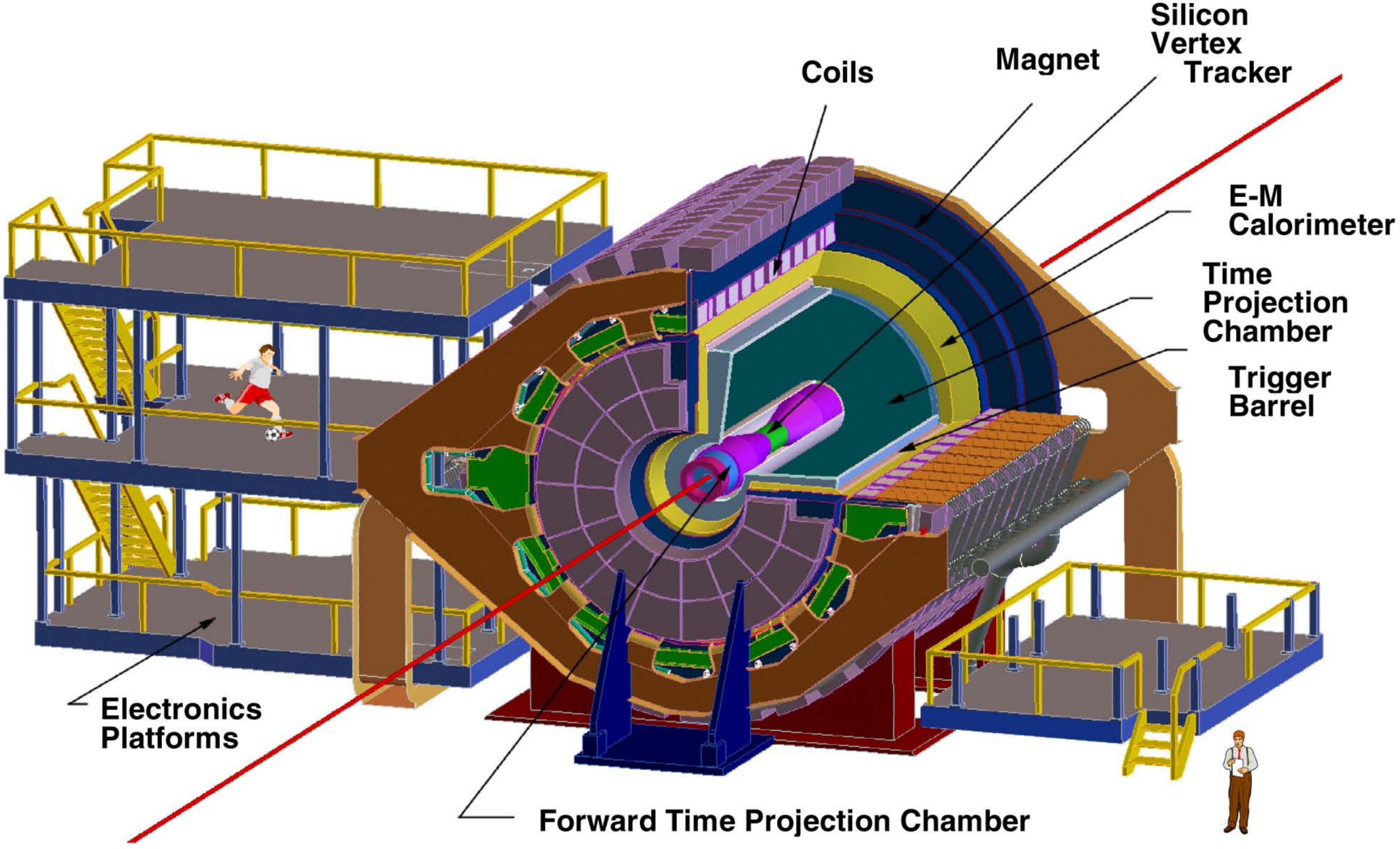
# Inner Sector Upgrade for the TPC

**Jim Thomas**
**for the iTPC Working Group**

**LBL February 6th, 2013**

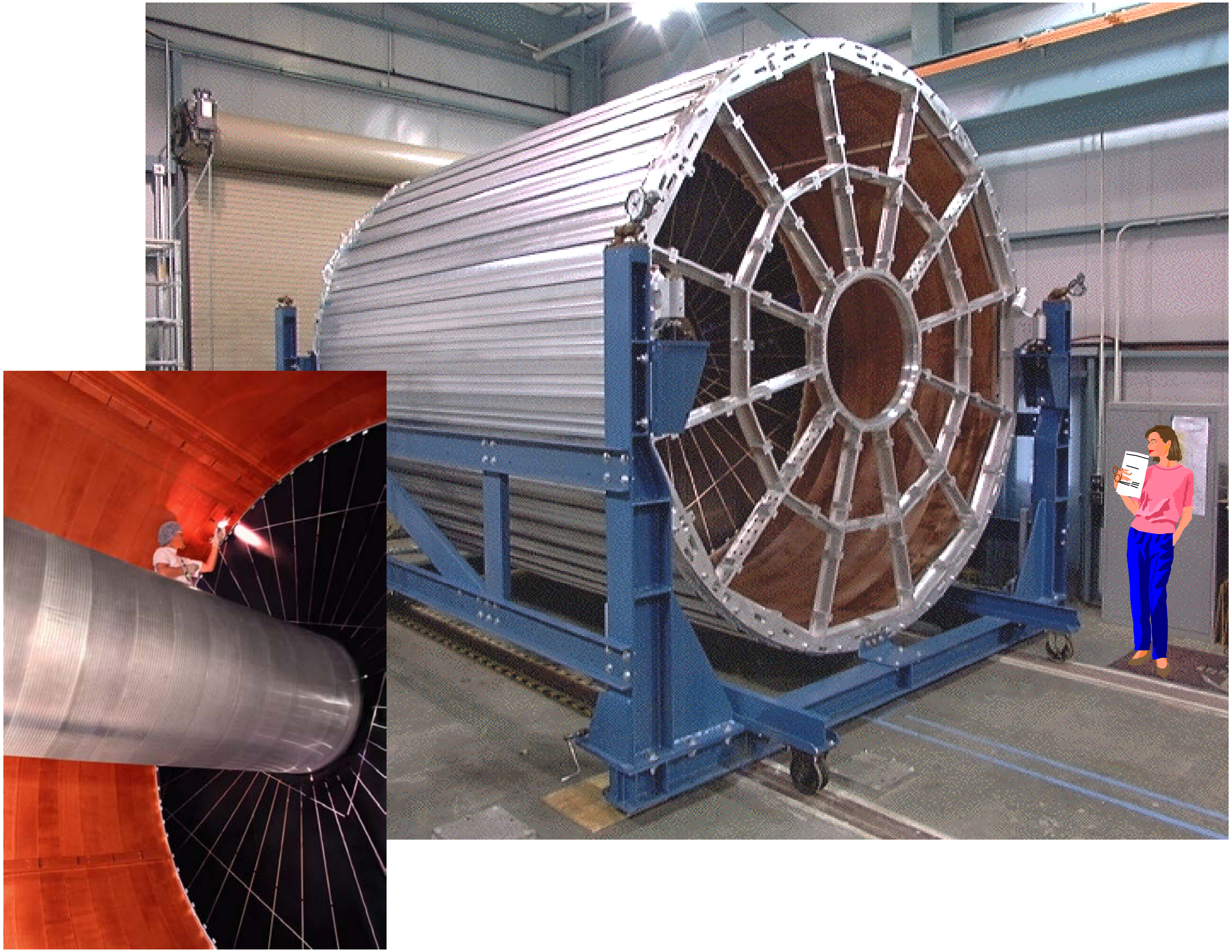
# The STAR Detector at RHIC



# Mating the OFC & Gas Vessel

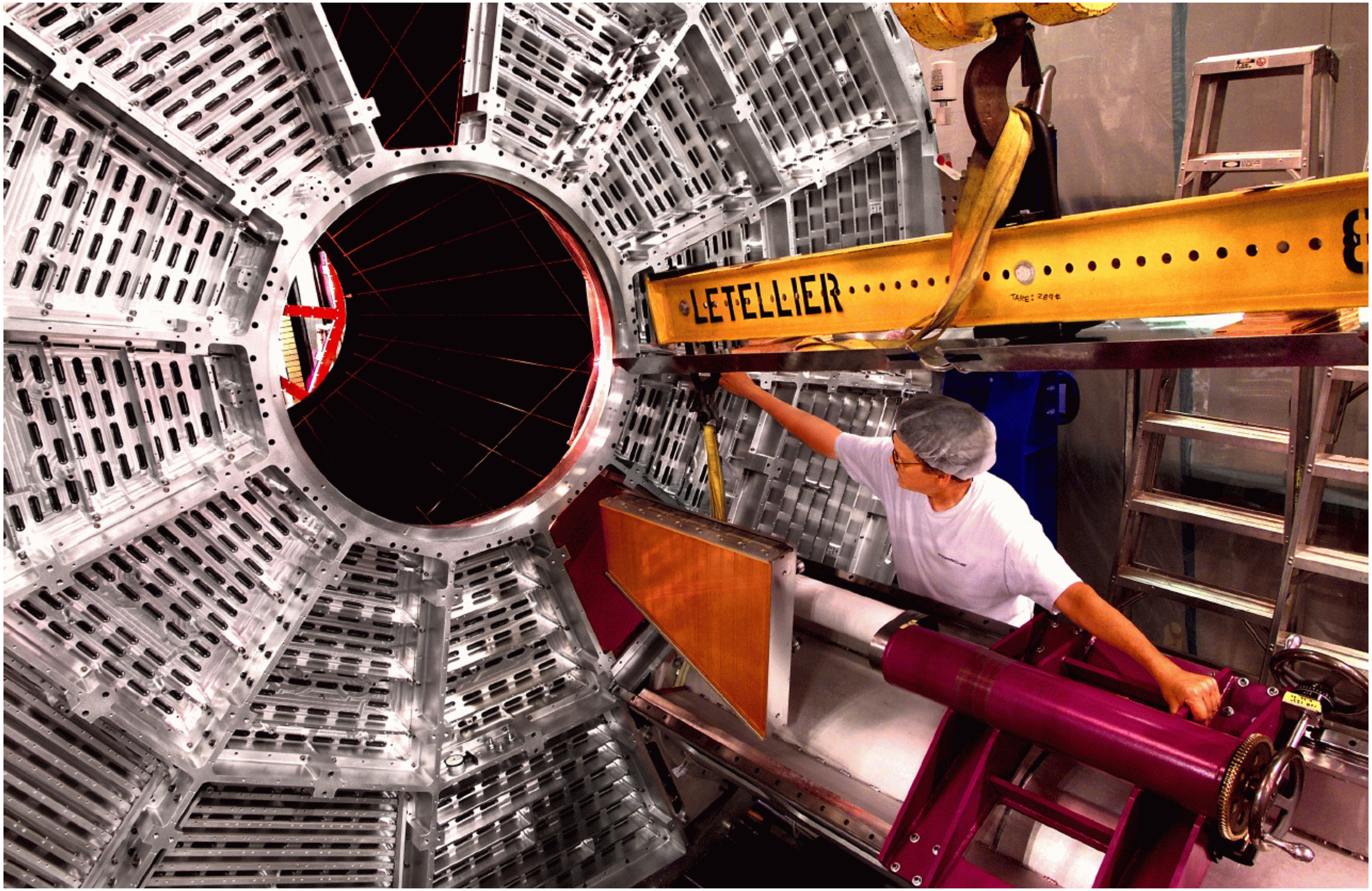
- Winding Outer Field Cage
- Mating OFC & Gas Vessel
- OFC Check
- Moving the Central Membrane

