The iTPC Project: Mechanical Issues and a few solutions

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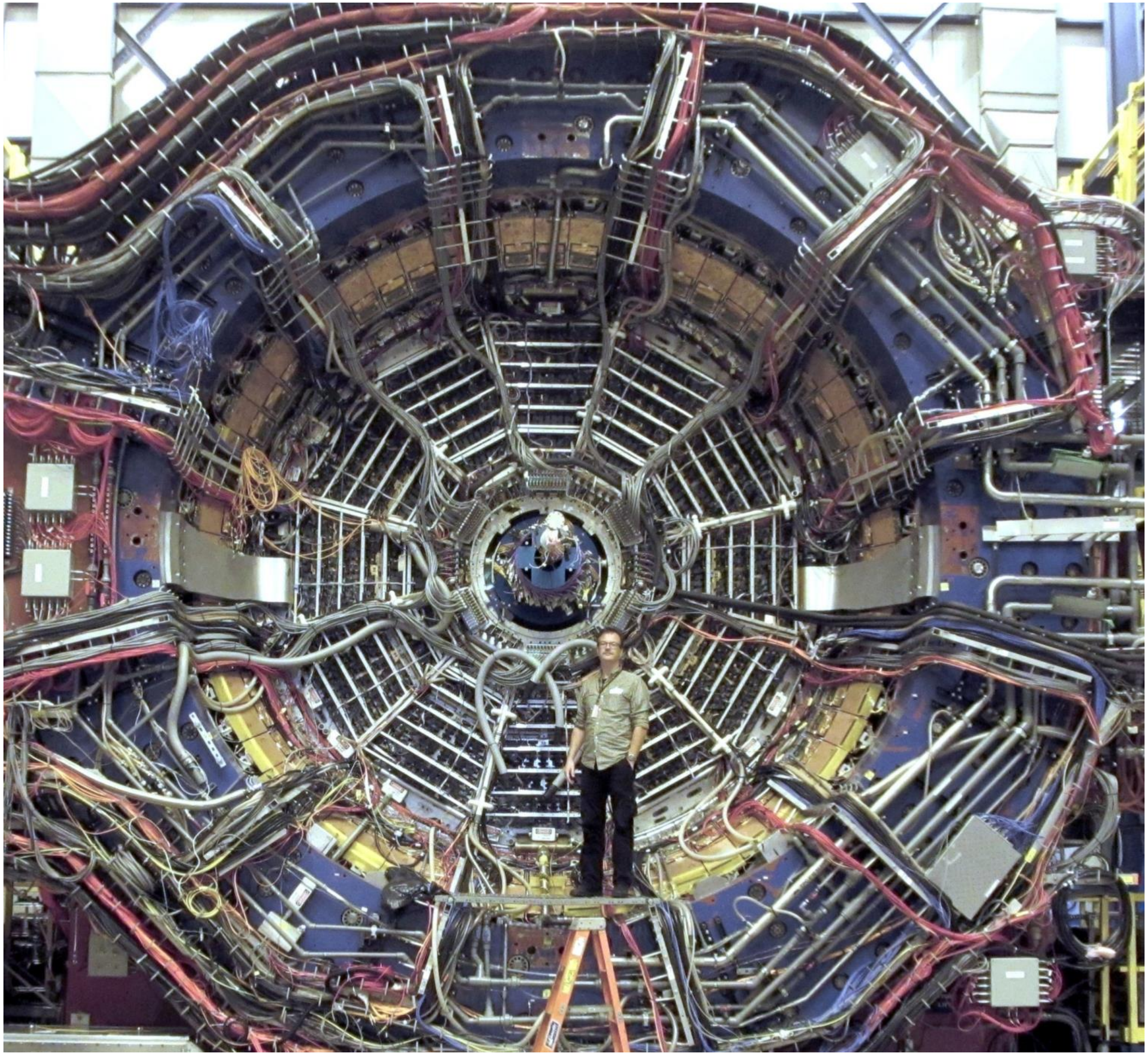
February 5th, 2015

The TPC Today – inside the magnet with electronics & cables



The ‘Naked’ TPC

4.2 m long

4.0 m diameter

The sectors were installed while the TPC was on the ground in B77

A (pretty good) clean room was built around the TPC for installation of the sectors

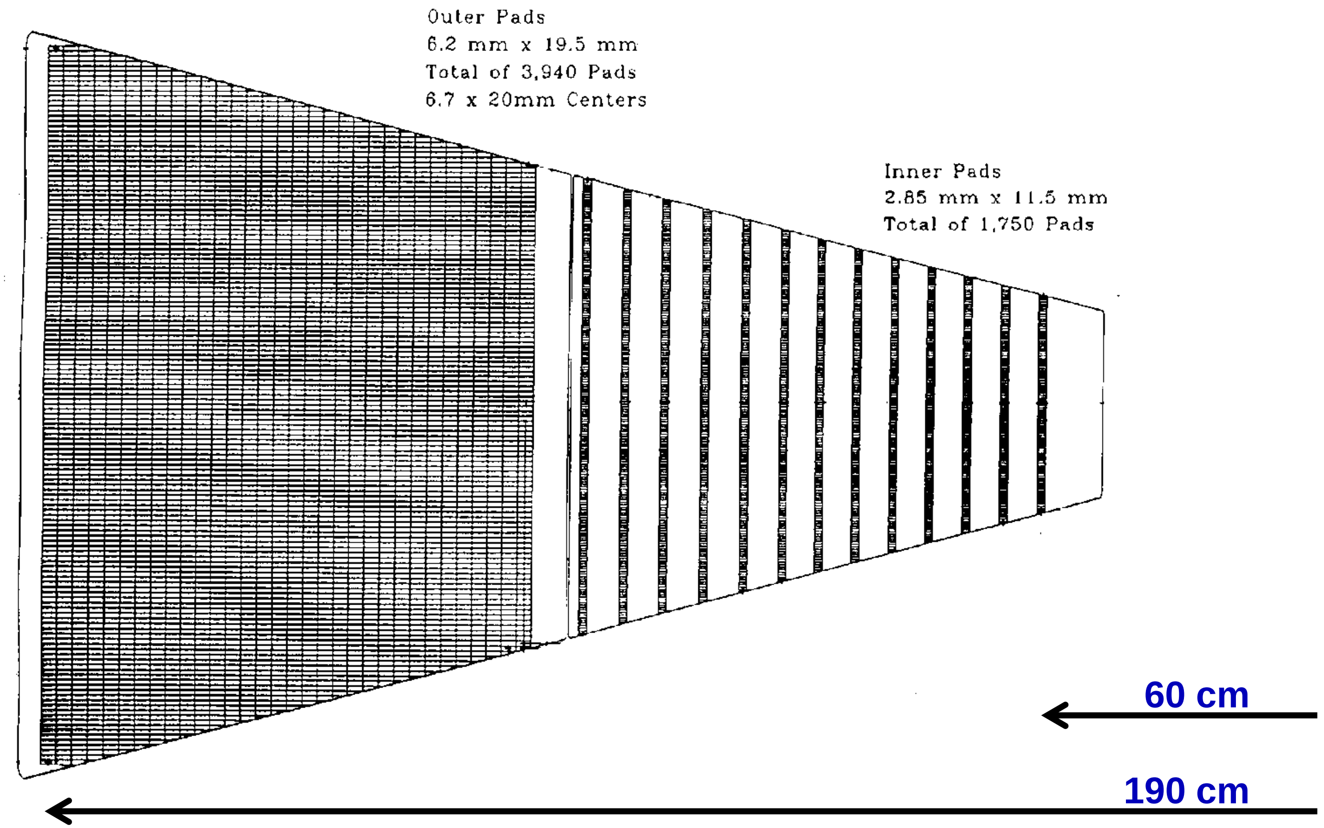
Critical Dimensions for the TPC

Item	Dimension	Comment
Length of the TPC	420 cm	Two halves, 210 cm long
Outer Diameter of the drift volume	400 cm	200 cm radius
Inner Diameter of the drift volume	100 cm	50 cm radius
Distance: cathode to ground plane	209.3 cm	Each side
Cathode	400 cm diameter	At the center of the TPC
Cathode potential	28 kV	typical
Drift gas	P10: 90% Ar, 10% CH_4	He-Ethane as an option
Drift Velocity	5.45 cm/μsec	typical
Transverse diffusion (σ)	230 μm/√cm	135 V/cm & 0.5 T
Longitudinal diffusion (σ)	360 μm/√cm	135 V/cm & 0.5 T
Magnetic Field	0, ±0.25 T, ±0.5 T	Solenoidal

Weight of TPC (lb.)

