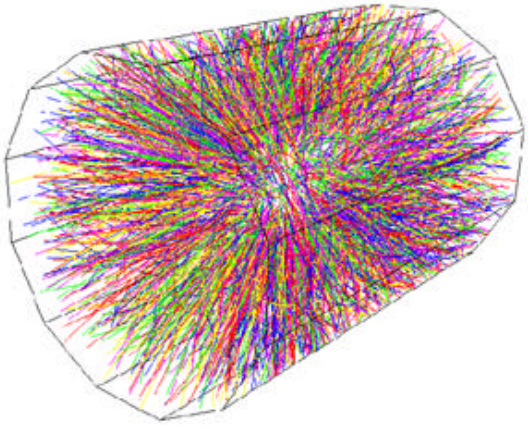
- 24+2 outer, and 24+2 inner, sectors built & tested
- gas vessel complete
- outer field cage installed in gas vessel.
- central membrane built and stretched
- field cage HV System complete.

Arrives at BNL October, 1997

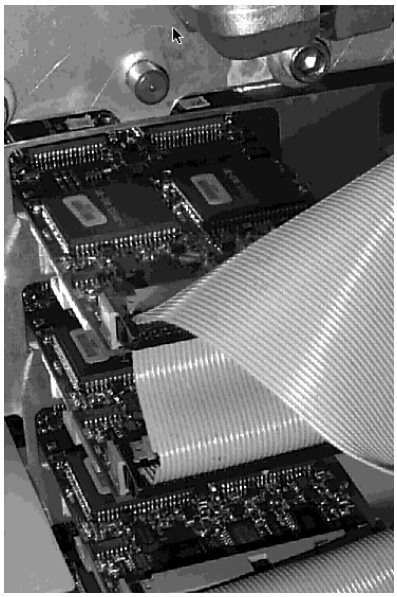
Wheels and Central Membrane



Au+Au
or
p+p



TPC Front-End Electronics



FEE Cards
- amplify, shape, and waveform digitize pad signals
- first 15 FEE cards in System Test
- 4% in production (full sector)

Readout Card (MUX, Glink, Xmit)
- clock/trig fanout, event memory, slow controls
- send digital data to DAQ over 1.5 Gbit/s fiber
- first prototype works, second in final layout

4/97: Full sector up in System Test
6/97: Start full-scale production (21 months)
4/98: Begin installation
6/98: On-chamber tests

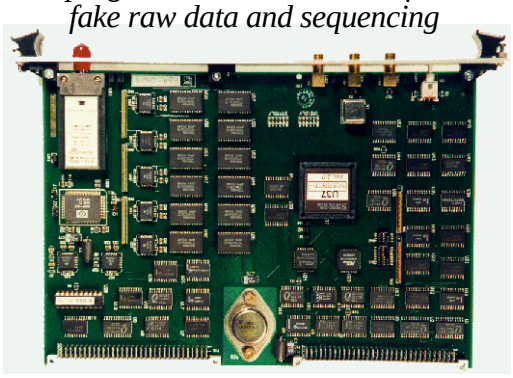
Data AcQuisition

Sector-based.
Accepts 100 Hz of data (7 GB/s).
Writes 1 Hz to tape (16 MB/s), network feed < 0.1 Hz

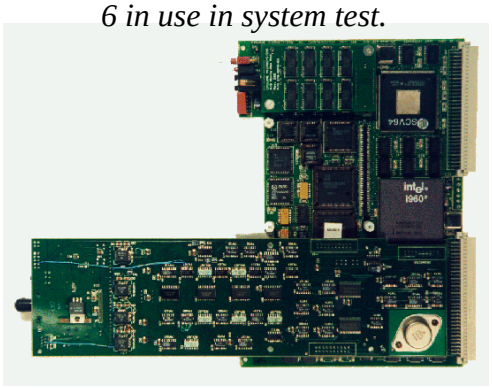
Preprocessing TPC ADC data: peds., 10 to 8 bits, space points (ASIC)
Level-3 Processing: sector-level tracking, L-3 decision
Event Building

Prototype receiver and mezzanine cards in System Test
ASIC submitted to the foundry, first batch being tested
Final DAQ hardware built and tested by Summer, 1997

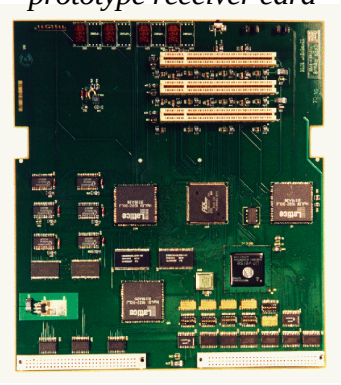
"Rosebud"
programmable data source for fake raw data and sequencing



"Rosie"
receiver board + mezzanine board
6 in use in system test.



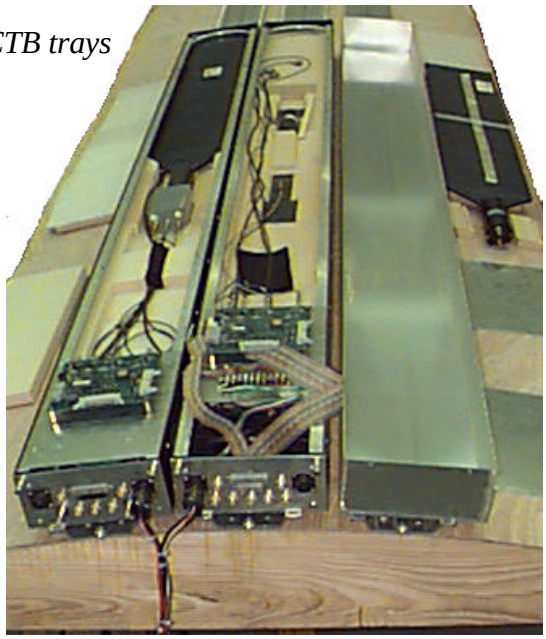
"Cher"
prototype receiver card



W.J. Llope
Rice University

Trigger

Prototype CTB trays



Vertex Position Detector
48 quartz radiators and Pb, 2 cylinders ±3.6m from IR
interaction vertex ±1cm, removes beam-gas interactions

Central Trigger Barrel/Time-Of-Flight (AEE)
240 scint. slats $(\Delta\eta,\Delta\varphi)=(0.5,0.1)$, on TPC OFC
charged particle multiplicities for $|\eta|<1$

MultiWire Proportional Chamber
~8000 TPC anode wires, ganged
charged particle multiplicities for $1<|\eta|<2$