# The STAR TPC Under Construction at LBL



First Successful Mating of:

- Gas Vessel
- Outer Field Cage
- Sector Wheels
- Central membrane

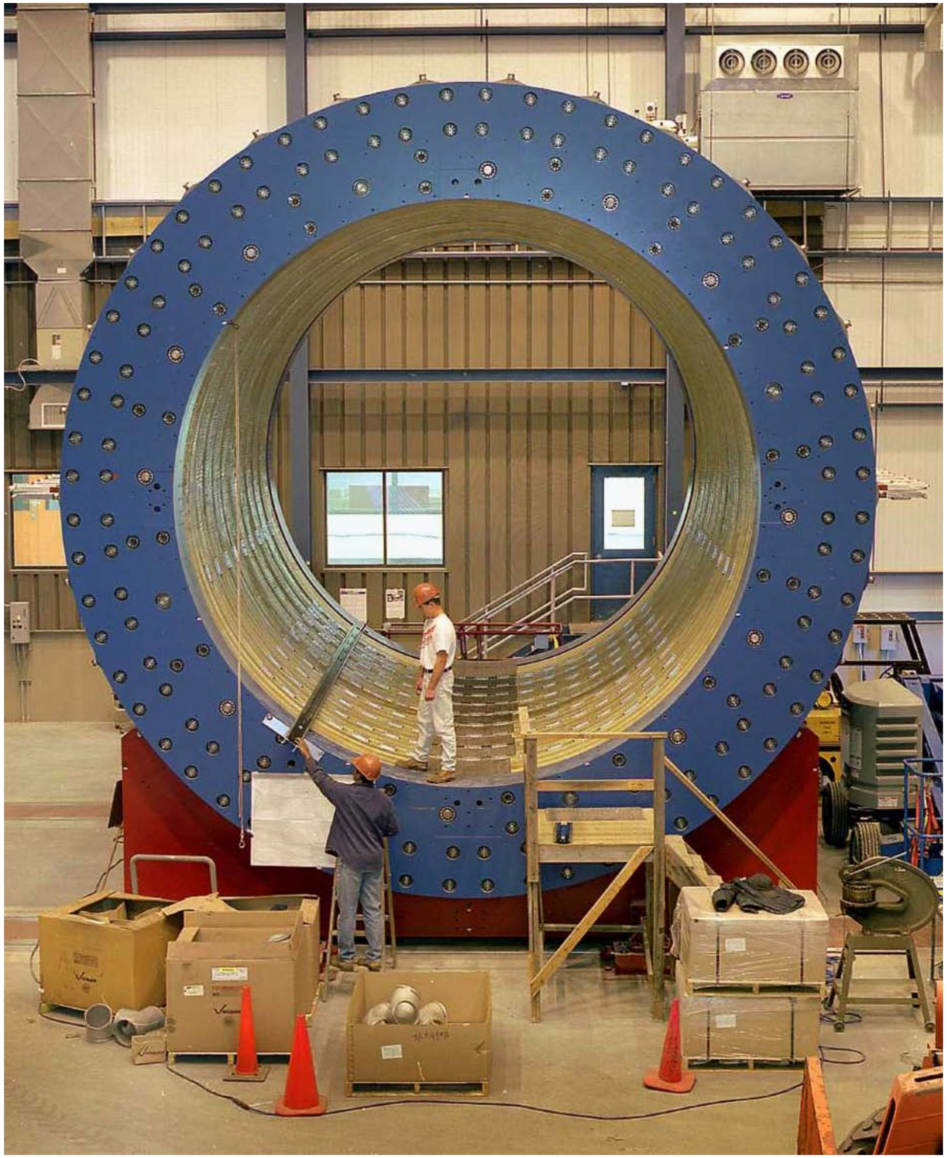



**Sector Installation & Tooling**


OVERSIZE LOAD
EAST BAY TRUCK
Blackberry Canyon Entrance
Welcome
BERKELEY LAB

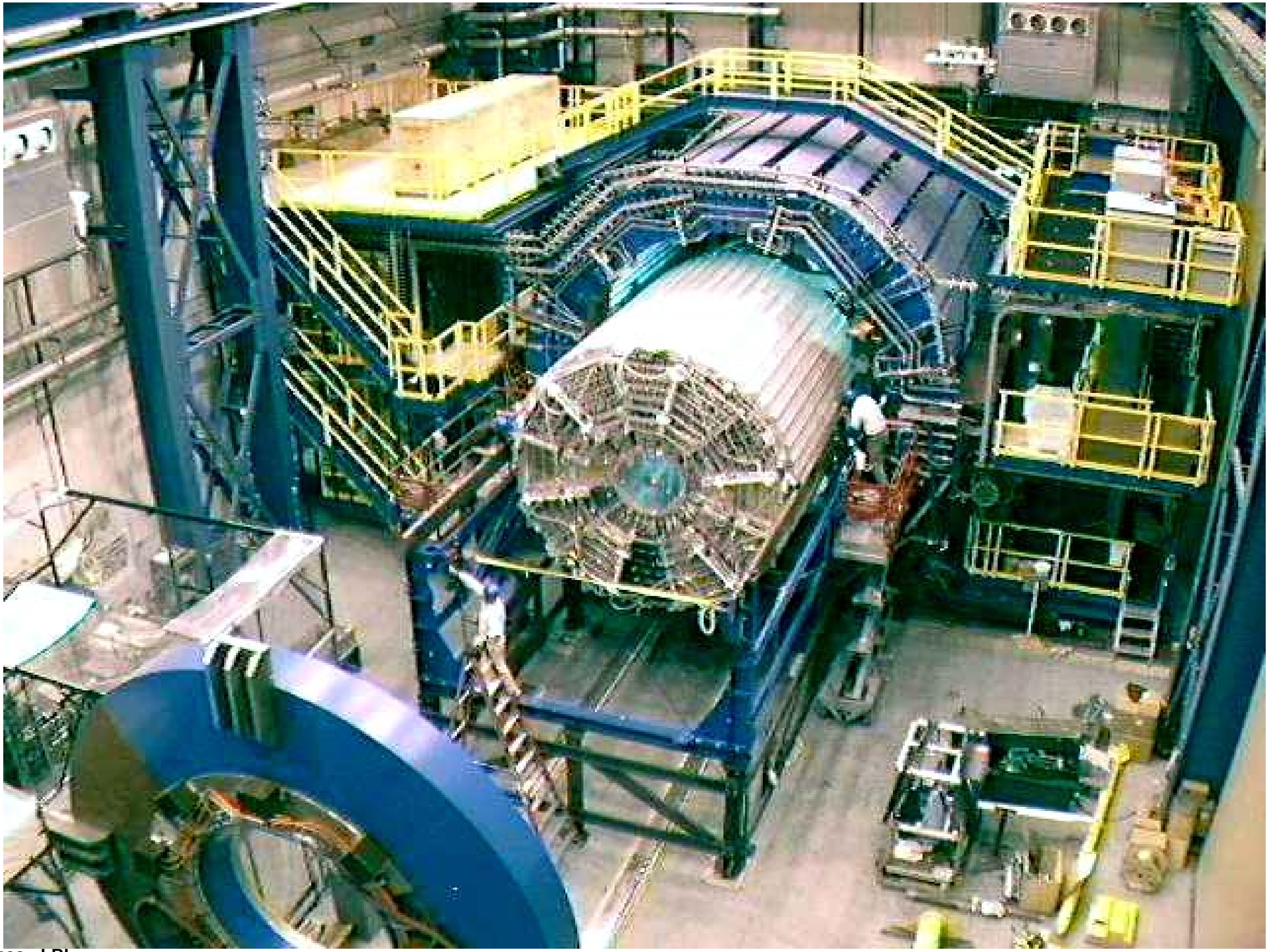

MACK
OVERSIZE LOAD