Item	Max LBNL	Max BNL Lift	Installed Wt. w/ CTB	Installed Wt. w/ TOF	Basis
IFC	107	107	107	107	close est
OFC	4991	4991	4991	4991	close est
Wheel	3100	3100	3100	3100	measured
Wheel Brkts/Adj	227	227	227	227	rough est
TOF rails	1080	1080	1080	1080	exact
Outer Sectors	2520	2520	2520	2520	measured
Inner Sectors	1752	1752	1752	1752	close est 75# ea,
Gas Manifolds at wheel	0	0	200	200	removed for lift
FEE	128	1539	1539	1539	measured
FEE Manifolds	480	480	480	480	rough
RDO	51	607	607	607	close est.
RDO manifolds	15	360	360	360	rough
RDO/FEE Cable	39	468	468	468	close est
Dist Manif/hose	240	390	390	390	rough
CTB modules (120 ea.)	0	660	3960	0	measured/ 33# ea.
TOF modules (120 ea.)	0	0	0	4800	Est, G.Mutchler 9/98
TOF cables/hose	0	0	240	240	rough
RDO elect. brkts	24	24	24	24	rough
SVT, Cone Assy &SSD	0	0	365	365	Mech Des Rev 3/98
FTPC	0	0	809	809	FDR action item 1
TOTAL	14753	18304	22409	23249	

Goal: Hermetic coverage & better acceptance

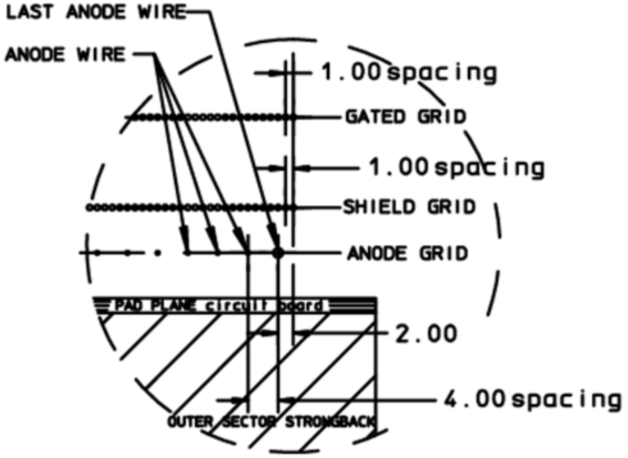


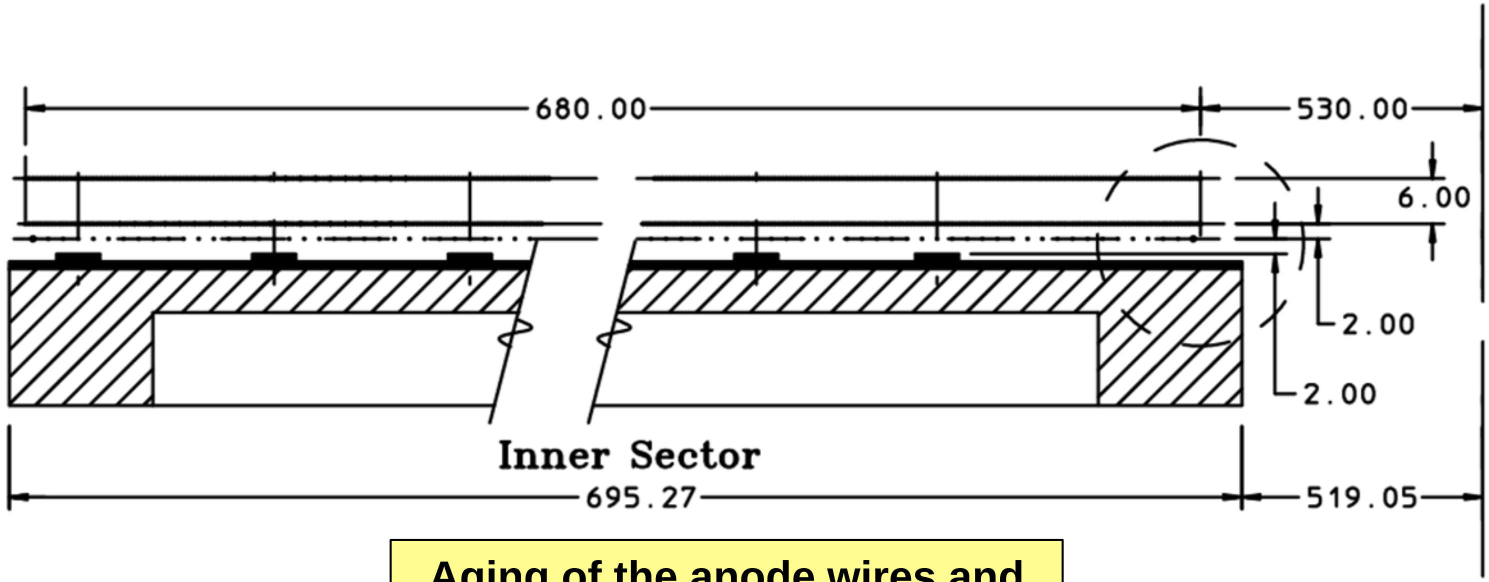
- **The outer pad plane is hermetic … while the inner pad plane is not**
  - **Increase the segmentation on the inner pad plane**
  - **Renew the inner sector wires which are showing signs of aging**

The upgrade will provide better momentum resolution, better dE/dx resolution, and improved acceptance at high η

Inner sector detail

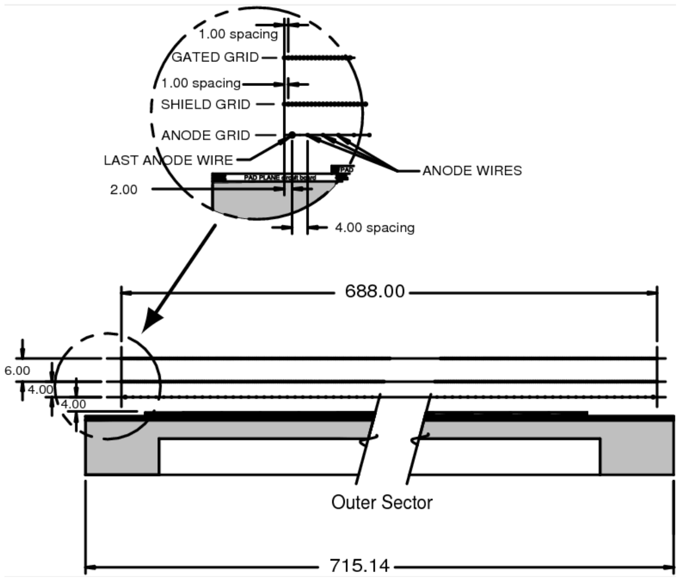
- **The inner sectors are affected the most due to 1/r² distribution of charge in the TPC**
- **See talk by A. Lebedev**