Veto Calorimeter
2 hadron calorimeters ~±15m from the IR
measure spectators

Electromagnetic Calorimeter (AEE)
4800 tower Pb/sci sampling calorimeter, ganged, $|\eta|<1$
transverse energy, neutral energy, flow, jet/mini-jet structure

Detector	*Level-0*	*Level-1*	*Level-2*	*Level-3*
VPD	vertex location			
CTB/MWC	coarse mult $\|\eta\|<2$	finer pixelation	full pixelation	
EMC	Global E_T $\|\eta\|<1$			
EMC	n-tower sums $\|\eta\|<1$		all tower info	
SMD		coarse E $\|\eta\|<1$	all E info	
TOF		fine mult $\|\eta\|<1$	time info	
TPC				outer sector tracks
SVT				wafer hits

Data Storage and Manipulation board (DSM)
stores det. data, Level-0 fast analyses
production prototype in System Test

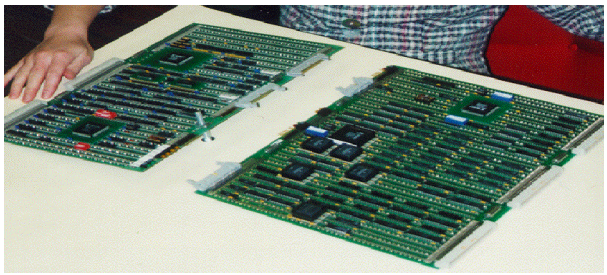
Trigger Control Unit (TCU)
Generates triggers, token FIFO, history FIFO, Scalers
production prototype in hand

Level-1 Processors, Level-2 Processors
More complex algorithms, event aborts and accepts

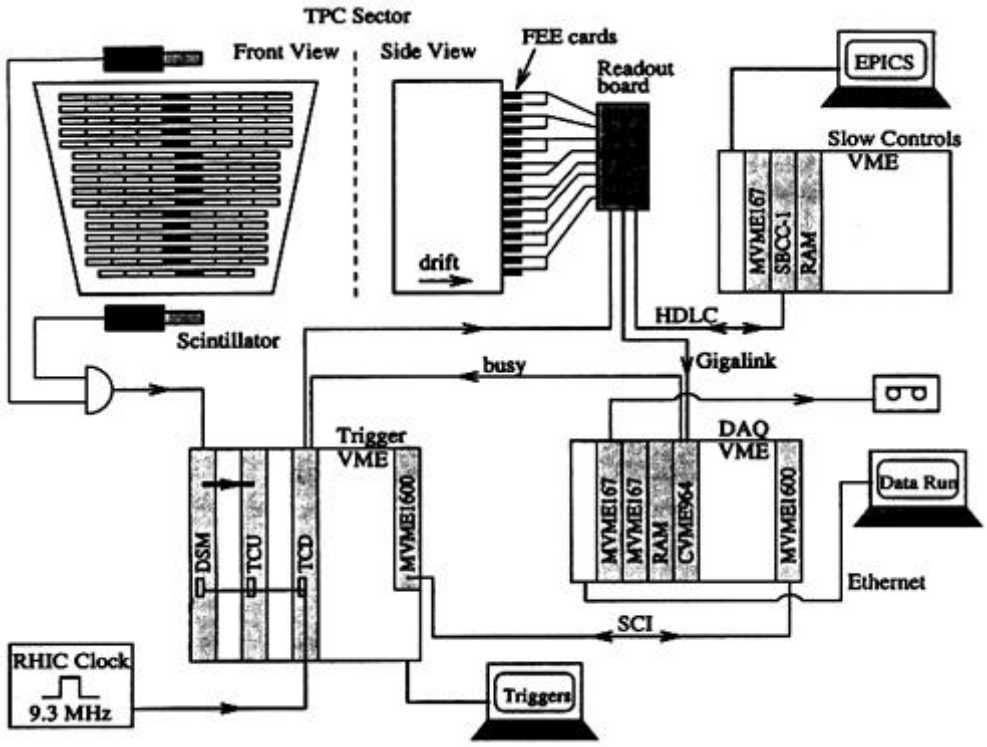
Successful "Trigger Physics Review" (June 1996)

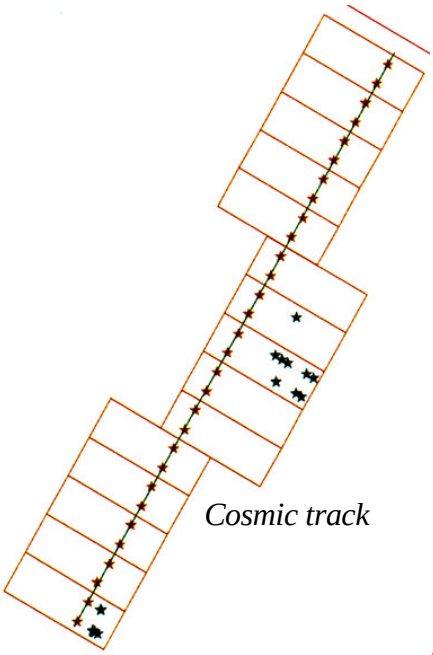
Trigger Electronics FDR (April 1997)
10 CTB trays in System Test (May 1997)
Begin Level-0 production (Oct 1997)

Prototype DSM and TCU



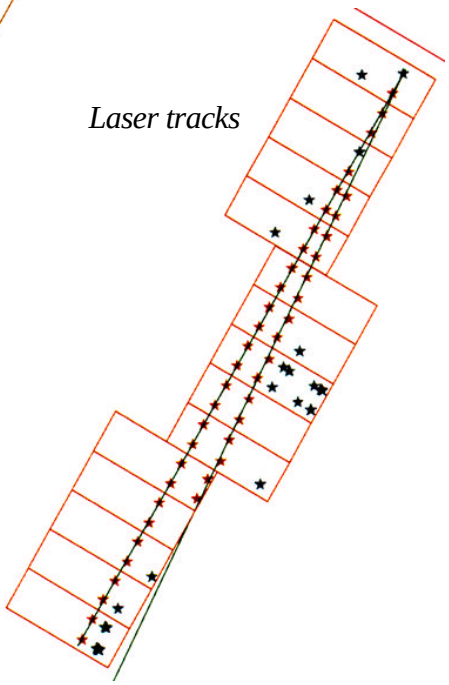
System Test





Cosmic track

Laser tracks



Done so far:

Dip angle response of outer sector

- space point resolution

	in φ (μm)	in Z (μm)
hit residuals:	390	780
diffusion limits:	400	700

- two-track resolution: ~1cm

In progress:

Dip and crossing angle response of inner sector

Next Big Step (Spring, 97)