Suffolk
Police
Suffolk
Police

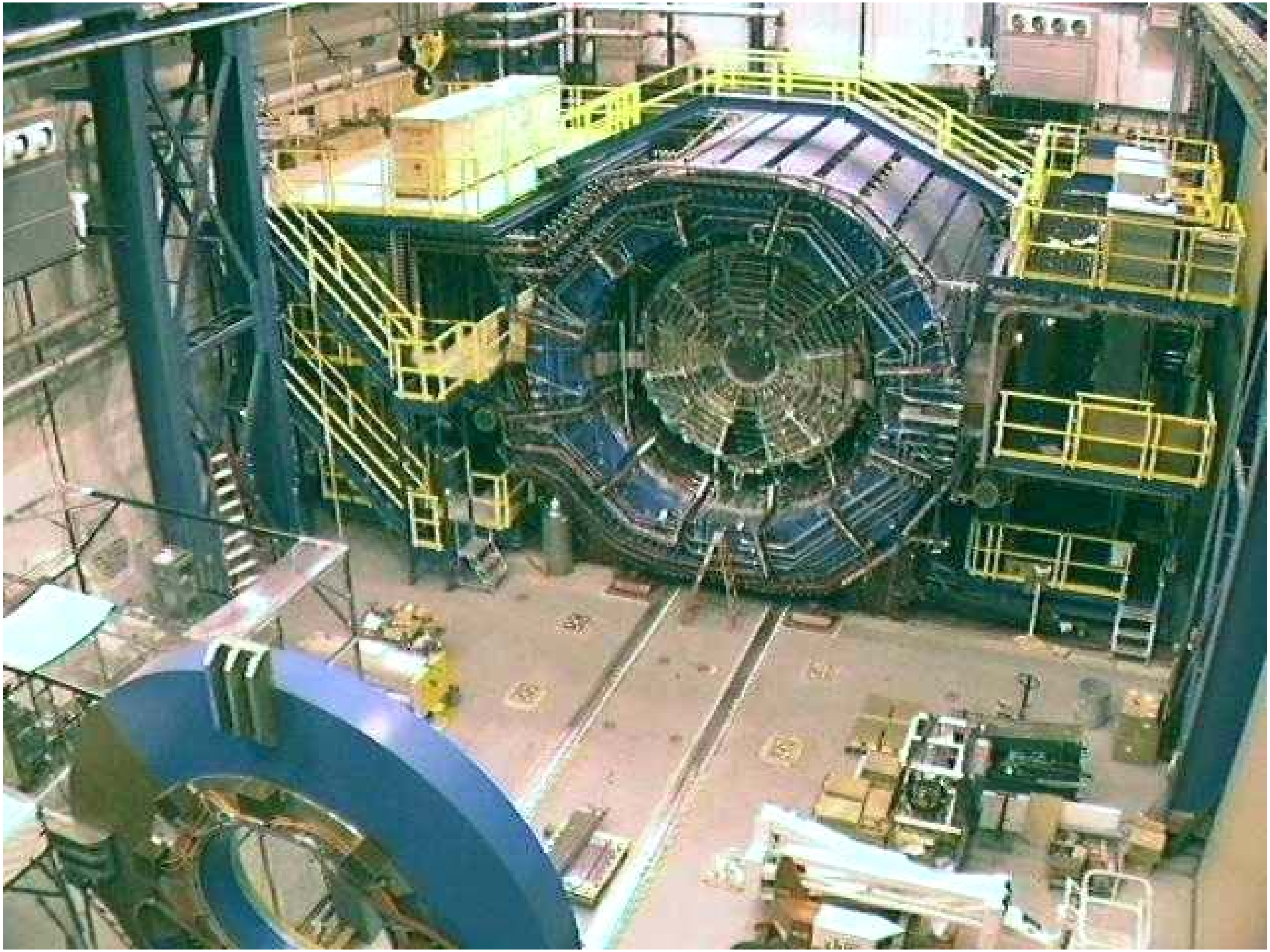
# Magnet

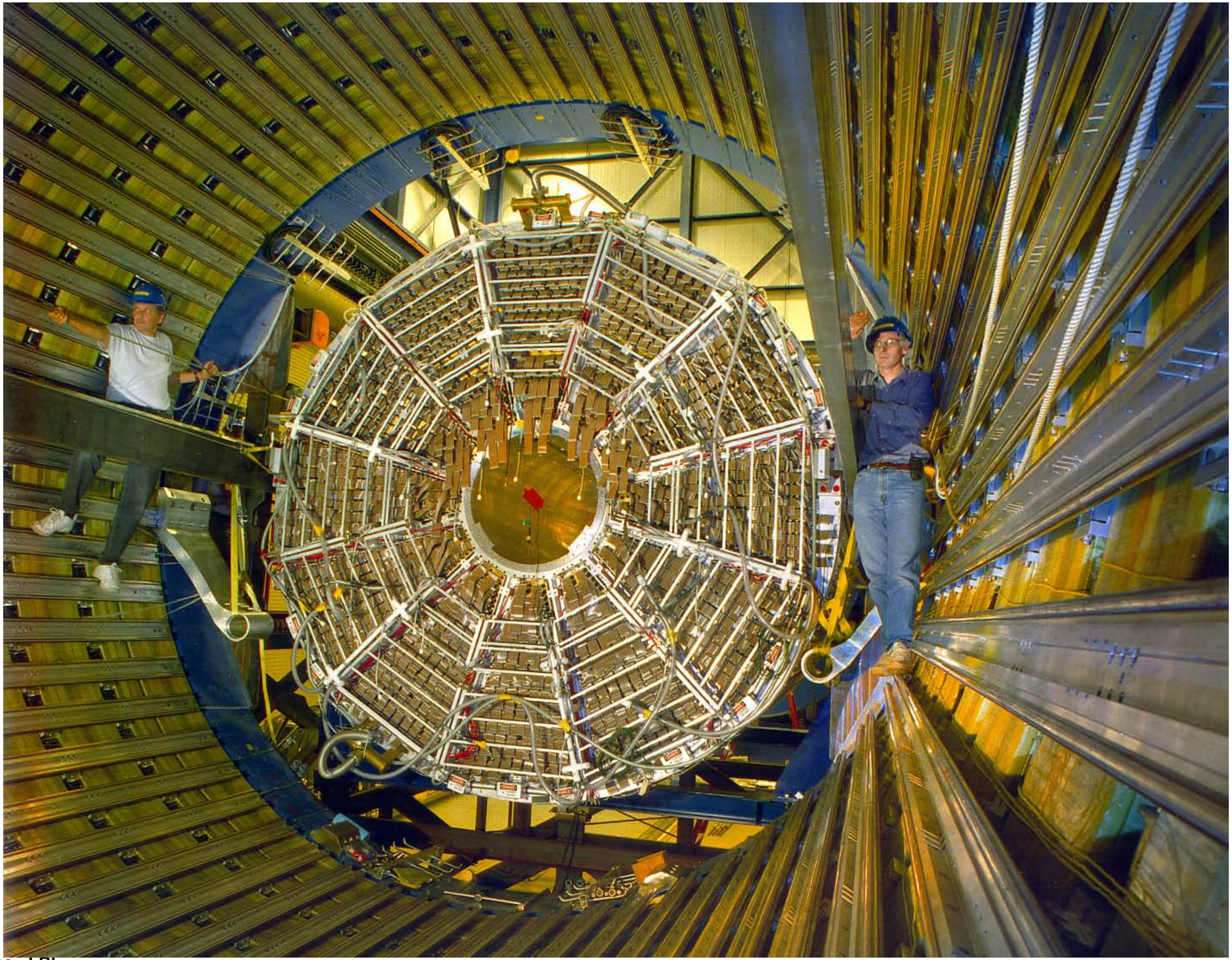


# Insertion of the TPC into the Magnet

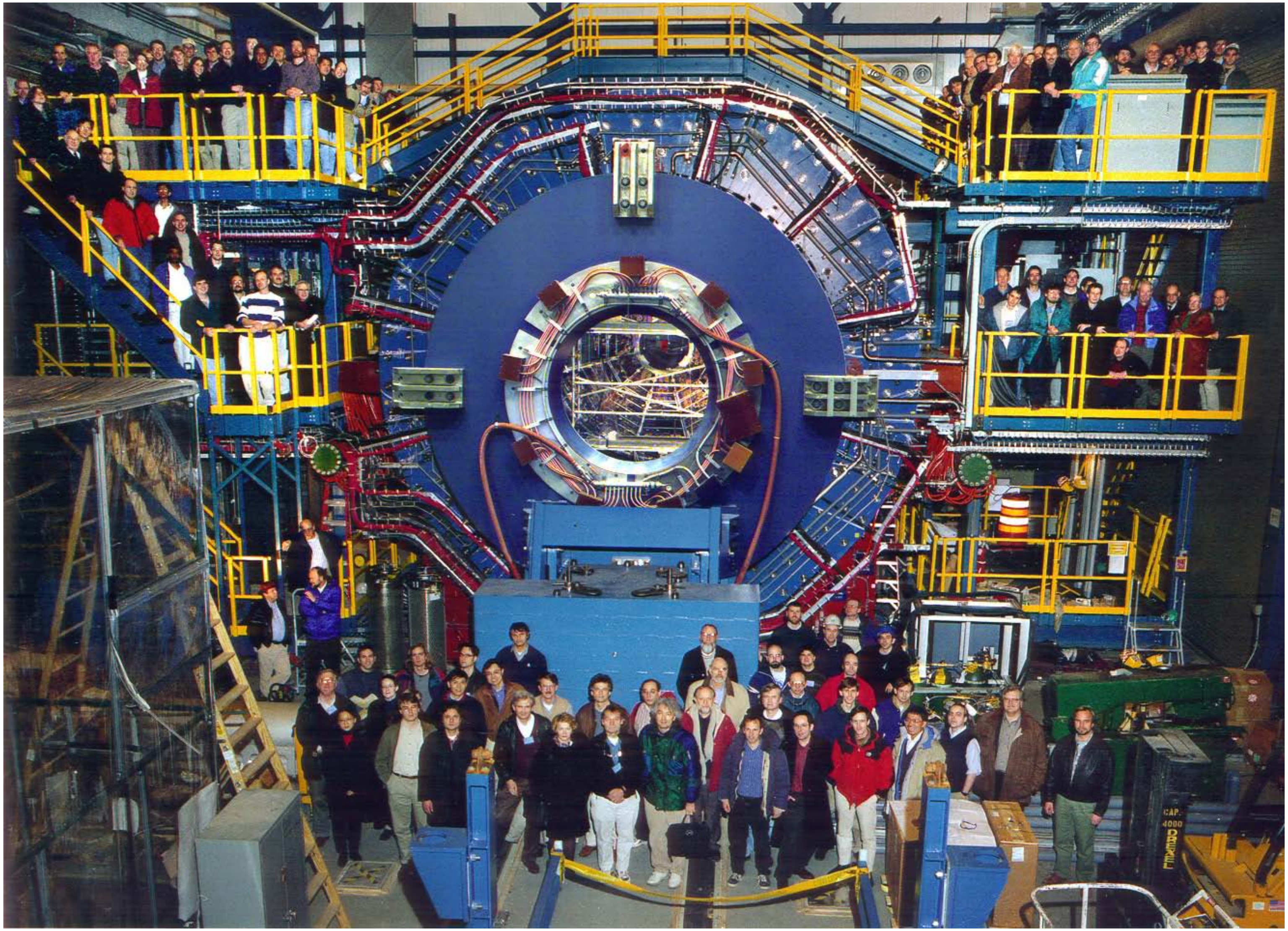
**12/2/98**







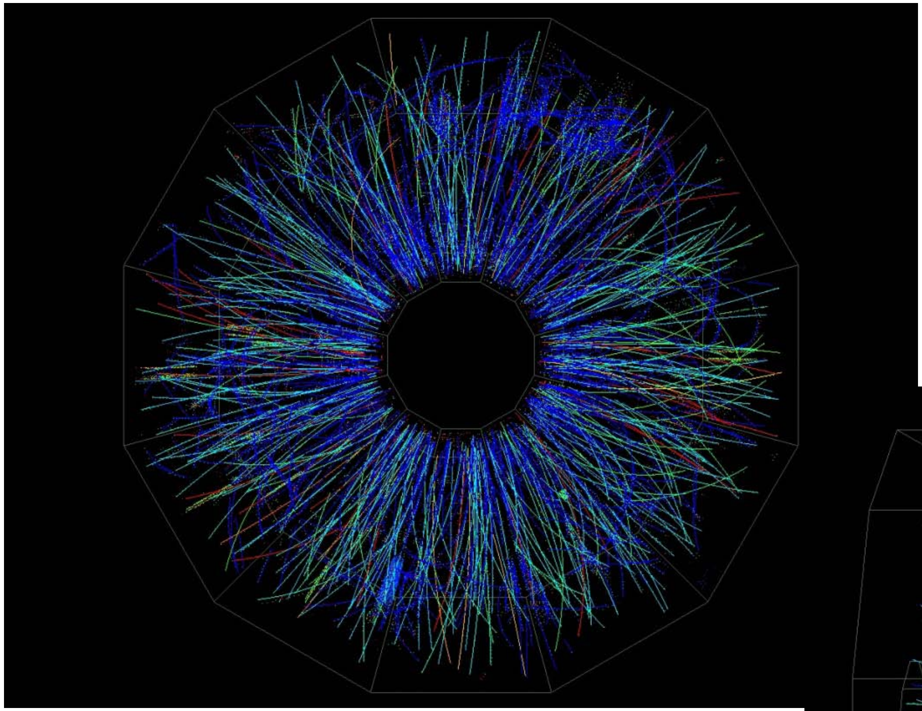
# The STAR Collaboration



# The STAR Detector at RHIC

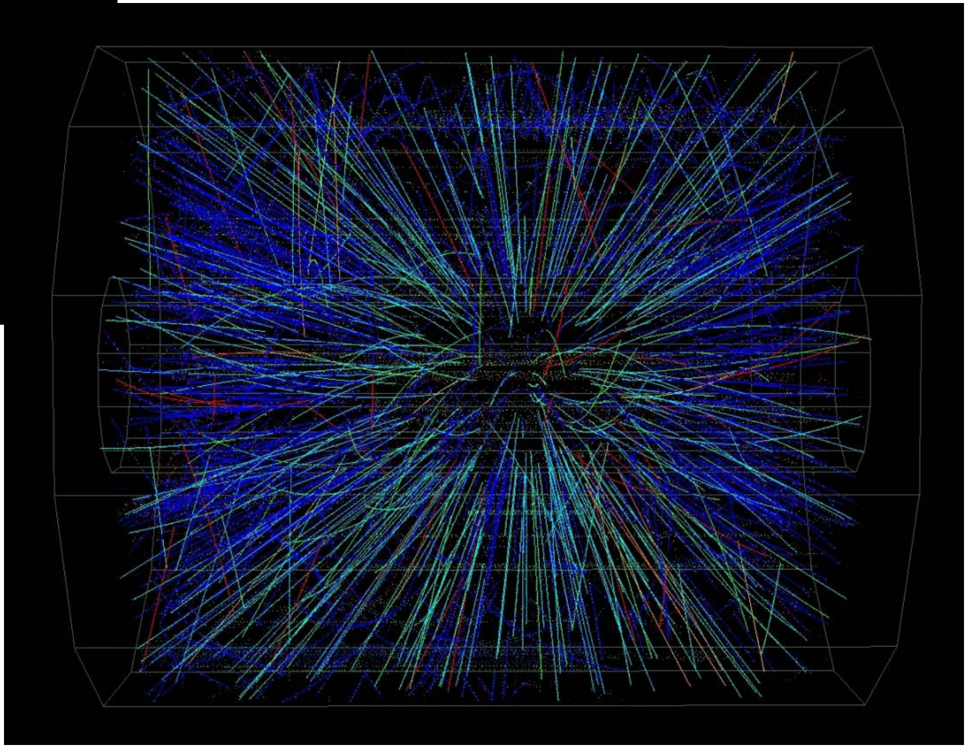