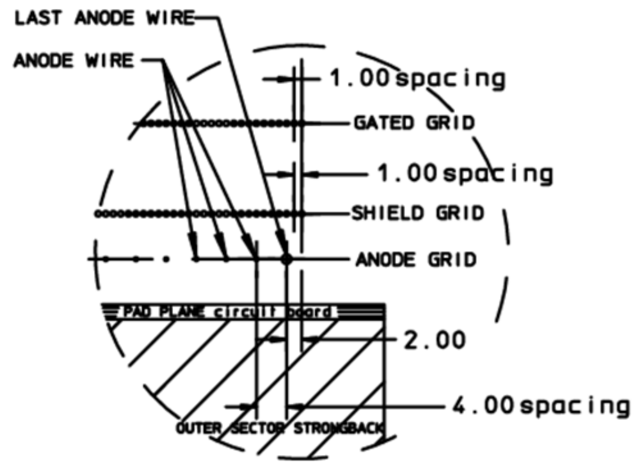


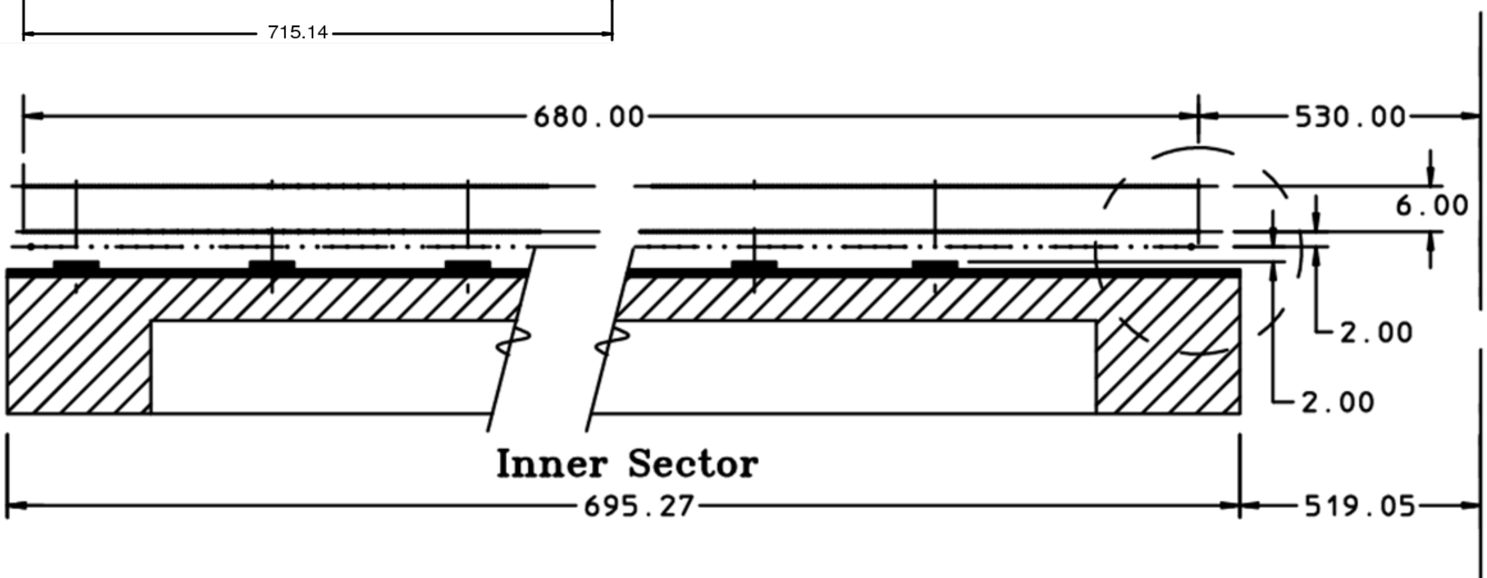


Aging of the anode wires and tripping on the cathode wires

Inner sector detail



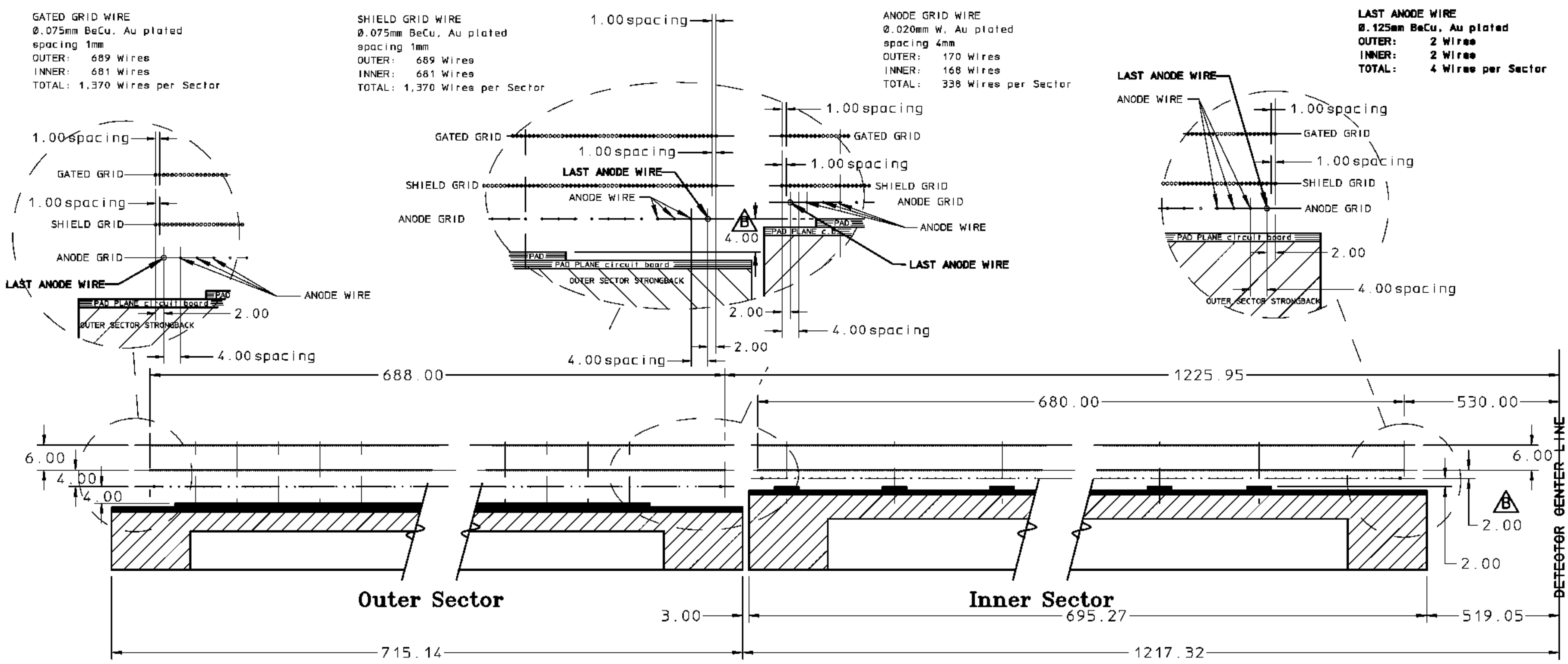




Inner sector construction: electrical & mechanical

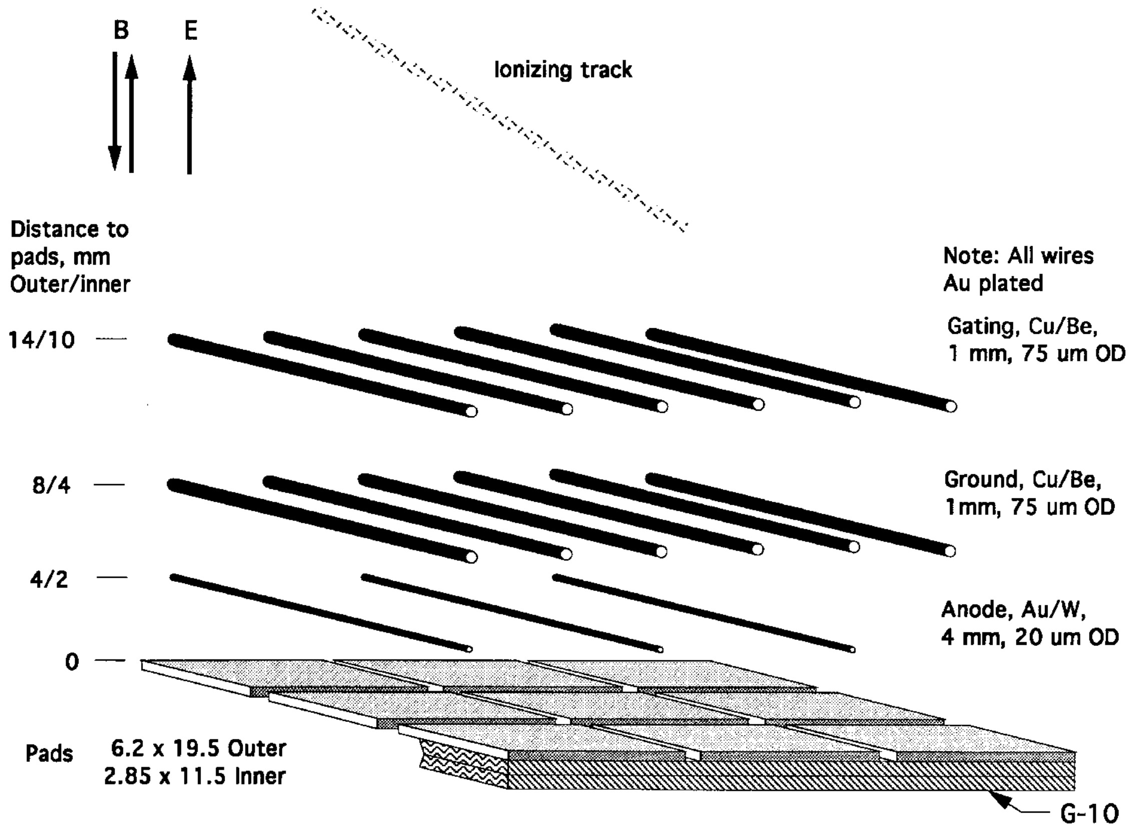
Figure 40: Experts examining a spare inner sector for the TPC. Note the old style pad plane with electronics cards (ABDB boards) mounted along the edge of the sector. Normally the spare sectors (STAR has two spare sectors) are sealed in a storage box and kept under dry nitrogen.

Inner / Outer sector detail



- Note that inner and outer pad planes not at the same height
- Pad plane to anode plane (etc) distance not the same (4/4/6 vs 2/2/6)
- 3 mm gap between sectors, this is an issue during installation

Sector Wire Geometry – special notes



Wires are phase locked to the pad locations. 4 wires located over each pad row. We can probably tolerate a phase shift of 200 microns.

Ground wires lie directly over the Anode wires to limit sparking (Alice did it differently and had a problem)

Parameters for the old and new sectors

Item	Inner	Outer	iTPC	Comment
Pad Pitch (center to center)	3.35 x 12	6.70 x 20	5.0 x 16	mm
Isolation gap between pads	0.5	0.5	0.5	mm
Pad Size	2.85 x 11.5	6.20 x 19.5	4.5 x 15.5	mm
Number of Pads	1750	3940	3496	
Anode to pad plane spacing	2	4	2	mm
Anode voltage	1170 V	1390 V	~ 1120 V	20:1 S/N
Anode Gas Gain	3770	1230	~ 2000	nominal
Anode Wire diameter	20 μm	20 μm	20 μm	Au plated W
Anode Wire pitch	4	4	4	mm
Anode Wires phase locked to pad location	3 wires, #2 over center	5 wires, #3 over center	4 wires, over center	grp centered over the pad

Pad Plane & wire planes must be flat to better than 20 μm to keep dE/dx resolution uniform to 1%

Wire	Diam. (μm)	Pitch (mm)	Composition	Tension (N)
Anodes	20	4	Au-plated W	0.50
Anodes—last wire	125	4	Au-plated Be–Cu	0.50
Ground plane	75	1	Au-plated Be–Cu	1.20
Gating grid	75	1	Au-plated Be–Cu	1.20