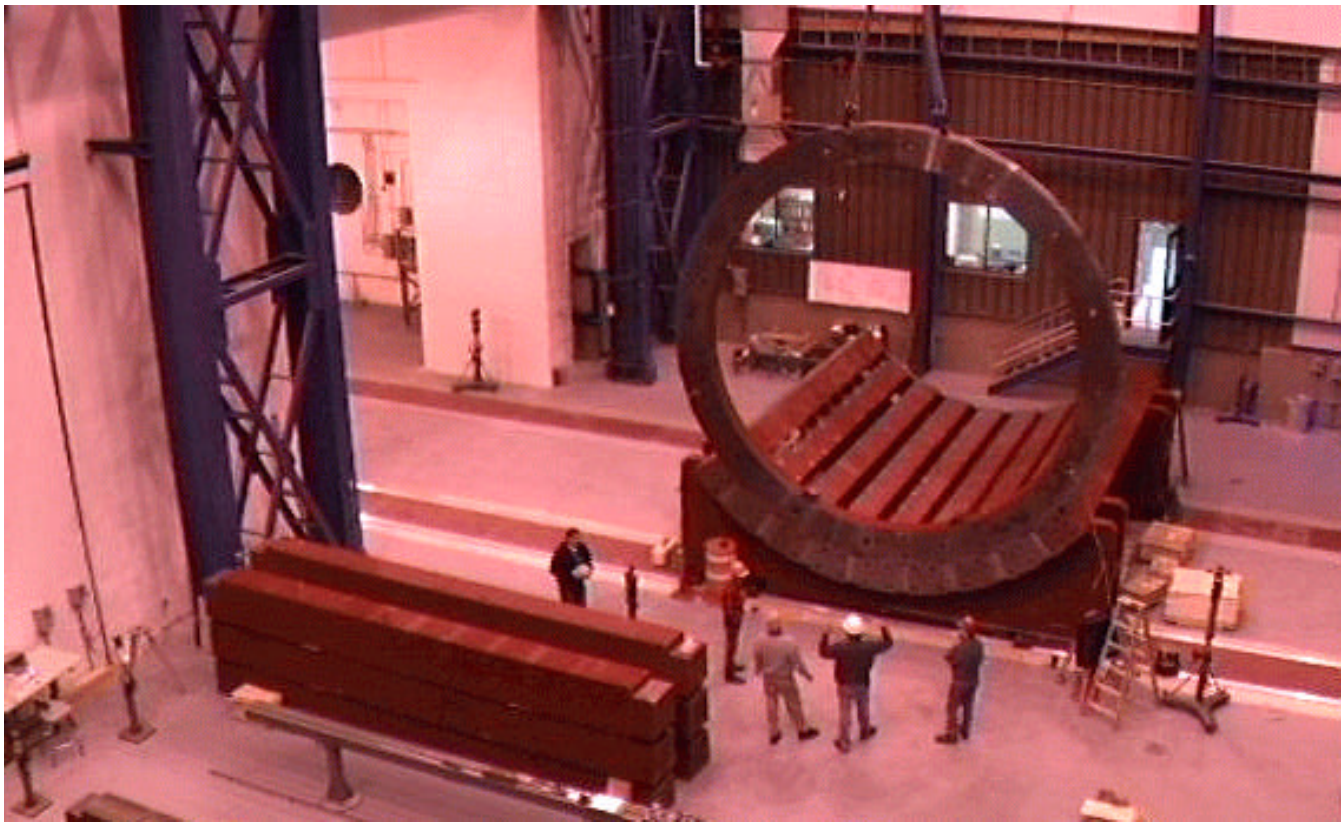
One inner plus one outer sector

- 216 FEE cards
- 6 readout boards
- 6 Rosie boards, 3 Cyclone boards
- Zero Supp., Gain Corr., Online
- Slow Controls data to tape

Magnet

- Warm coil solenoid, 5.26m ID, 6.2m long, 1200 tons, 3.4 MW
- Space-trim and pole-tip coils to correct end effects
- 0.5 Tesla operating field
- Maximum field distortions: <1/1000, or $\int \frac{Br}{Bz} dz < 0.7cm$ (try for 0.3cm)
- Accommodate EMC inside coil
- Endcaps roll back “in-situ”, to allow servicing of inner detectors

Lower 9 back legs in place.



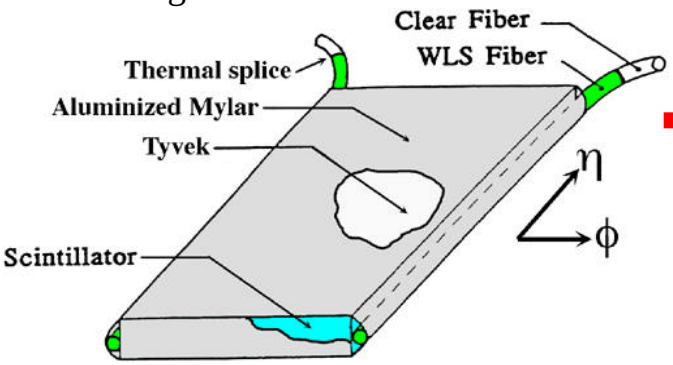
Next:

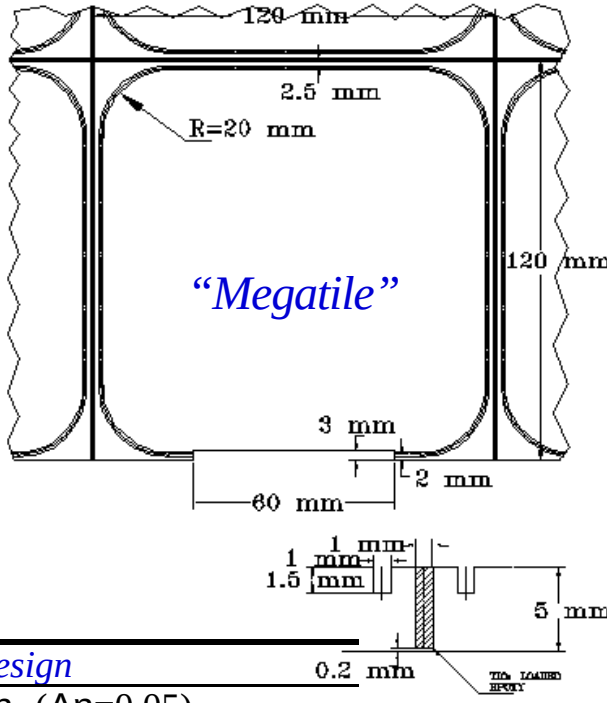
- install end rings and next six backlegs to complete lower half
- install main and space-trim coils
- install rest of backlegs, pole-tip steel, and remaining coils

On schedule for testing in mid-1998.