- **RHIC accelerates a variety of heavy ion beams up to 100 GeV/amu**
- **Two Large and two small detectors have been built**
- **STAR is the “Hadronic Signals” experiment**
- **At its heart is a large Time Projection Chamber**

# Au on Au Event at CM Energy ~ 130 GeV*A

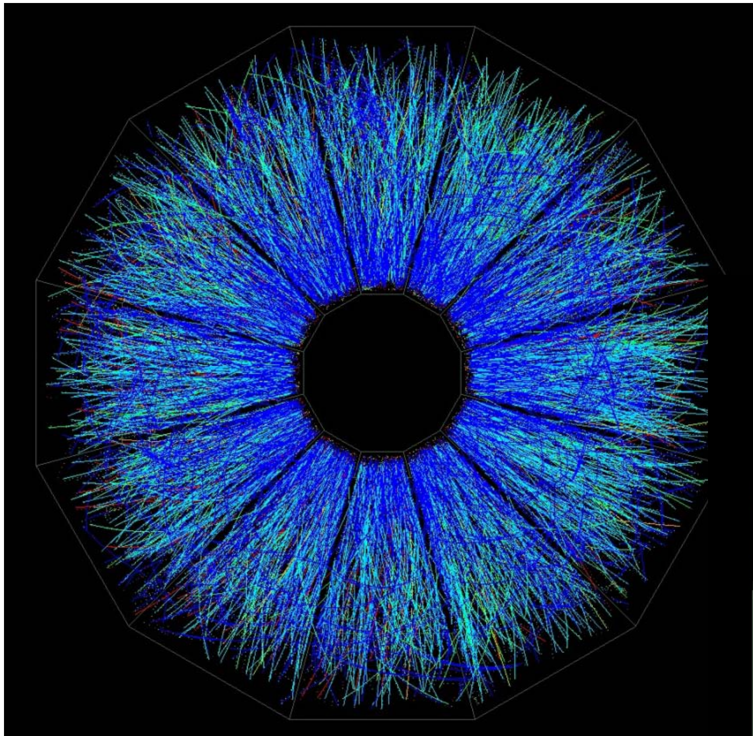


Data Taken June 25, 2000.