Grid Leak

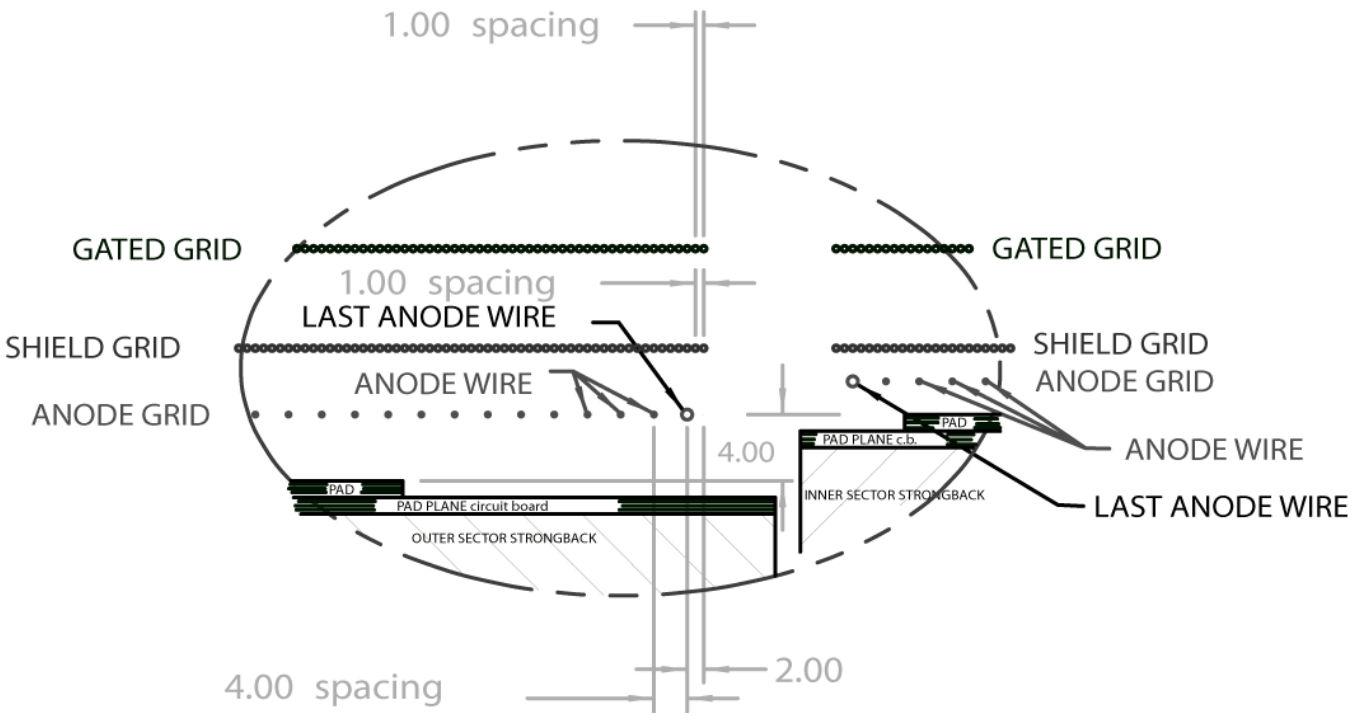
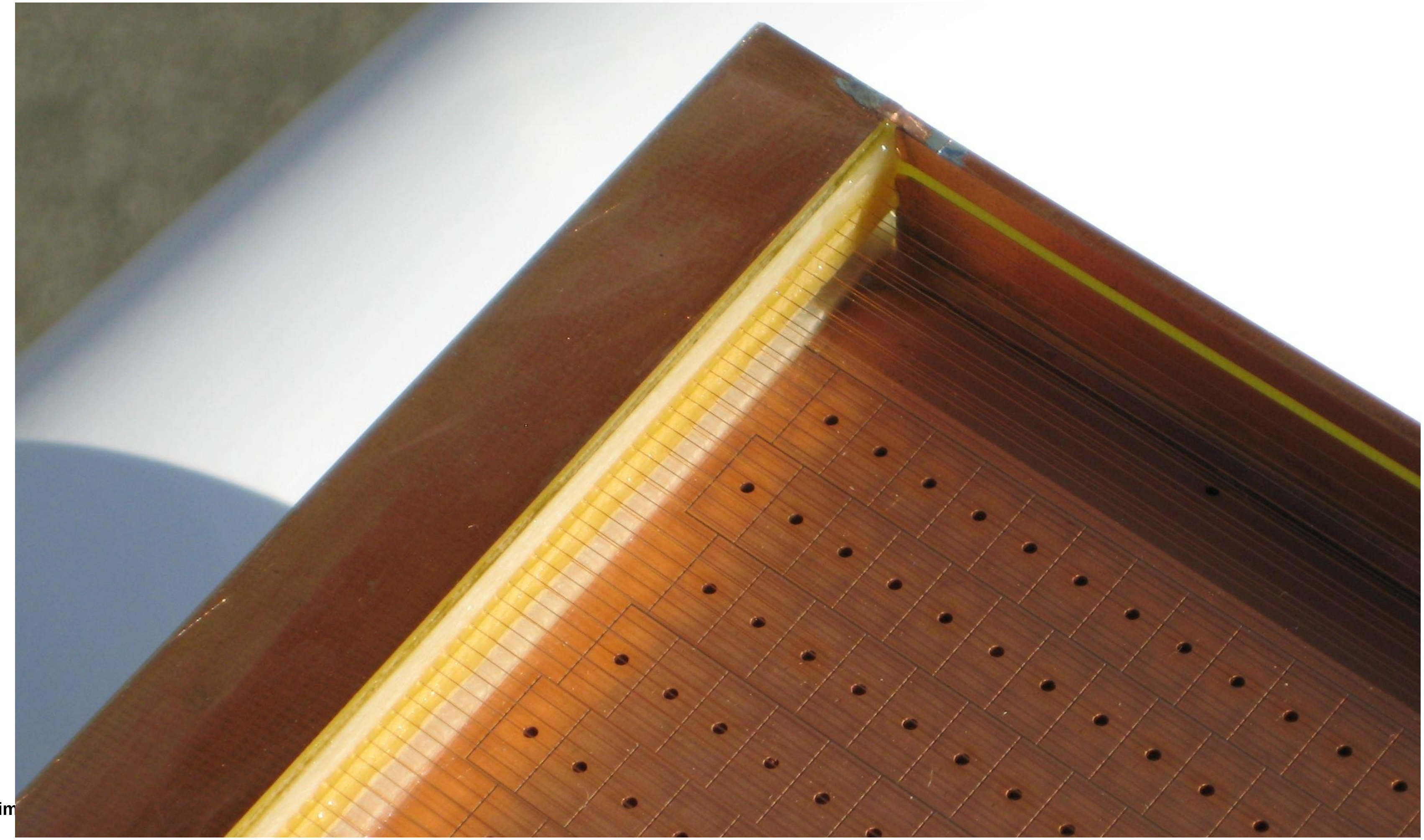


Figure 29: A detailed view of the gap between the inner and outer sectors. Note that there is a 16 mm gap between the end of the gated grid in the inner sector and the start of the gated grid in the outer sector. Also, note that the last anode wire is larger in diameter (125 μm) than the rest of the anode wires (20 μm).

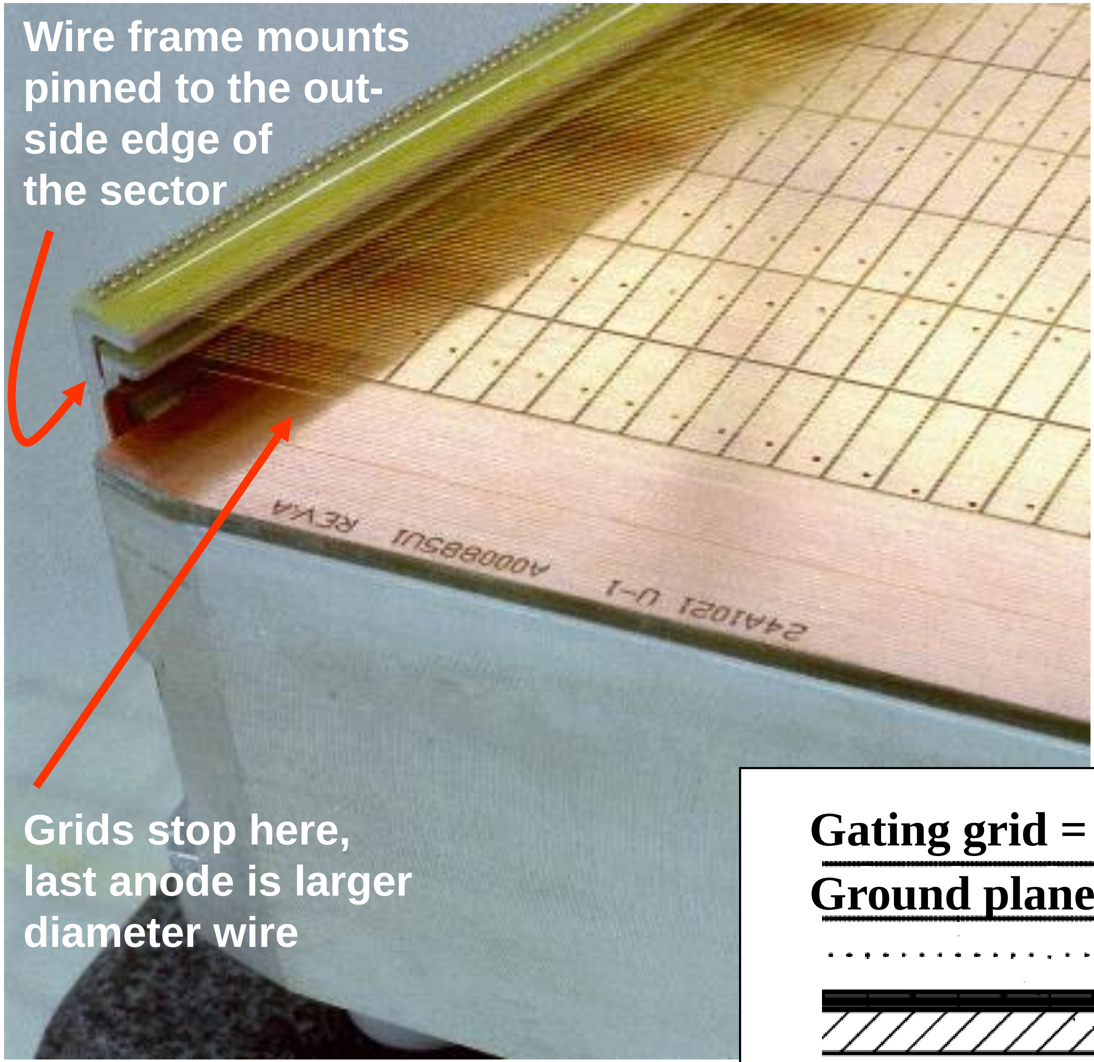
- **Two improvements to the grid leak problem are possible**
  - **Add more large diameter wires (125 μm) at top and bottom of grid**
  - **Install a wall between the inner and outer sector with bias rings**
  - **Simulations required and mechanical integration to be done**