ElectroMagnetic Calorimeter

Stack and Shower Maximum Detector (SMD) redesigned:





	Old Design (e.g. SPEMC)	*New Design*
tiles	Equal-Z ($\Delta\eta$~0.05)	Equal-η ($\Delta\eta$=0.05)
	$\Delta\varphi$=0.1	$\Delta\varphi$=0.05
	4mm thick	5 mm thick
Sci/WSF	parabolic mylar wrapping	α or σ groove
fiber	1mm Bicron SC	0.83mm Kurary MC
Npe/mip	~1.7	~3 (α-groove, 1mm fiber)
SMD	strips ($\Delta Z, \Delta\varphi$)=(1.5cm,0.1)	strips ($\Delta Z, \Delta\varphi$)=(1.5cm,0.1)
SMD	wires ($\Delta\eta, \Delta Y$)=(0.5,1.5cm)	strips ($\Delta\eta, \Delta Y$)=(0.1,1.5cm)

Improved stack resolution, lower occupancy/tower
SMD occupancy ~23% in central Au+Au

Major push to prototype new features...

α *vs.* σ groove, splicing *vs.* optical connectors, SMD prototypes w/ in-stack electronics

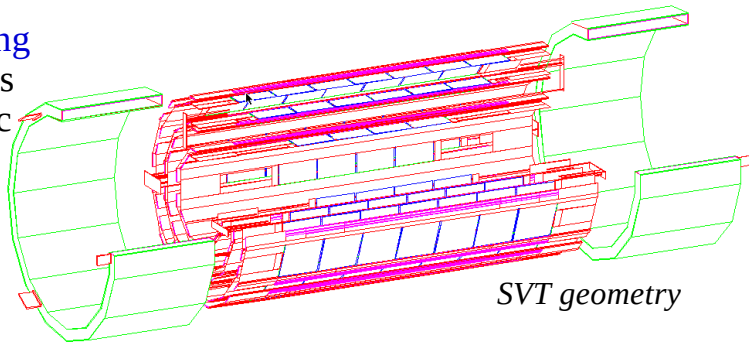
Test beam scheduled for May 7-14, 1997.

EMC FEE are dual-range variants of the CTB FEE
EMC Rails installed before TPC installed.
Proposal for EEMC/ESMD to NSF

EMC Construction Readiness Review (Dec. 1996)
"...[new] design well matched to goals..."
"...powerful additional tool for study of pp, pA, and AA..."

Silicon Vertex Tracker

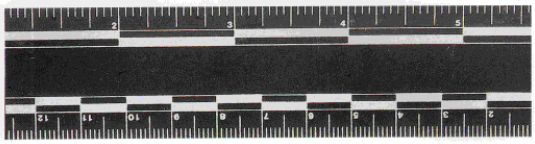
High-resolution tracking and vertexing
- Strange and multi-strange baryons
- π and p measurements >50 MeV/c

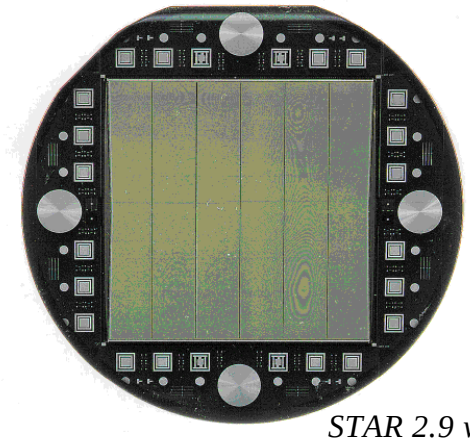


SVT geometry

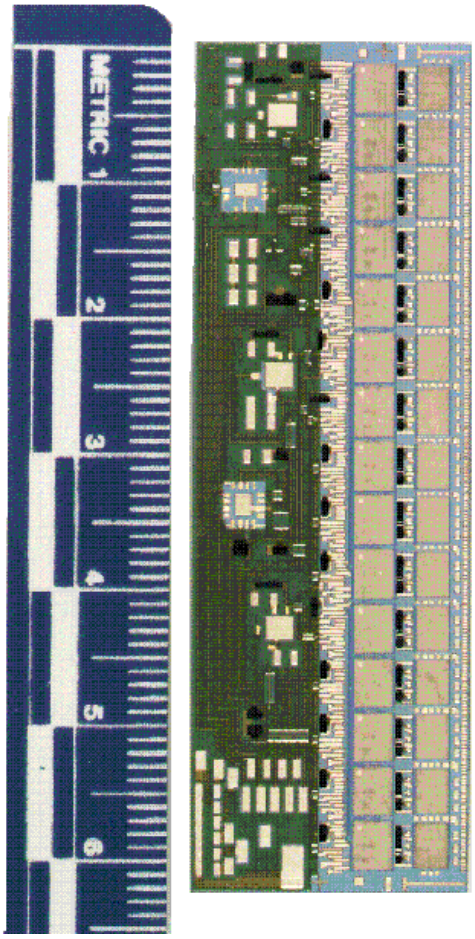
216 Silicon Drift wafers in 3 barrels
- 6 to 15 cm from the vertex
- $|\eta|<1$
- 2D resolution of 20×20 μm
- PID via dE/dx

R&D phase is concluded
Wafer performance well-understood
PASA/SCA hybrid prototyped





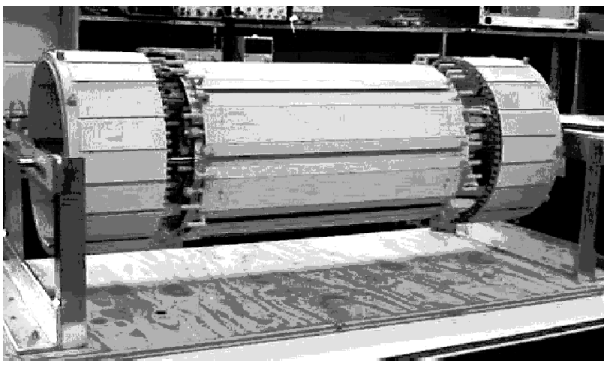
STAR 2.9 wafer (final)