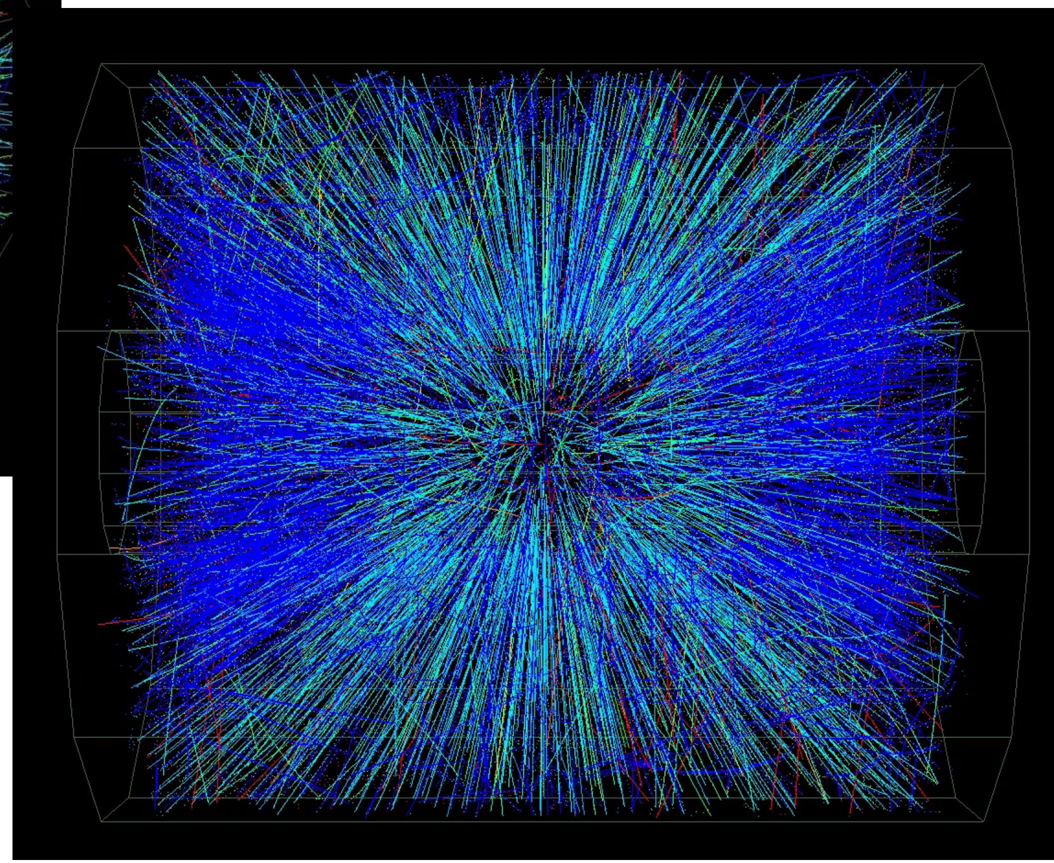
Pictures from Level 3 online display.



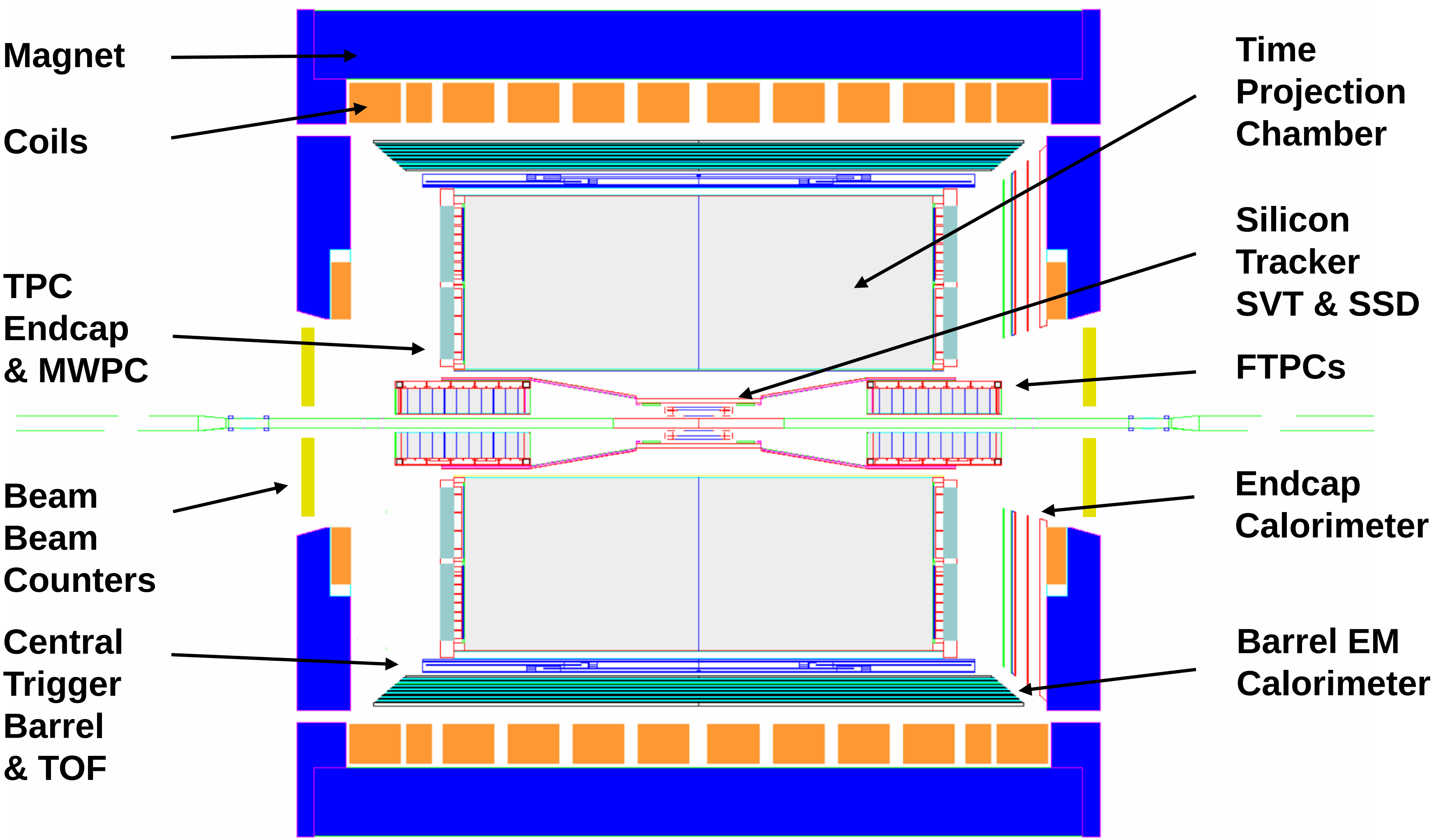
# Au on Au Event at CM Energy ~ 130 GeV*A



Data Taken June 25, 2000.



# STAR from the Inside - Out




**Not Shown: pVPDs, ZDCs, PMD, and FPDs**

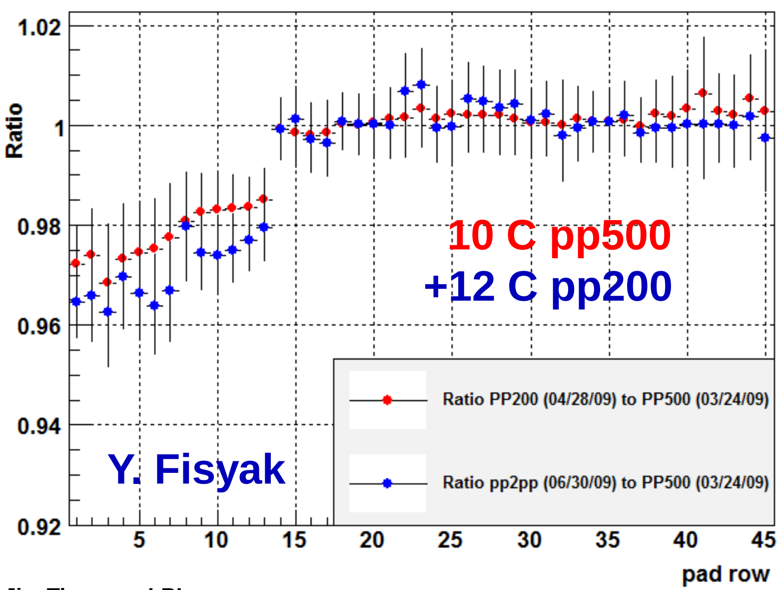
# Outlook for the Future of the TPC

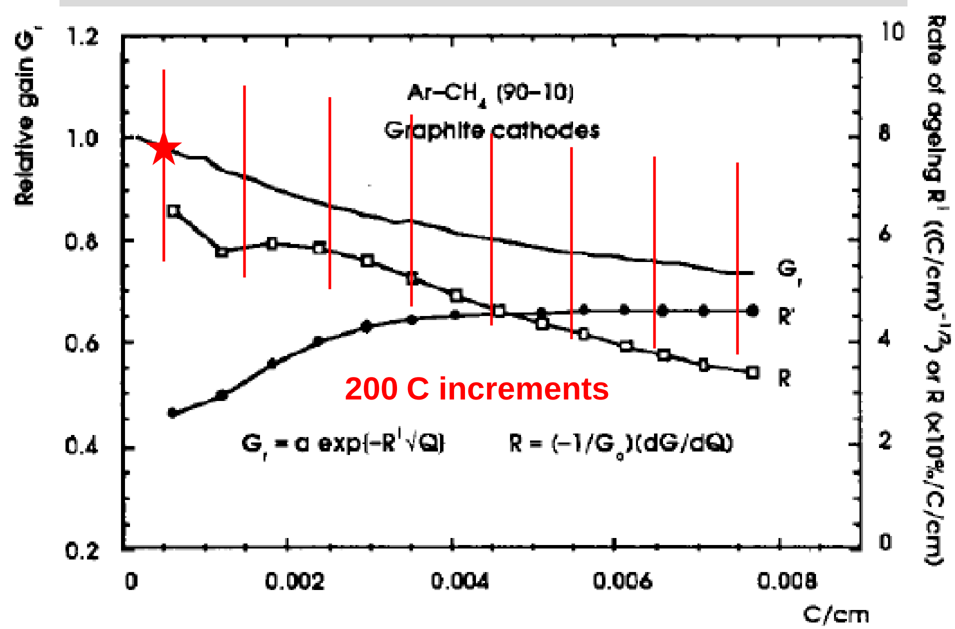
- Q: Can we rely upon the TPC for another 10 or 15 years?
- A: Probably not
- Timescale
  - eRHIC physics starts in 2022
  - The TPC is ideal for 5 GeV $e^-$ beam operations
    - See past talks by Ernst and others about physics & kinematics
  - Fortunately, not so ideal for 20 GeV operations … so there is a logical end of the life for the TPC about 15 years from today
- Strengths and Weaknesses
  - Gas system good, but relies upon "home made" electronics
  - Field Cage good, two permanent shorts, more on the way?
  - Other systems good enough, could always be improved
  - Electronics excellent, recently upgraded
  - Inner sectors need work