The Alice Solution to the Grid Leak problem

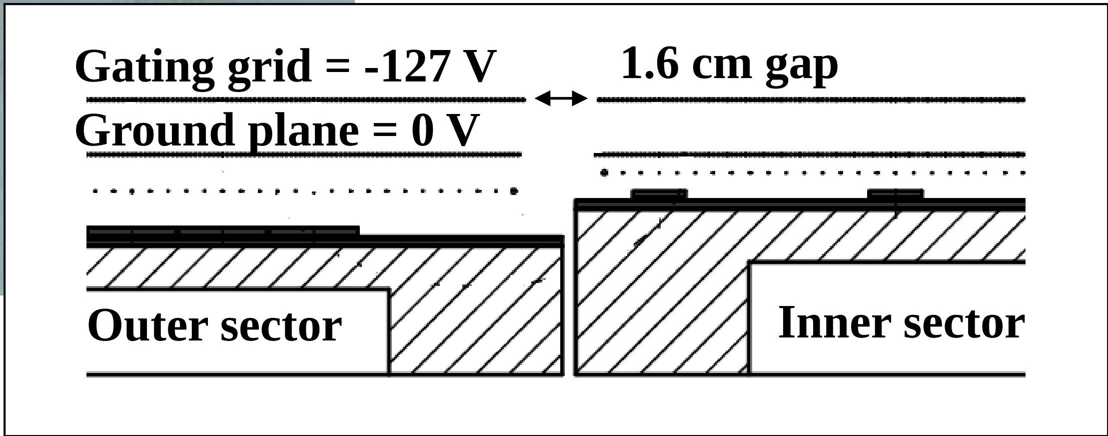
- **Multiple thick anode wires near the boundaries of the sectors**
- **A wall – to terminate the field lines from the Anode wires with ground potential and "cover" potential (match field gradient)**



STAR MWPC Detail (outer sector shown)



- **Gating Grid**
- **Ground Plane of Wires**
- **Anodes**
  - No field shaping wires
    - Simple and reliable
  - Individually terminated anode wires limit cross-talk
  - Low gain
    - Inner Sector gain: 3000 at 1150 volts
    - Outer Sector gain: 1100 at 1380 volts
- **Pad Plane**



Drawing DataBase

24A051-	SR0204	RHIC-STAR-TPC OUTER SECTOR **GATED GRID WIRE MOUNT, LEFT**	J. BOEHM	J. BERCOVITZ	
24A052-	SR0204	RHIC-STAR-TPC OUTER SECTOR **GATED GRID WIRE MOUNT, RIGHT**	J. BOEHM	J. BERCOVITZ	
24A053-	SR0204	RHIC-STAR-TPC OUTER SECTOR **WIRE MOUNT INSULATING BOARD**	J. BOEHM	J. BERCOVITZ	
24A054C	SR0204	**OUTER AND INNER SECTOR WIRE MOUNT PIN, TAPERED**	J.BOEHM J.BERCOVITZ		April 2nd, 1993
24A055B 24A055A	SR0204	RHIC-STAR-TPC INNER AND OUTER SECTOR **WIRE GRID CONFIGURATION**	J. BOEHM	J. BERCOVITZ	
24A056A	SR0204	RHIC-STAR-TPC TPC END WHEEL **SECTOR SURVEY TARGETS LOCATION**	J. BOEHM	J. BERCOVITZ	
24A057-	SR0204	RHIC-STAR-TPC OUTER SECTOR ASSEMBLY **COOLING MANIFOLD MACHINING**	J. BOEHM	J. BERCOVITZ	
24A058-	SR0204	RHIC-STAR-TPC COOLING MANIFOLD ASSEMBLY **HEADER PORT, LEFT**	J. BOEHM	J. BERCOVITZ	
24A059-	SR0204	RHIC-STAR-TPC COOLING MANIFOLD ASSEMBLY **HEADER PORT, RIGHT**	J. BOEHM	J. BERCOVITZ	
24A060-	SR0402	RHIC-STAR-TPC OUTER SECTOR **WINDER PLATFORM SUPPORT FRAME (30.5 X 48)**	R. CAYLOR		March 24th, 1993
24A061-	SR0402	RHIC-STAR-TPC OUTER SECTOR **WINDER PLATFORM SUPPORT FRAME (48 X 96)**	R. CAYLOR		
24A062-	SR0402	RHIC-STAR-TPC OUTER SECTOR **MOUNTING WHEEL END SUPPORT**	R. CAYLOR		
24A063-	SR0402	RHIC-STAR-TPC OUTER SECTOR **WIRE FRAME - 30 X 45 ID**	R. CAYLOR		March 11th, 1993

- **We have a nearly complete collection of all mechanical drawings in pdf and dwg format (probably 90% of all components)**
- **We have copies of all of the electrical drawings (paper copies, due to obsolescence of electronic formats, circa 1993)**

The Strongback … yes, we can do it :-)

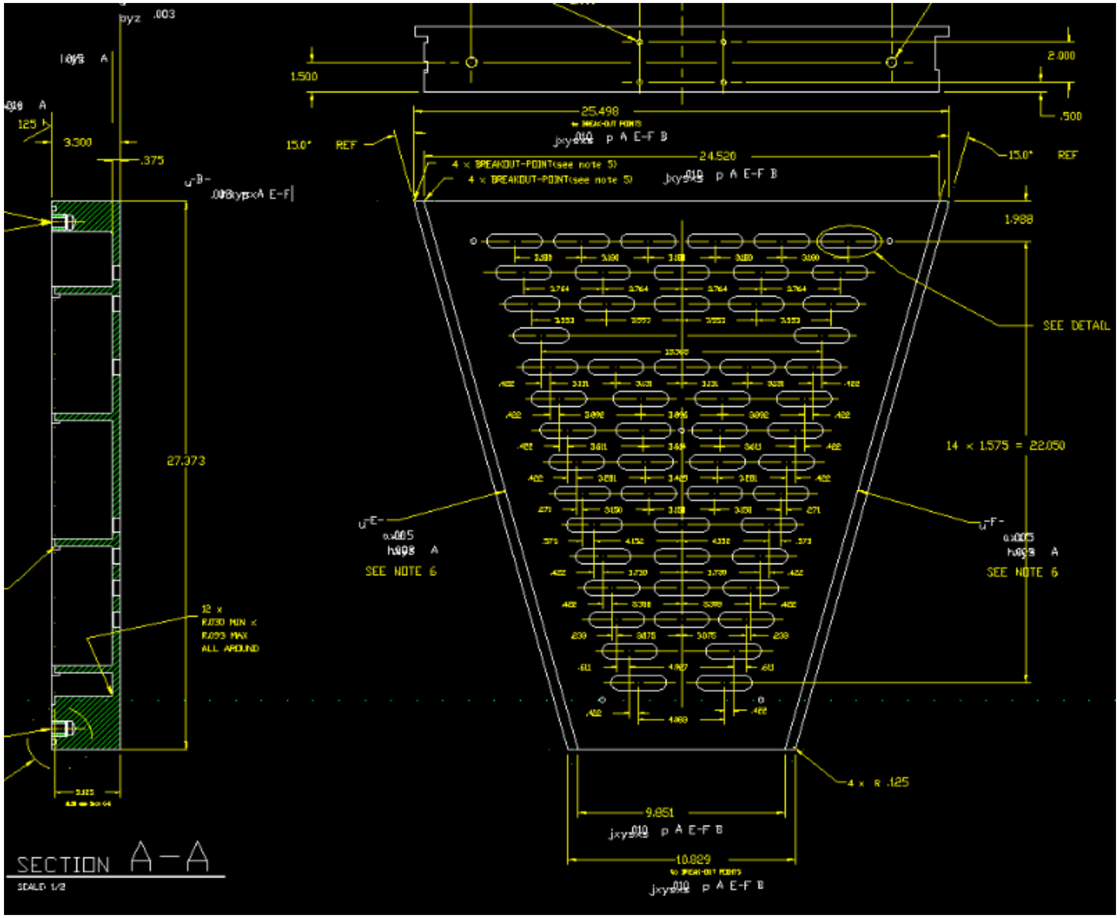
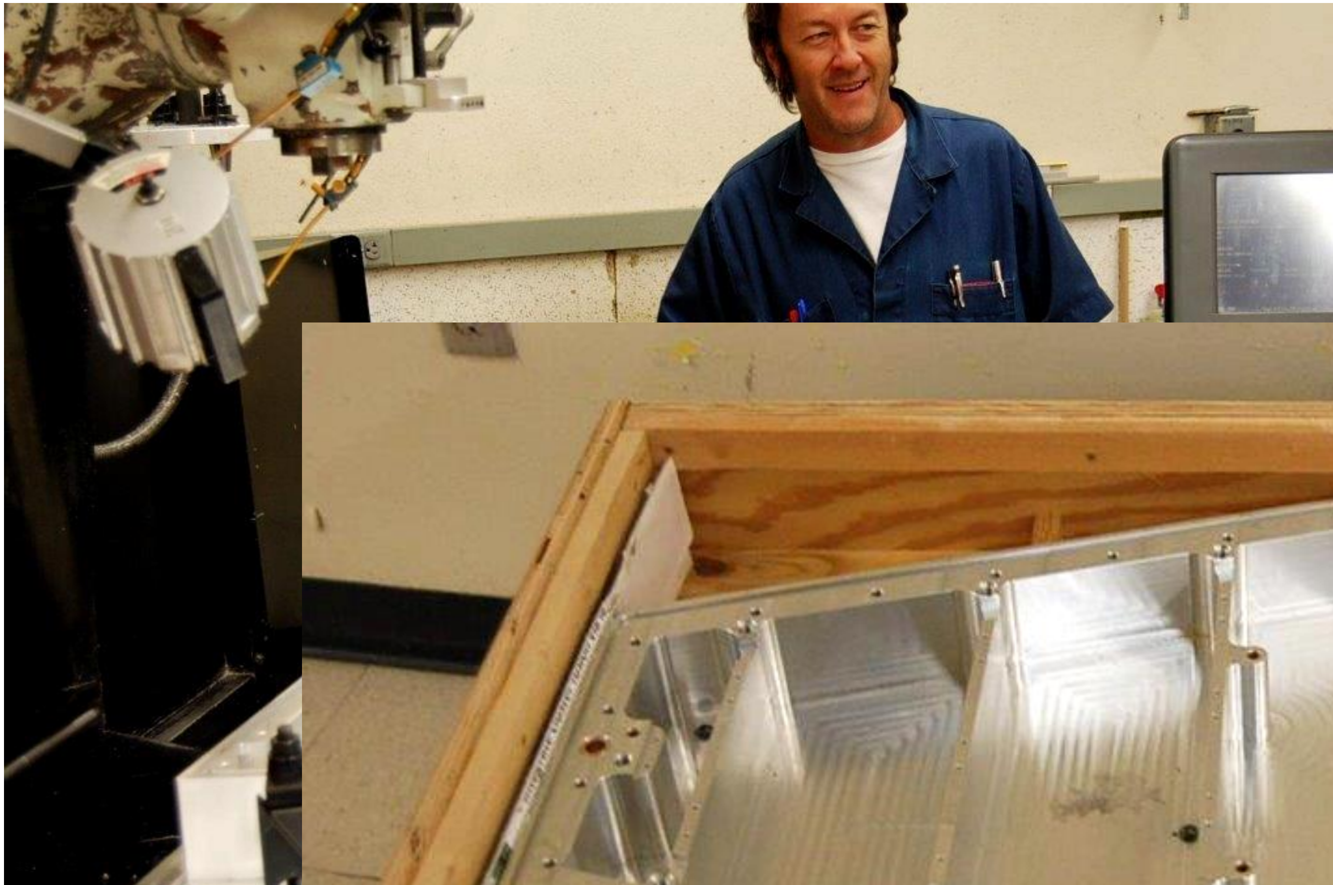