prototype PASA/SCA

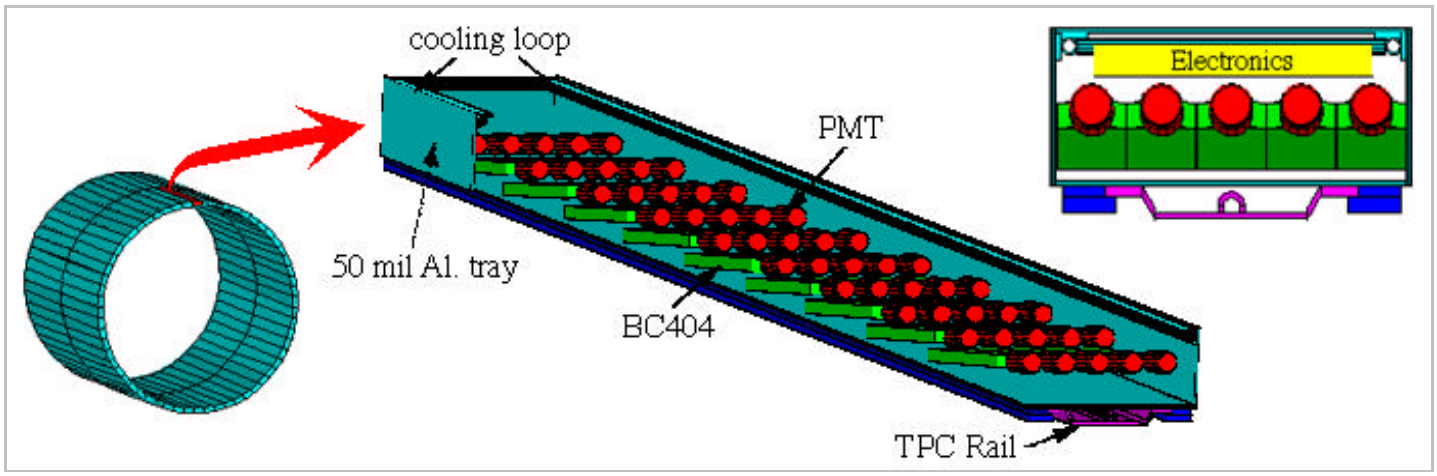
In Progress:
- hybrid tests
- read-out electronics tests
- commercial wafer production
- commercial production of Be support structure

Wooden full-size SVT



Time-of-Flight

- 6000 slats of single-ended TOF counters...
- dramatic increase in M_T range with direct-PID...
- factors of 2-3 larger multiplicities of directly-ID'd π,K,p...

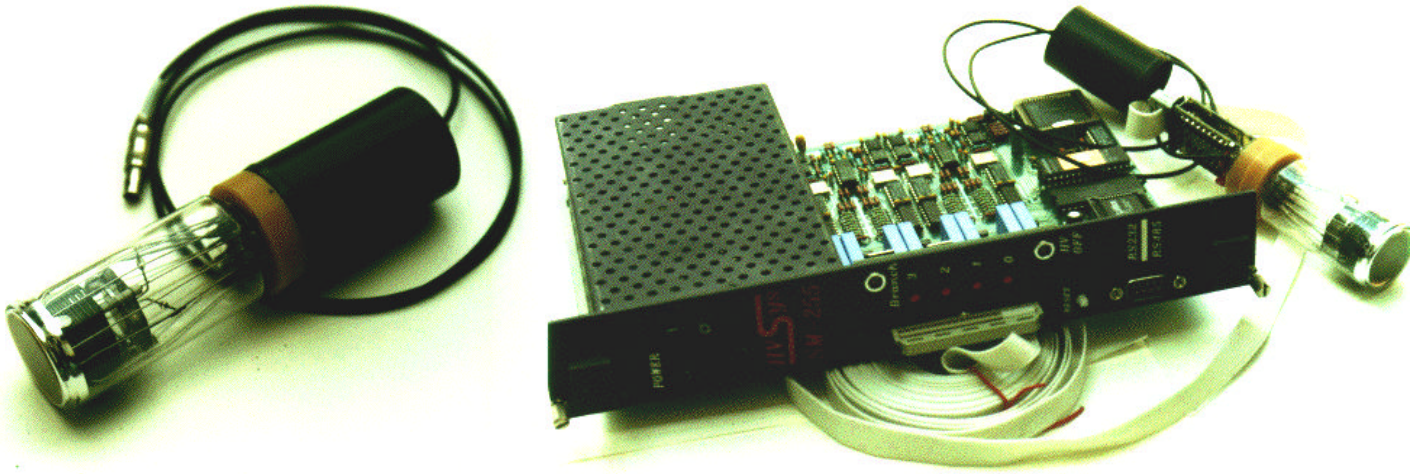


Many aspects same as CTB (under construction)
trays, cooling, electronics

Hamamatsu Proximity Mesh Dynode PMTs ~ 1200 $/ea.

Funding from Initiative to Prevent Proliferation (DOE), and CRDF (NSF), to develop low cost Mesh Dynode PMTs in Russia (<250 $/ea).

~1/2 in first batches meet specs, working to improve acceptance...

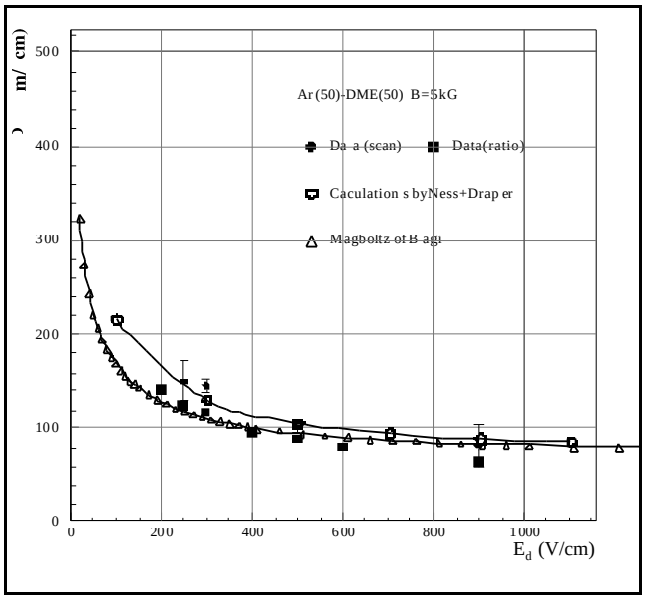


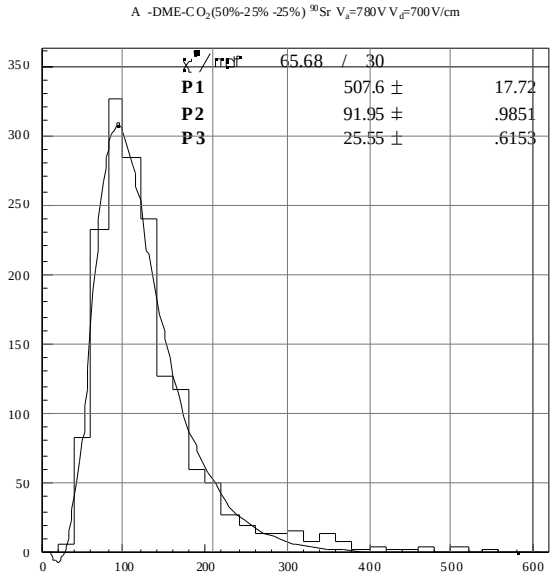
Forward Time Projection Chambers

Radial TPC with micro-strip gas chamber (MSGC) and pad readout
- 8≤R≤31 cm, 150≤|Z|≤270 cm (inside the STAR magnet.)
- Δp/p~12%, hence good charge separation
- 2≤η≤4, P_T<few GeV/c

important extension of STAR's acceptance...