# Anode Aging – should see annual gain shift

- **Aging on the anode wires is very hard to measure**
- **It is like global warming … the systematic errors are larger than the annual trend**
- **We have made many measurements and surveyed the literature; the results don't tell a consistent story**

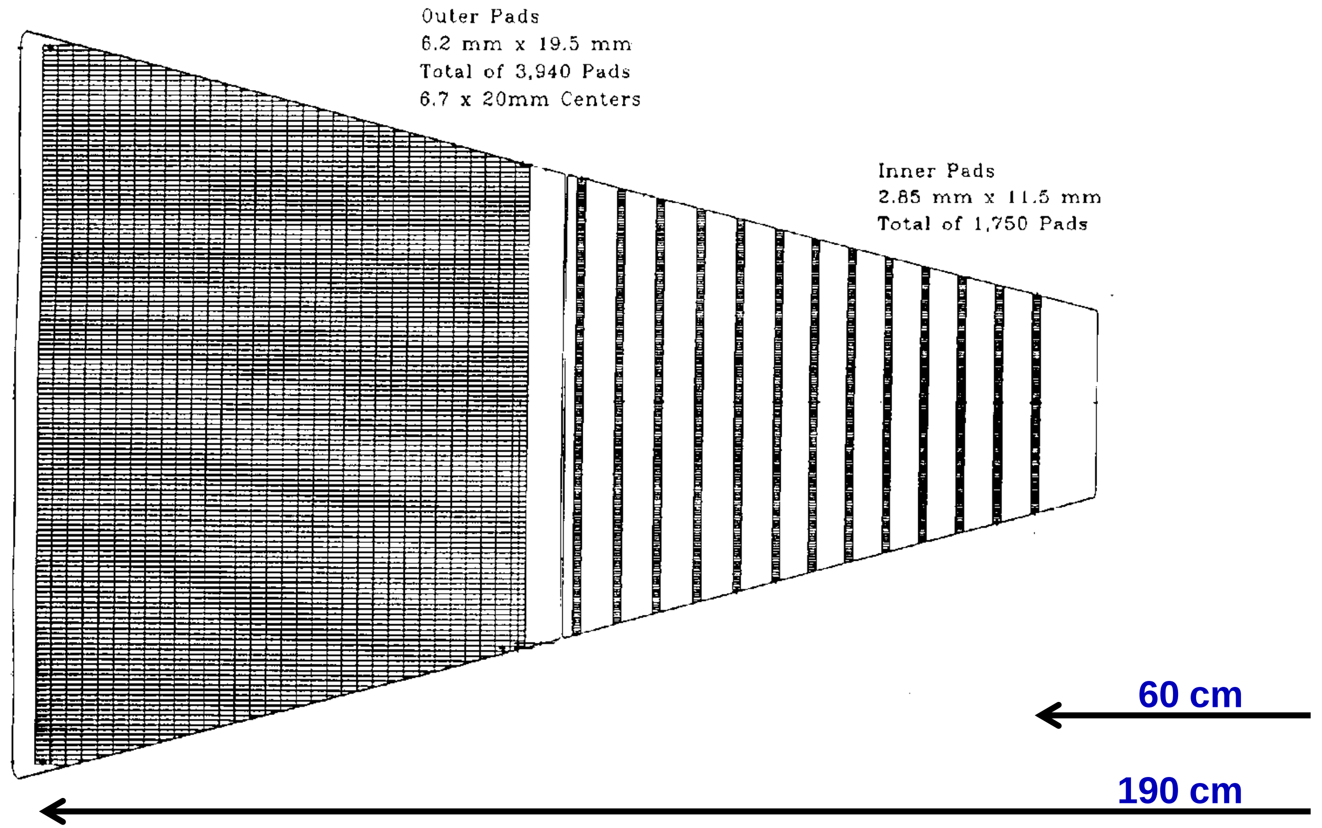
- **During the pp500 run, STAR accumulated 10 C of charge on the inner sectors of the TPC**
  - **Approximately 1600 m of wire**
- **During the 2009 pp200 run, STAR accumulated another 12 C**
- **Prior to 2009, we estimate that STAR accumulated 40 C of charge on the inner sectors**




R. Bouclier, M. Capeáns, C. Garabatos, et al., Nucl. Instr. and Meth. **A346** (1994) 114.

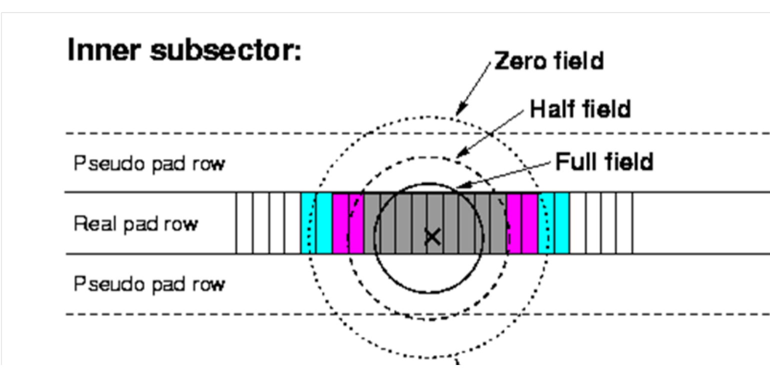
# Purpose of the upgrade



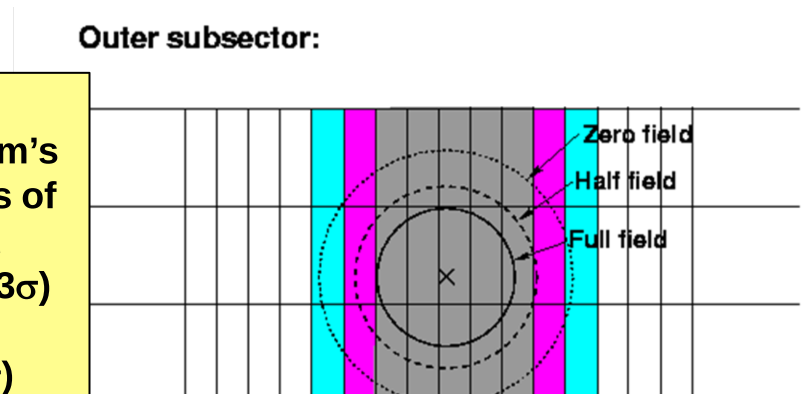

- Increase the segmentation on the inner pad plane and renew the inner sector wires which are showing signs of aging
- The upgrade will provide better momentum resolution, better dE/dx resolution, and improved acceptance at high $\eta$
- Acceptance at high rapidity is a crucial part of STAR's future for forward physics topics such as p-A, e-A and BES studies

# The Current Inner Sector Pads are small

- The <u>outer</u> sector pad size was chosen to match the diffusion limit of P10
  - Width (pitch) in the outer sector is 6.7 mm
  - Tonko has measured an average of 3 pads hit per cosmic ray track
- The inner sector pads were deliberately made smaller
  - Width (pitch) in the inner sector is 3.35 mm
    - note different pad plane to anode wire spacing & gain (2 mm vs 4 mm)
  - Tonko has measured an average of 4 pads hit per cosmic ray track
- It seems quite reasonable to increase the size of the inner sector pads so that an average of 3 pads are hit per cosmic ray track
  - Note, this does not mean 6.7 mm pitch is best … due to different gain and wire geometries in the inner and outer sectors
  - Real simulations are required … but not difficult




Roy Bossingham's simulations of the old pad geometry (3σ) agree with Tonko (~2σ)



# Pad Size: The full range of possibilities … (numbers, not science)

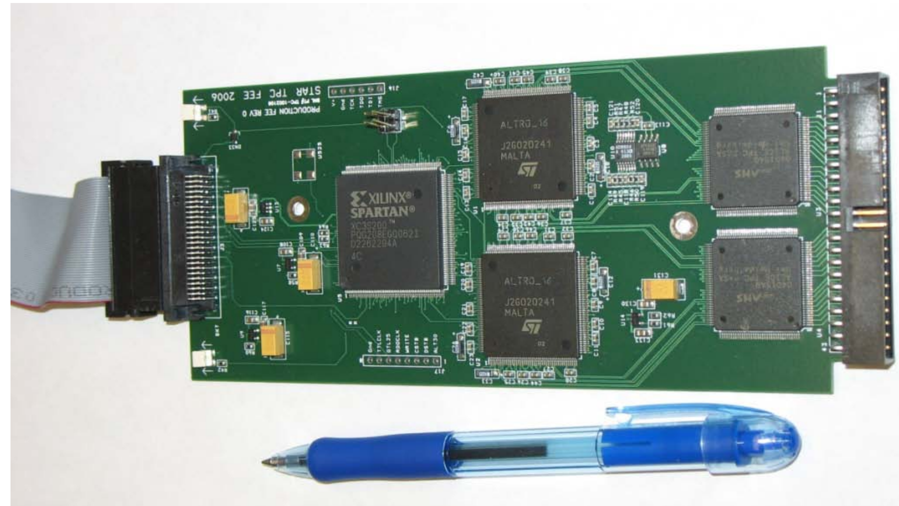
- **The outer sectors are 6.7 mm x 20 mm (pitch)**
- **The inner sectors are 3.35 mm x 12 mm (pitch)**
- **The full range of possibilities for the new inner pad plane**
  - **Height from 12 mm to 20 mm (nb: 0.5 mm gap on all edges)**
    - **Note: only 12, 16 and 20 mm match anode wire spacing (3x, 4x, 5x)**
  - **Width from 3.35 to 6.7 mm**
- **Translate to number of electronic channels**
  - **6,650 channels if 3.35 by 12 mm (50 rows)**
  - **2,000 channels if 6.7 by 20 mm (30 rows)**
  - **Currently 1750 channels in 13 rows (widely spaced at ~5 cm)**
  - **Range is from 1 to 4x number of channels (for hermetic coverage)**
    - **1x would accommodate 6.7 x 20 pad pitch (87% coverage, 30 rows)**
    - **2x would accommodate 4.8 x 16 pad pitch (100% coverage, 40 rows)**
    - **3x would accommodate 4.2 x 12 pad pitch (100% coverage, 50 rows)**
    - **(For reference, ALICE uses 4x7 pads, but note that Neon-$CO_2$ has better diffusion characteristics so we expect smaller pads in their case)**