Figure 39: A prototype inner sector strongback is shown during fabrication at the University of Texas (circa 2013). The sector was machined out of a single piece of aluminum. Dimensions are: ~27 inches tall, ~25 inches wide and weight 73 lbs. The sector is viewed from the backside; the side upon which the electronics and cooling manifolds will eventually be mounted.

Prototype Strongbacks built at UTA

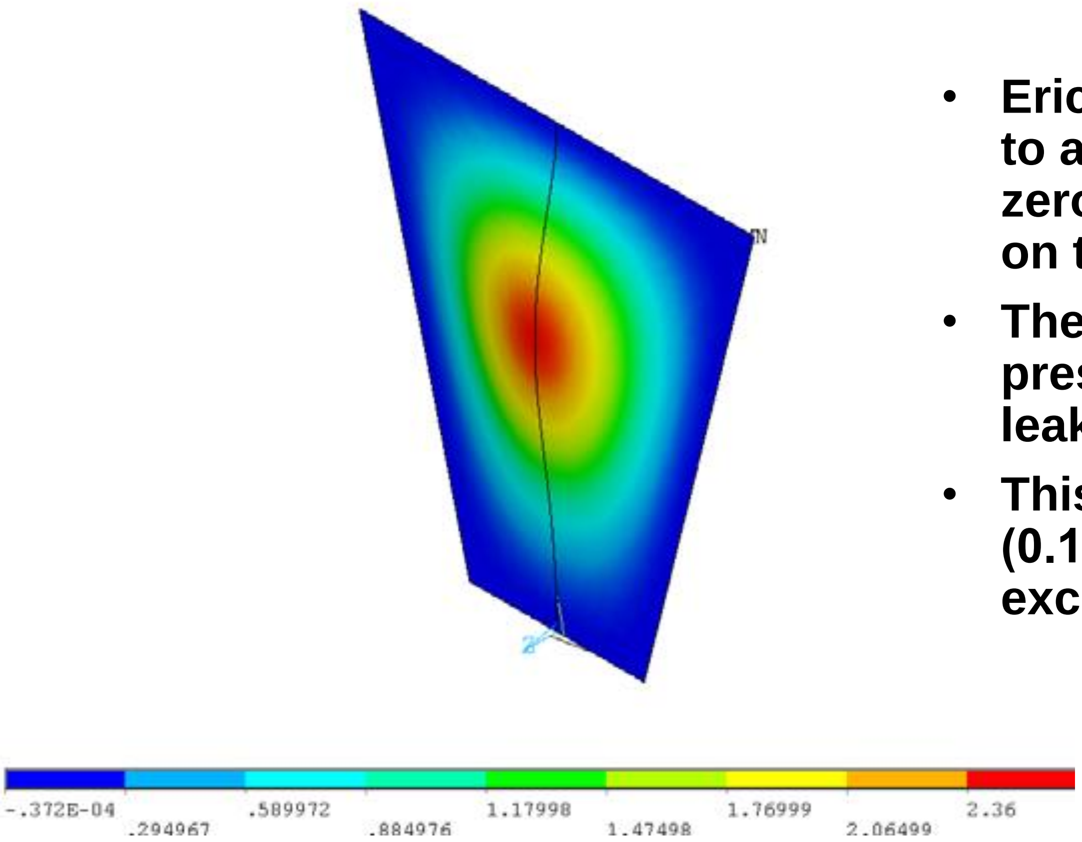
Note Mounting Fixtures on Ribs

Prototype Strongbacks built at UTA in 2013



Note Mounting Fixtures on Ribs

Can we adopt a radical new design?

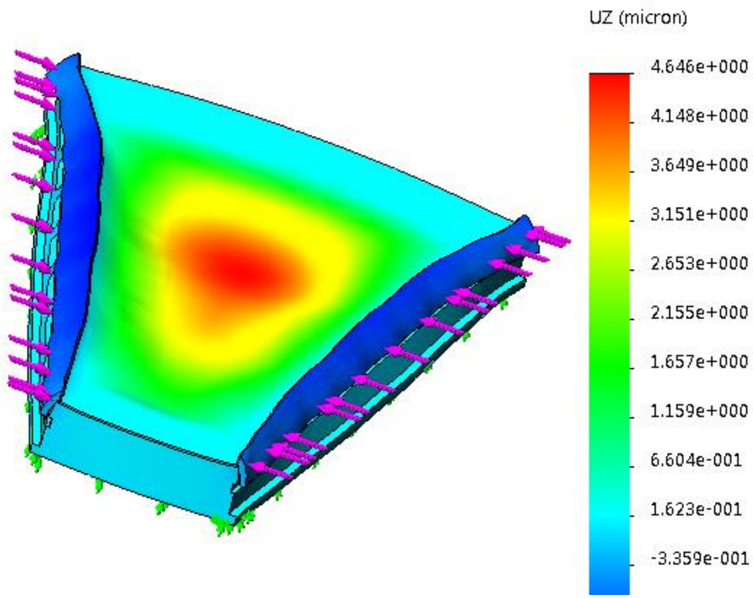


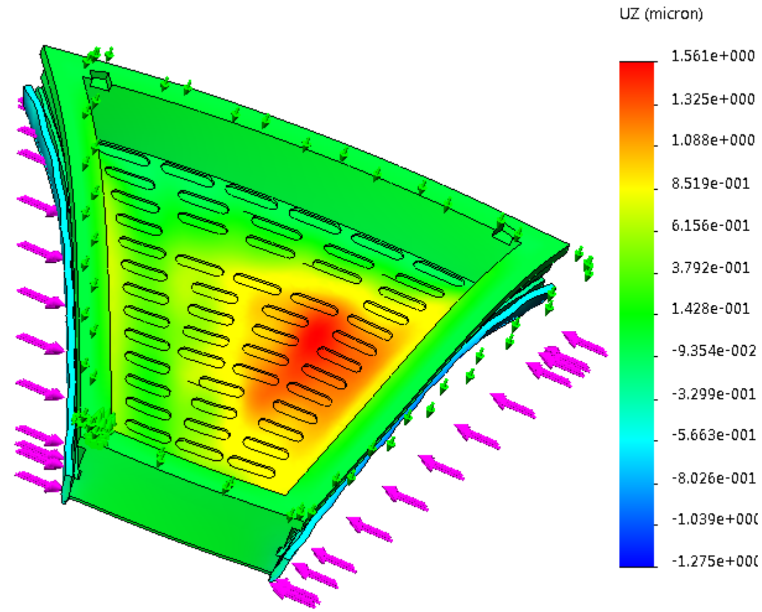
- Eric Anderssen was asked to analyze the case with zero thickness Aluminum on the front face & no ribs
- The TPC is over-pressurized to prevent leaks (2 mBar)
- This leaves only the G10 (0.125” thick) to support the excess pressure in the TPC

- Deflection due to pressure changes in the TPC leads to 300 μm bulge
- Can be reduced by 8x with a rib … but still not enough

No. A radical new design does not work … and is not useful

Distortions due to wire tension … do we need ribs?