Two FTPC prototypes have been built
1. uniform drift field and μ-strip readout
2. radial drift field and MWPC readout.





Recent R&D Results

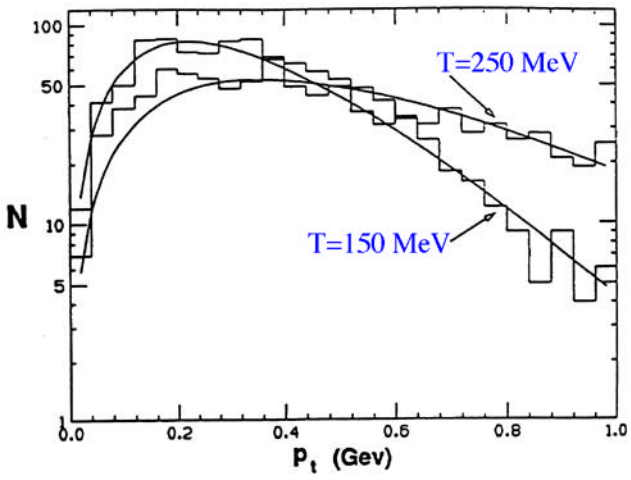
- Mixtures based upon CO_2 or DME have diffusion low enough to allow track reconstruction.
- S:N using the MSGC-pad readout >20:1 with existing electronics.
- Field cage designed and successfully tested.
- forming μ-strip glass plate to curved surface at high temperature is feasible.

Investigating applicability of TPC FEE for FTPCs...

Additional detector proposal ~Spring, 1997.

STAR Physics

- Large acceptance and large multiplicities in central Au+Au events allow
  - *Event-by-Event physics*
  - "T, S, μ, ε, ρ" in each event...
  - Select classes of interesting events...



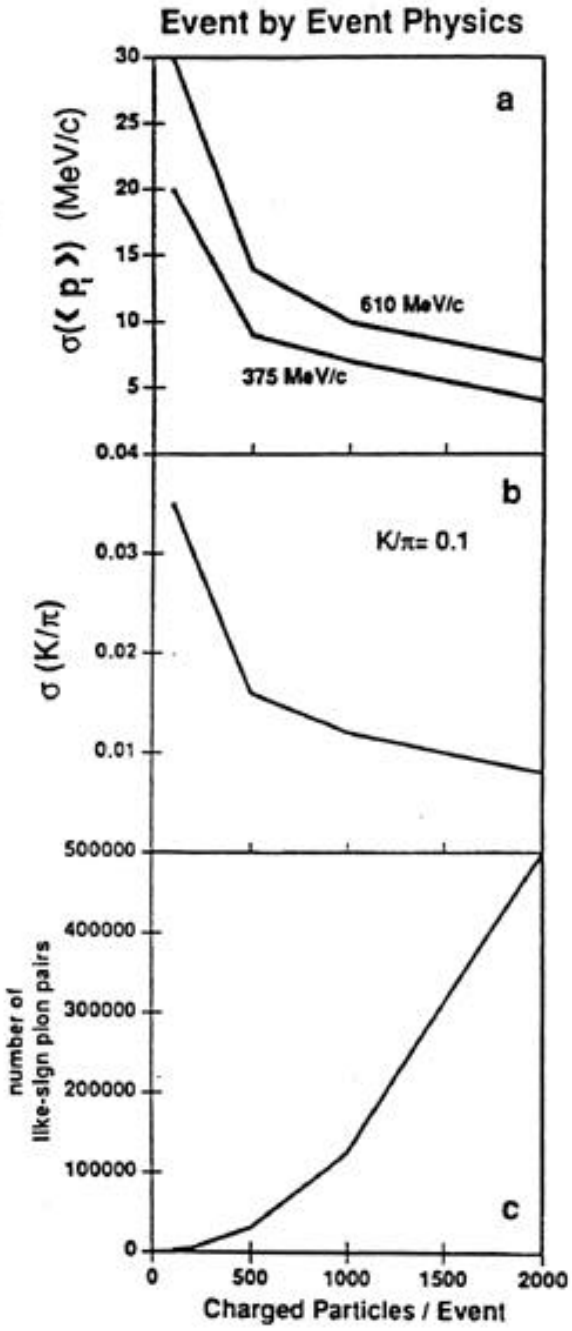
- Hard parton scatters from jets and direct-γ
  - Quark and gluon structure functions
  - Shadowing and quenching

- Hadronic signatures of QGP or CSR
  - Strangeness content
  - Anti-baryon content
  - Resonance widths and masses

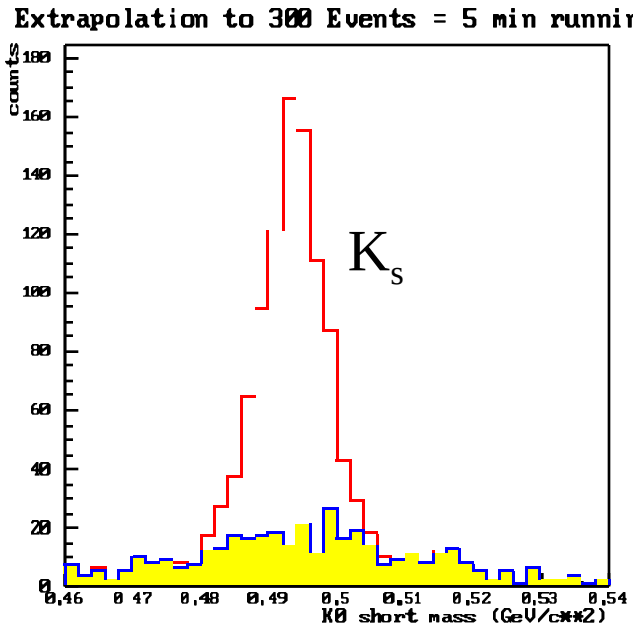
- The hadronization transition
  - DCC and BEC searches
  - Freeze-out conditions
  - Strangeness distillation