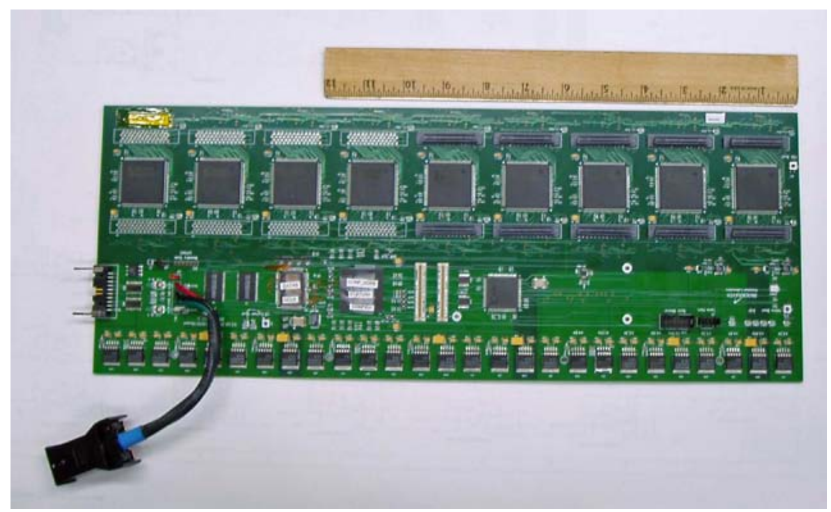
**Optimize this number for cost and engineering factors**

# New Electronics (TPX shown …)

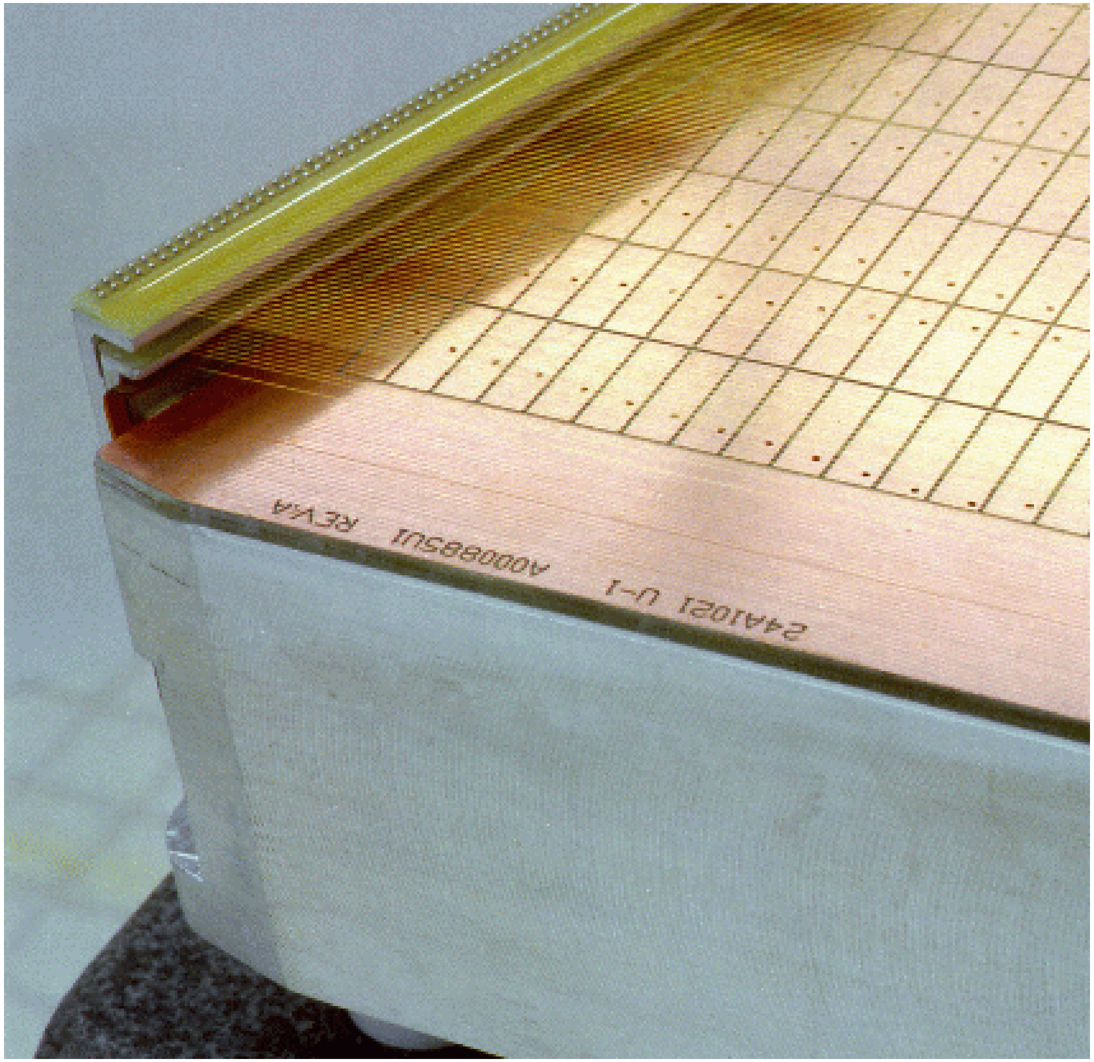
- **More pads require more channels of electronics and new connector technologies**
- **“Old” TPX chips are not available due to intellectual property rights issue**
  - **Open source PASA developed**
  - **Open source sALTRO needs our participation to make it a reality**
- **Material**
  - **FPGA development kit to study fast serial links**
  - **TPX FEE modification for the new S-ALTRO chip test**
  - **Preliminary pad plane test PCB(s)**
- **Engineering Effort (2 months)**
  - **Preliminary pad plane design study (interconnect topology)**
  - **Pre-prototype of the iTPC FEE**

    **(study connector to pad plane, cabling to the RDO, grounding, power, cooling, mounting, etc.)**



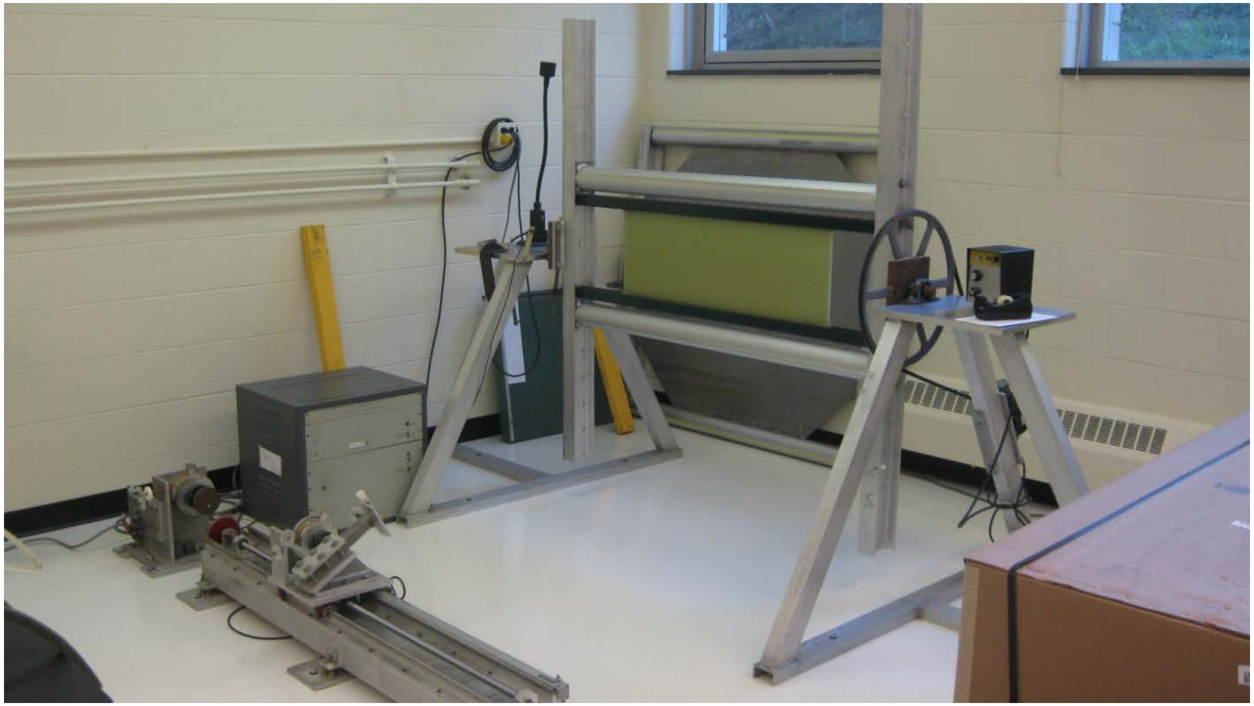
# New Pad Plane – new strongbacks (outer shown)



- Avoid “missing rows”
- Hermetic coverage $\eta > 1$
- Increased segmentation
- Better dE/dx & tracking for tracks that leave thru the endcaps
- Building strongbacks and Wiring pad planes is a lost art
- One goal of this proposal is to relearn how to do it
- Recover 2D drawings and recast in 3D