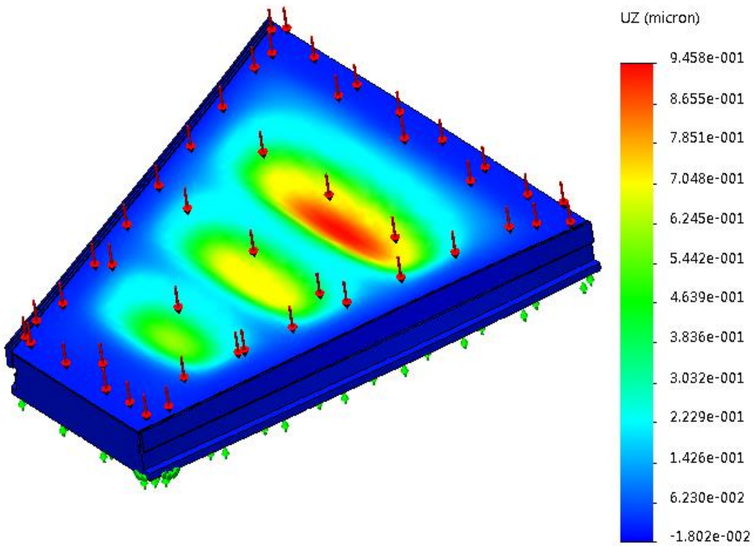
With ribs, G10 & 0.1" Al

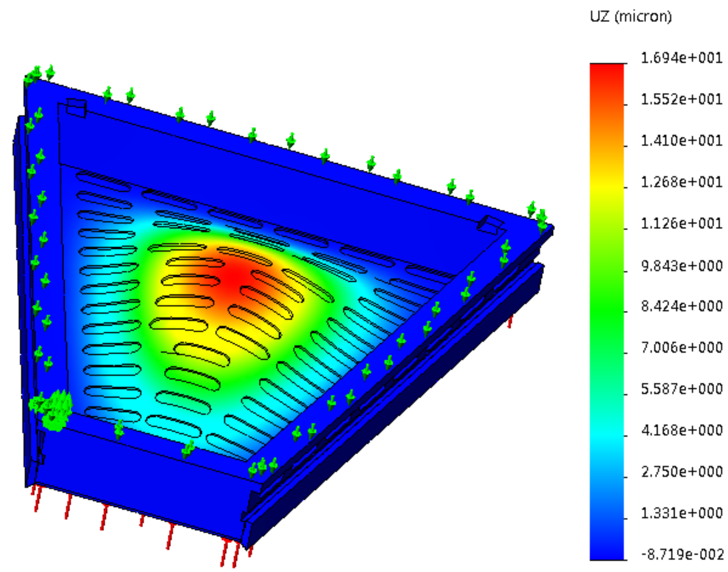
Without ribs, but with G10 and 0.1" Al

Figure 42: Simulated distortions in a proposed iTPC strongback due to the tension on the wire grids. The figure shows the result with the original rib design on the left, and without ribs on right. The maximum displacement of the pad plane, with ribs, is 4.6 microns. The deformation of the padplane without ribs is less, only 1.6 microns. Summary: ribs are not needed to support the tension on the wires. Simulations courtesy of Howard Wieman.

No, ribs are not needed to support the tension on the wires

2 mBar over-pressure (again) … do we need ribs?





With ribs, G10 & 0.1” Al

Without ribs, but with G10 and 0.1” Al

Figure 43: Simulated distortions in a proposed iTPC strongback due to an excess pressure of 2 mBar inside the TPC. With ribs, we see a maximum distortion of 9.5 microns. Without ribs, the distortion grows to 16.5 microns. Simulations courtesy of Howard Wieman.

Yes, ribs are not needed to support the pressure inside the TPC but their height can be reduced … and a radial rib may be better

Lumpy mass distribution … ribs are important

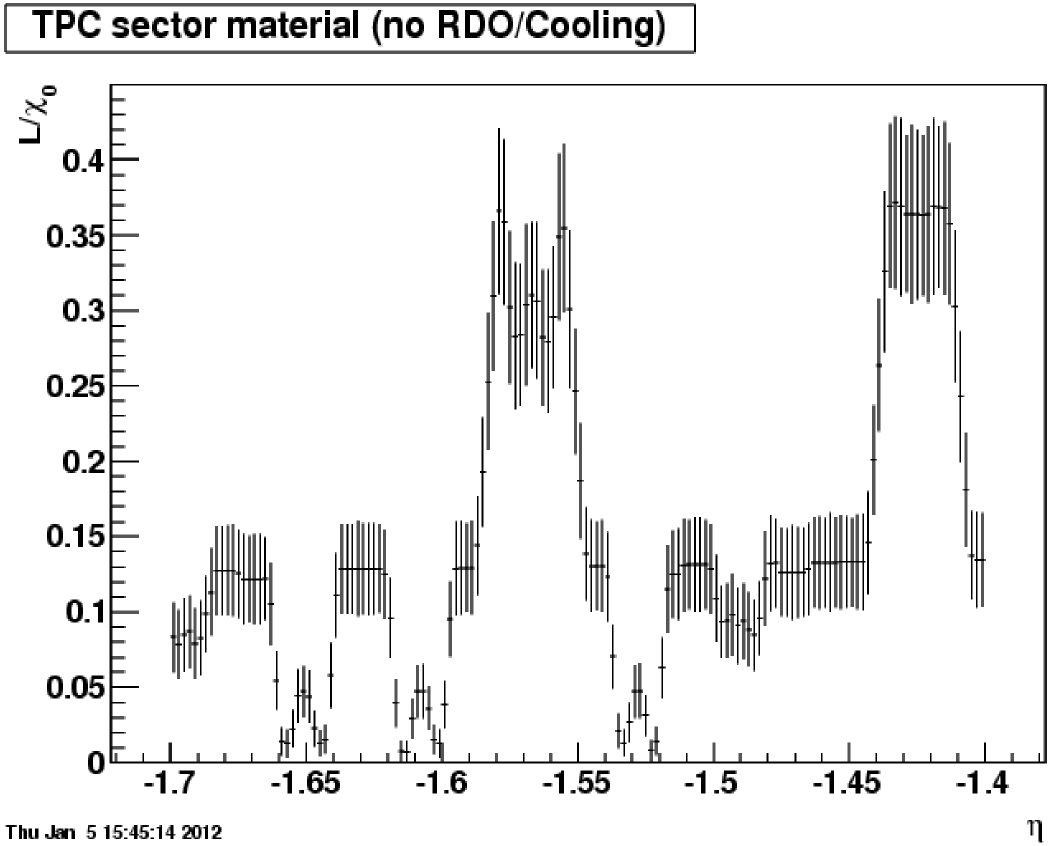


Figure 41: Radiation length vs. eta for the original strongback. Electronics, cables and cooling manifolds are not included in these calculations. The lowest points are the cutouts for the electronics … and so these numbers are not representative of the final assembly because this is where the FEE cards will sit and their ***average*** thickness is greater than 7%.

3/8" front face of Al is 10.5% Rad Length, G10 0.5% and small angle ⇒ 13%

Average mass distributions (±10°, 1.5 < η < 2.0)

FEE	3.60 %
FEE mounting bracket	3.45 %
FEE rib	0.45 %
FEE socket	0.15 %
Cooling manifold	3.25 %
RDO card	0.90 %
Ribs	2.70 %
Sector G10	0.45 %
Sector Aluminum	3.20 %
Cables	~1% (estimate)
FEE sub Total	**7.65%**
Total	**19.15%**

Table 6: The *average* radiation length budget for the components associated with a TPC inner sector (circa 1993) averaged over the fiducial volume of the sector. The average takes out the lumps in the mass distribution (for better or worse) but also illustrates how the budget for the Al on the front face compares to the electronics and cooling budget. The sector data have been averaged over a range from $1.5 < \eta < 2.0$ and $-10 < \phi < 10$ degrees. Geant simulations courtesy of Irakli Chakaberia.

Three candidates for reduction: FEE mounting bracket, Sector Aluminum and Ribs.
It does not make sense to reduce sector Al to less than 3/16" (5% absolute, 1.6% average)

Decisions, decisions …

- **Decisions need to be made before the strongback design is final**
  - **Thickness of front face (recommend 3/8” (5mm))**
  - **Height of ribs & location … analysis needed but perhaps 1 cm high will work**
  - **Final decision needed on location of holes for electronics because it affects the location of the ribs, spider mounts and optical targets**
  - **Choose new location for spider mounts and optical target**
  - **Check that the sector can be installed without damage**
    - **satisfies clearance checks, is stable, and is strong enough**
    - **For example, sector insertion should not interfere with TPC endwheel**
- **Timeline**
  - **UT can fabricate 1 sector per month. We need 24 + spares.**
  - **Fabrication should start soon**
- **Optimistic note: we can proceed with the strongback fabrication in 2 steps, i.e. touch the strongback multiple times. 1.) Hog out Al in the middle, 2.) apply finishing touches.**
  - **Need to carefully to think out step 1 so that it doesn’t interfere with step 2 (example: thickness of ribs, spider mounts and location of electronics). Also don’t want to build something that cannot be installed. Have to understand spider mounts and insertion tool before finalizing design and approving fab.**

Manpower

- The assembly of the TPC sectors relied upon an outstanding group of senior technicians with good hands and a wealth of experience.