- Spin physics
  - Quark distribution functions
  - Gluon contribution to nucleon spin
  - Parity-violating asymmetries

- Peripheral physics
  - γ−γ processes and pomerons

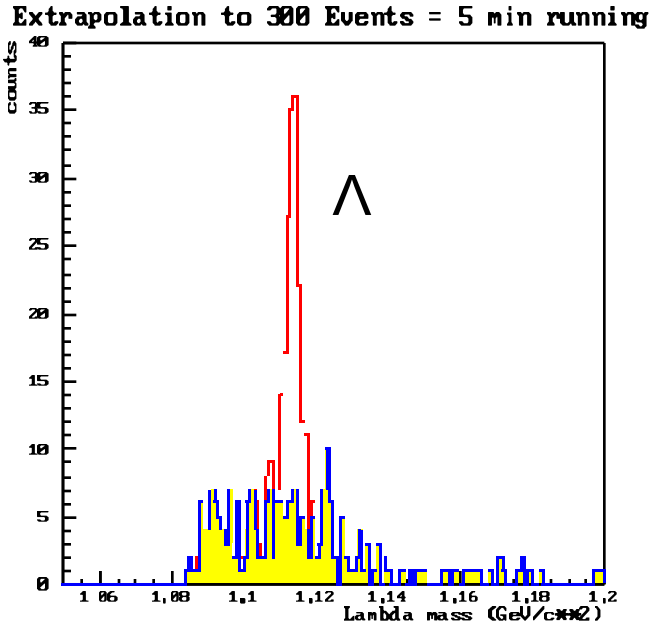


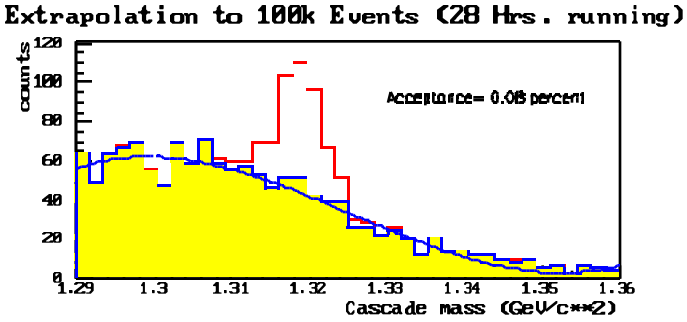
Strangeness

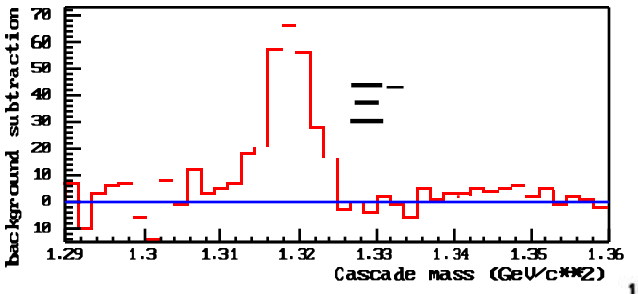


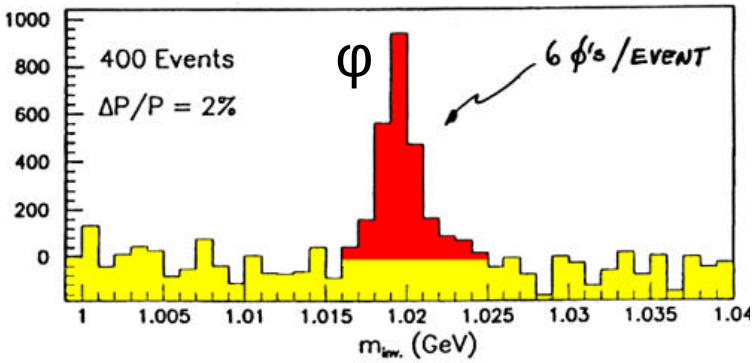
Secondary vertex finding:
K_s, Λ, $\bar{\Lambda}$, $\Xi^{\pm}$, $\Omega^{\pm}$, …