# A small factory is required

# A big part of the job: Winding new grids



- Recovering the technology (materials, glues, alignment) is a major goal of this R&D project.  Interview & learn from experts.
- Winding machines exist at Indiana CEEM, China and BNL
- Once optimum strategy decided … we should try to wind and install a set of grids using old TPC sector prototypes

# R&D Budget & Conclusion

| | |
|---|---|
| Electronics R&D - manpower | 25K |
| Electronics R&D – supplies | 12K |
| Mechanical Engineering and 3D Drafting | 30K |
| CEEM Wire Frame Engineering | 10K |
| CEEM Materials | 10K |
| Travel | 10K |

- **We propose to upgrade the inner sectors of the STAR TPC in order to achieve better segmentation at high rapidity and to improve the quality of information for tracks that leave the TPC through one of the end caps.**
- **This proposal will enable us to answer the most critical questions regarding the technology that underlies the upgrade proposal.**
- **The results of this R&D work will be used to prepare a formal proposal to the DOE and other outside agencies**

# The purpose of this meeting

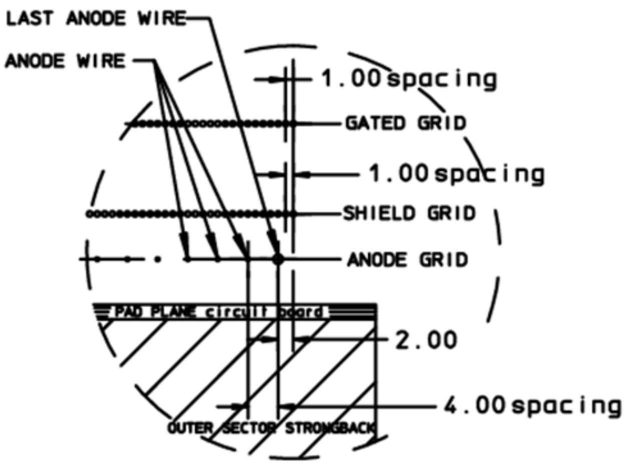
- **The STAR TPC has been a huge success**
  - **Thanks to everyone in the room**

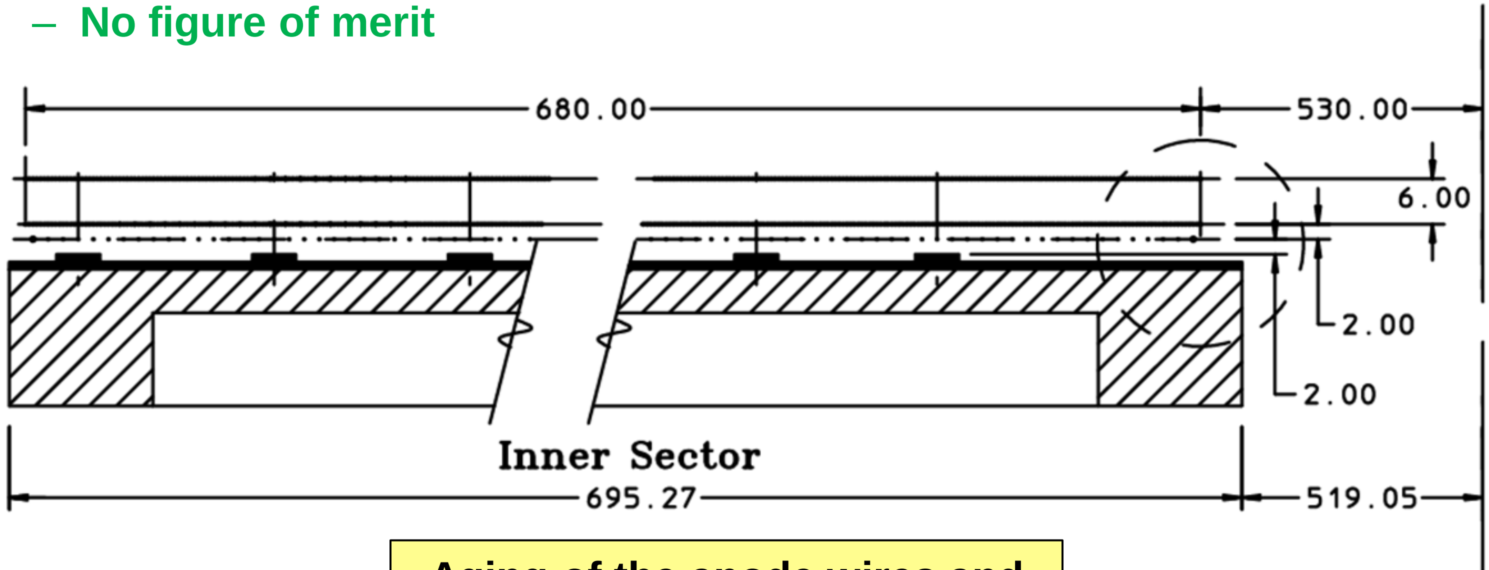
- **If you had to do it all over again, how would you do it?**
  - **Engineering drawings**
  - **Design**
  - **Design Changes**
  - **Tools and techniques**
  - **Log Books**
  - **Black Magic**
  - **Wisdom**

# Backup Slides

# Our concern is about the inner sectors

- **The inner sectors are affected the most due to $1/r^2$ distribution of charge in the TPC**
- **We expect a gain shift on anode wires due to charge, gain & dirt**
  - Figure of merit is 1 mC / cm
- **Malter effect on the cathode wires due to build up of insulating oxide layers … leads to breakdown**
  - No figure of merit




**Aging of the anode wires and tripping on the cathode wires**

# STAR Inner TPC Sector Upgrade

- **Physics Motivations**
  - **Study of the QCD phase diagram (Beam Energy Scan Phase II)**
    1. **Increase eta coverage for hadron acceptance and correlation**
    2. **Improve low-pt coverage for hyperon reconstruction**
    3. **Increase dE/dx resolution for particle identification**
    4. **High eta coverage for fixed-target dataset**
  - **Study of the QGP Properties**
    1. **A tool to systematically map chiral symmetry restorations**
    2. **Improve low-pt coverage for weak-decay reconstruction**
    3. **Heavy-Flavor physics by improving acceptance and dE/dx**
    4. **Identified high-pt hadron spectra and correlation for understanding jet properties**
  - **Spin structure in polarized p+p collisions**
    1. **Improved forward tracking with FGT+EEMC**
    2. **Interference Fragmentation Functions at high x**
    3. **Rapidity depdence of Lambda hyperon polarization**

- **Eliminate the space charge distortion induced by charge leak from the Gating Grid**

- **Eliminate the concerns on problems related to wire aging**

# Technical Driven Schedule I

1.) Organize the project, recover previous skills.
Review available drawings and documentation.
Arrange for best available manpower and write contracts with institutions.
6 FTE months.

2.) Mechanical design:
- a.) Strongback - 6 FTE months
- b.) Pad Plane (mechanical) - 3 FTE months
- c.) Grids and Wire Factory design and layout - 6 FTE months

These activities can be done in series or in parallel (assume series).

3.) Electrical design (see slide#3):
- a.) Pad Plane (electrical) - 3 FTE months
- b.) FEE - 6 FTE months
- c.) RDO - 6 FTE months

These activities can be done in series or in parallel (assume series).

4.) Cooling - 3 FTE months

# Electronics Schedule

- **Assume CERN Super-ALTRO chips will be available.**
- **A combination of 2 ASICS.**
- **Could be used for other detectors in the future.**
- **The ADC is not licensed and proprietary (unlike the original ALTRO) so the chip production could be easier and its lifetime might be longer.**
- **Possible cheaper than DAQ1000, but our estimate based on DAQ1000.**
- **Its production schedule is unknown, but due to CERN and other interests, we are optimistic and we expect to have a clear picture within 6 months.**

| | Manpower (in FTEs)* | Funding for |
|---|---|---|
| FY13 | 0.5 Physicist[1]<br>(architecture, design, firmware, test, software, project)<br>0.5 EE[2]<br>(FEE prototype, RDO&FEE board design, planning)<br>0.1 Tech[3]<br>(PCB design, other) | - small prototypes<br>- travel to CERN etc. |
| FY14 | 0.5 Physicist<br>(same as above)<br>0.6 EE<br>(FEE &RDO design & test, planning, other)<br>0.2 Tech<br>(PCB design, parts procurement, other) | - S-ALTRO<br>- some electronics parts |
| FY15 | 0.5 Physicist<br>(same as above)<br>0.4 EE<br>(integration, oversight)<br>0.8 Tech<br>(parts procurement, boards Q&A, installation) | - other electronics parts<br>- PCBs<br>- PCB stuffing |

# Technical Driven Schedule II

5.) Mechanical Fabrication

a.) Strongback - 3 months duration at outside shop plus time to write and sign contract.

b.) Grids - 1 year duration. Need to build small factory. 3 Techs fulltime.

6.) Electrical Fabrication

a.) Pad plane - 3 months duration at outside shop plus time to write and sign contract.

b.) FEE - less than 1 year duration.

c.) RDO - less than 1 year duration.

7.) Installation

a.) Mechanical - 3 months duration. 3 techs full time.

b.) Electrical - 3 months duration. 3 techs full time.

This plan assumes:

- the Sector Installation tool design (not part of this project) completed in 2013;
- fabricated and safety approved and tested in 2014;
- One or more sectors installed and tested in 2014;
- iTPC upgrade can be installed in the summer of 2015 (for run 16).

this is fairly fast paced and assumes that all the efforts are available at the schedule time.
45% contingency is assumed at this stage of development ;
Grand Total: 2 Million labor + 1.75 Million Fabrications + 45% = $5.4M
Duration: 3 years