dE/dx, TOF, & kink finding:
K^+, K^-





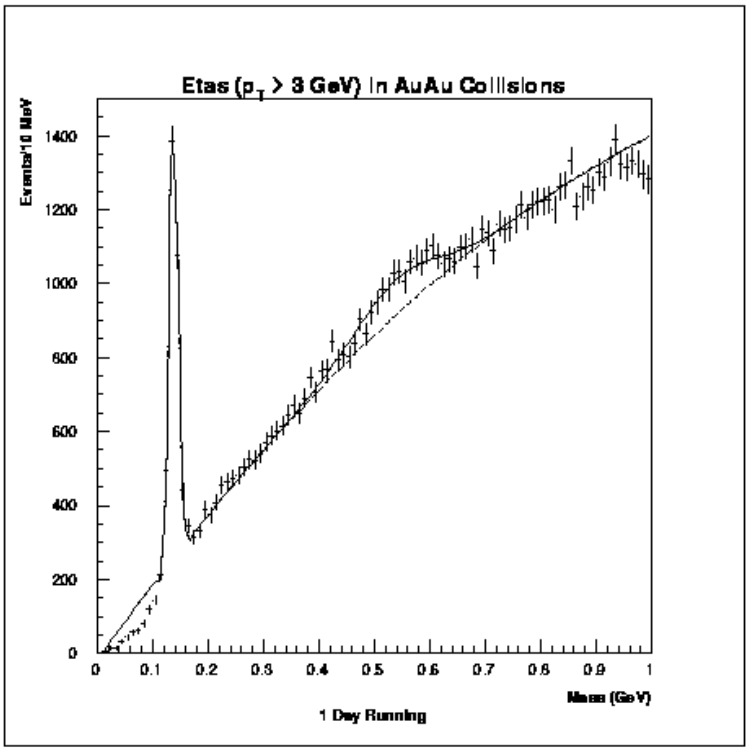




π^0 and η

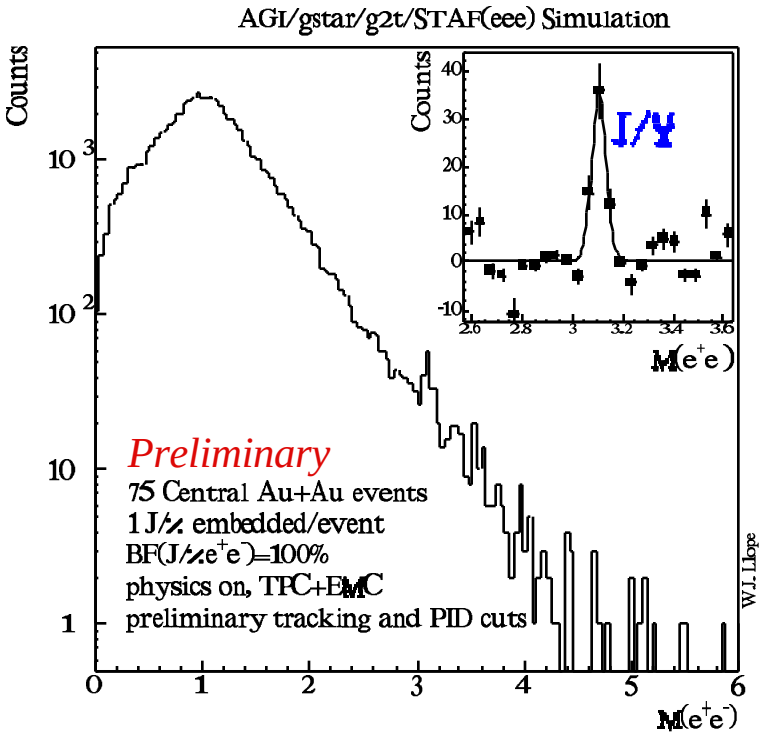
Generator level...
Asymmetry < 0.4
Pair P_T > 3 GeV.
Hijing central Au+Au
dN/dy = 800
($\pi^+\pi^-$ only)

One full day of running...



J/Ψ

Full simulation...
TPC, EMC only
physics on
Hijing central Au+Au
preliminary cuts



Spin Physics

DIS experiments cannot fully account for the spin of the proton

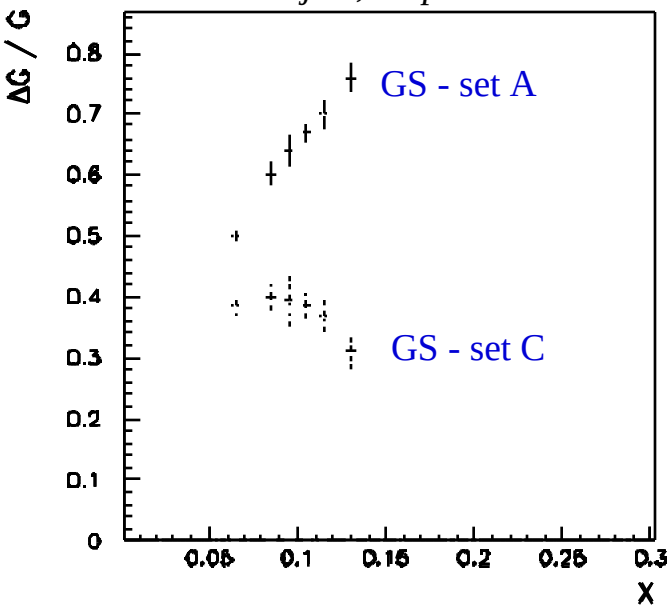
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_Z$$

world average: $\Delta\Sigma = 0.27 \pm 0.04$ (NLO)

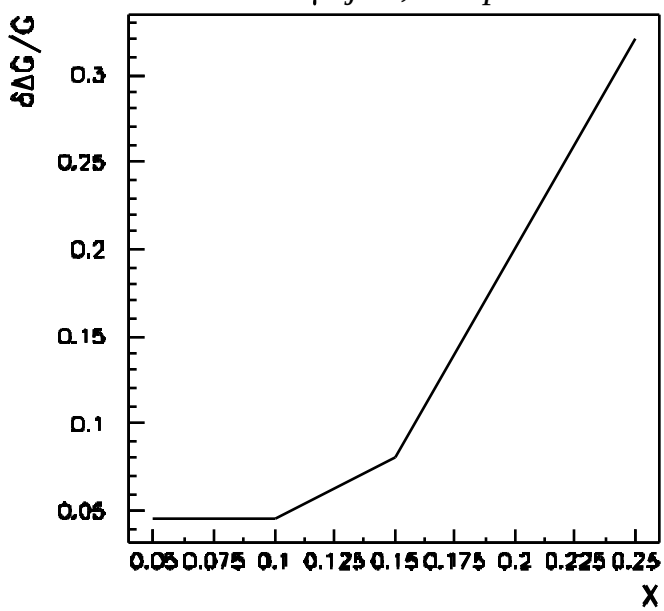
RHIC is in the right q^2 and x region for a full investigation of the nucleon spin...
($0.05<x<0.25$, $q^2>200$ GeV^2)
The QCD is perturbative...

STAR measures A_{LL} in di-jet and jet+direct-γ events with large acceptance...

di-jets, 50 pb^{-1}



direct-γ+jets, 800 pb^{-1}



STAR spin physics:

- polarized structure: $\Delta G(x)$, $\Delta u(x)$, $\Delta d(x)$, $\Delta\bar{u}(x)$, $\Delta\bar{d}(x)$
- unpolarized structure: $G(x)$, $\bar{u}(x)$, $\bar{d}(x)$
- A_{PV} with inclusive jets (a path to new physics?)
- possible sensitivity to h1(x) in di-jet and Z-production

Last but Not Least...

Formation of "Physics Working Groups"
focus on development of analysis software for use on Day 1

E-by-E	*T,S,μ,ρ,ε event-by-event, fluctuations*
Spectra	*T,S,μ,ρ,ε statistically, Low-P_T, Psi, Phi (?)*
Strangeness	*Secondary vertices and kinks*
Correlations	*HBT, n-body, pion-lasers*
High-Pt	*jets, direct-γ*
Spin	*asymmetries with polarized p beams*
Peripheral	*γ–γ physics, pomerons*

Major renovation to Simulations chain
namelist/gxintX11/mct/TAS → AGI/gstar/g2t/STAF
Major renovation to Analysis Shell
TAS → STAF

Slow Controls - in System Test and in good shape...
Online - a little behind here, but counter-measures recently taken ...

RHIC Year-One

After RHIC Test run, and RHIC Commissioning run...
37 weeks of beam starting September, 1999
10% of design luminosity by week 37
β*=2m by week 37
Au+Au, √s=200A GeV (lower energies likely alternative)

STAR during Year 1...
Final Magnet
Fully instrumented TPC
Fully instrumented CTB
~25% of BEMC/BSMD
small patch of TOF
SVT after first few months
Basic Level-0 (luminosity is low anyway)
DAQ