- Like most wire chamber techniques, many of these techniques have not been academically documented
  - Example: what kind of epoxy to use, how to prepare large amounts of the epoxy and store it, how to apply it
  - Combs for aligning the wires over the pad plane
  - Holding pad plane flat to 10 microns
  - Alignment of pad planes with strongback while gluing (50 microns)

- We have to learn, document and share these techniques
  - Unique, one of a kind fabrications
  - Physicists are not good at this stuff
  - Outstanding technicians are required

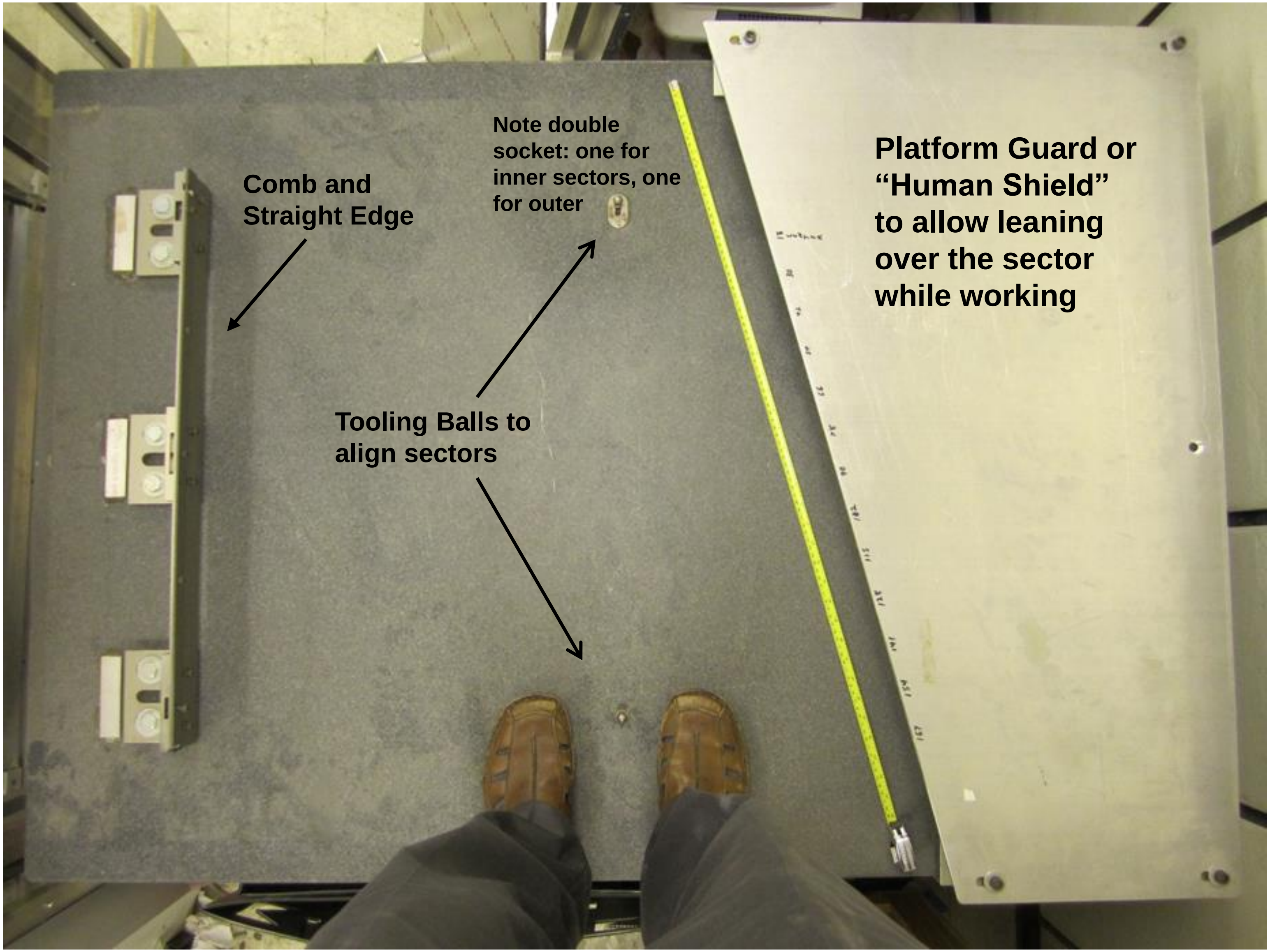
Granite table … the secret ingredient

The pad plane must be held flat on the table with vacuum

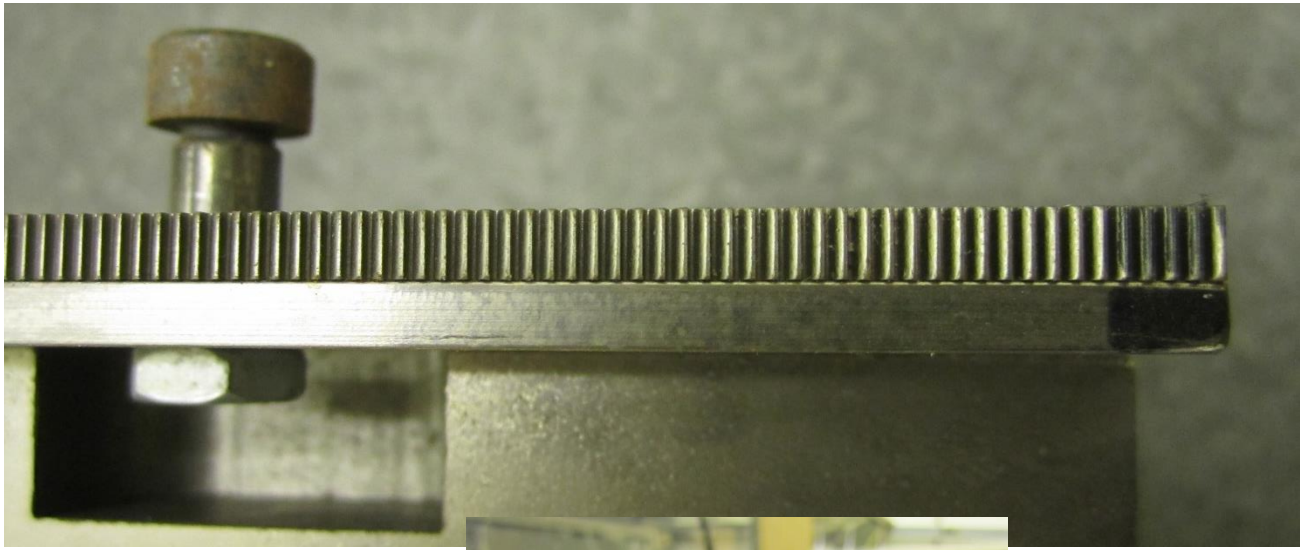
- One of the original granite tables is stored in the basement at BNL
- Black granite is preferred
  - contains less water and thus parts don't rust so quickly
- Dimensions (at BNL)
  - 60 x 42 x 8 inches
  - 36 inches off the floor (floor to top surface) although this is probably not critical
- Grade A surface plate, see:
  - http://www.precisiongraniteusa.com/Products.aspx
    Grade A "Inspection Grade" is defined here
  - http://precisiongraniteusa.com/pdffiles/fed_spec.pdf
- Flat to 10 μm (!)
- Original manufactured by Mojave Granite
  - 1651 Miller Ave, Los Angeles CA
- Fortunately, several manufacturers of granite tables in Shandong province.

Granite table, tooling balls and platform guards

Comb and Tooling Balls exposed – note: table has 2 combs



Teeth on the comb



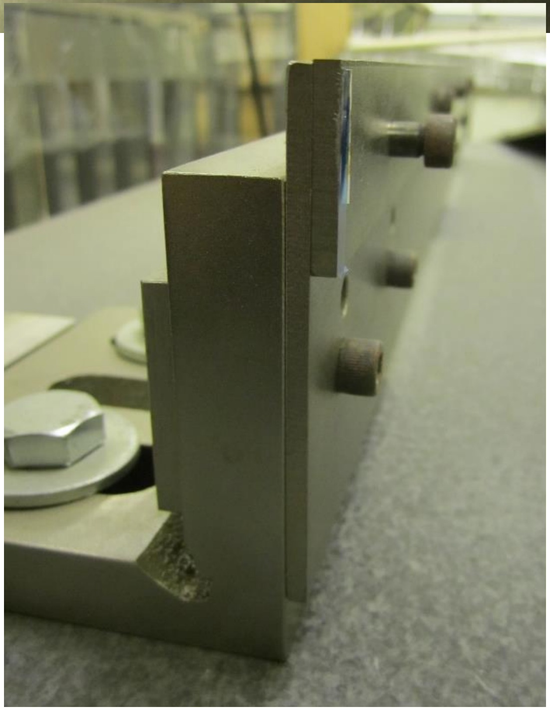
Comb plate and top of straight edge plate shown at left. “Bottom” of comb is below the level of the straight edge.

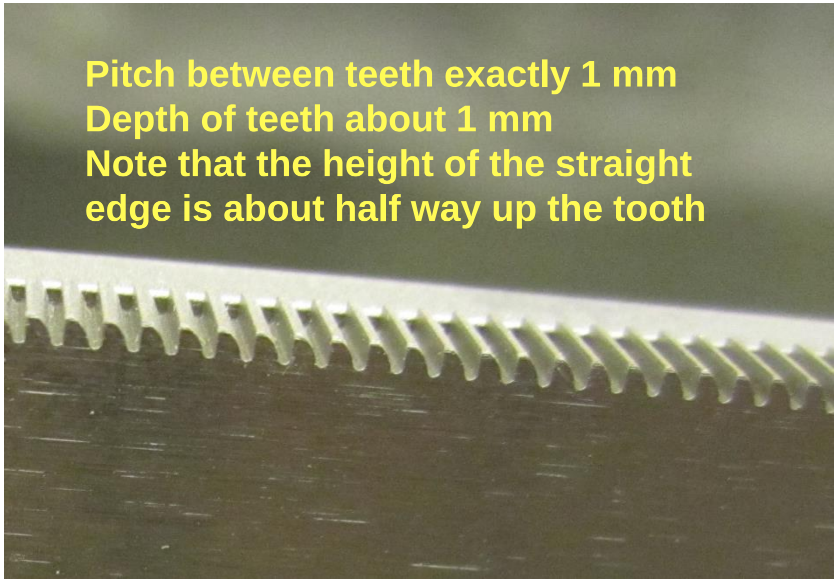
Teeth on the comb have an asymmetrical shape – one edge is vertical but the other is well-rounded.

Wires will rest on the top surface of the straight edge

Wires are laid on the straight edge then “slid” to contact the vertical sides of comb

Loose wires are pushed into contact with the comb using a brush

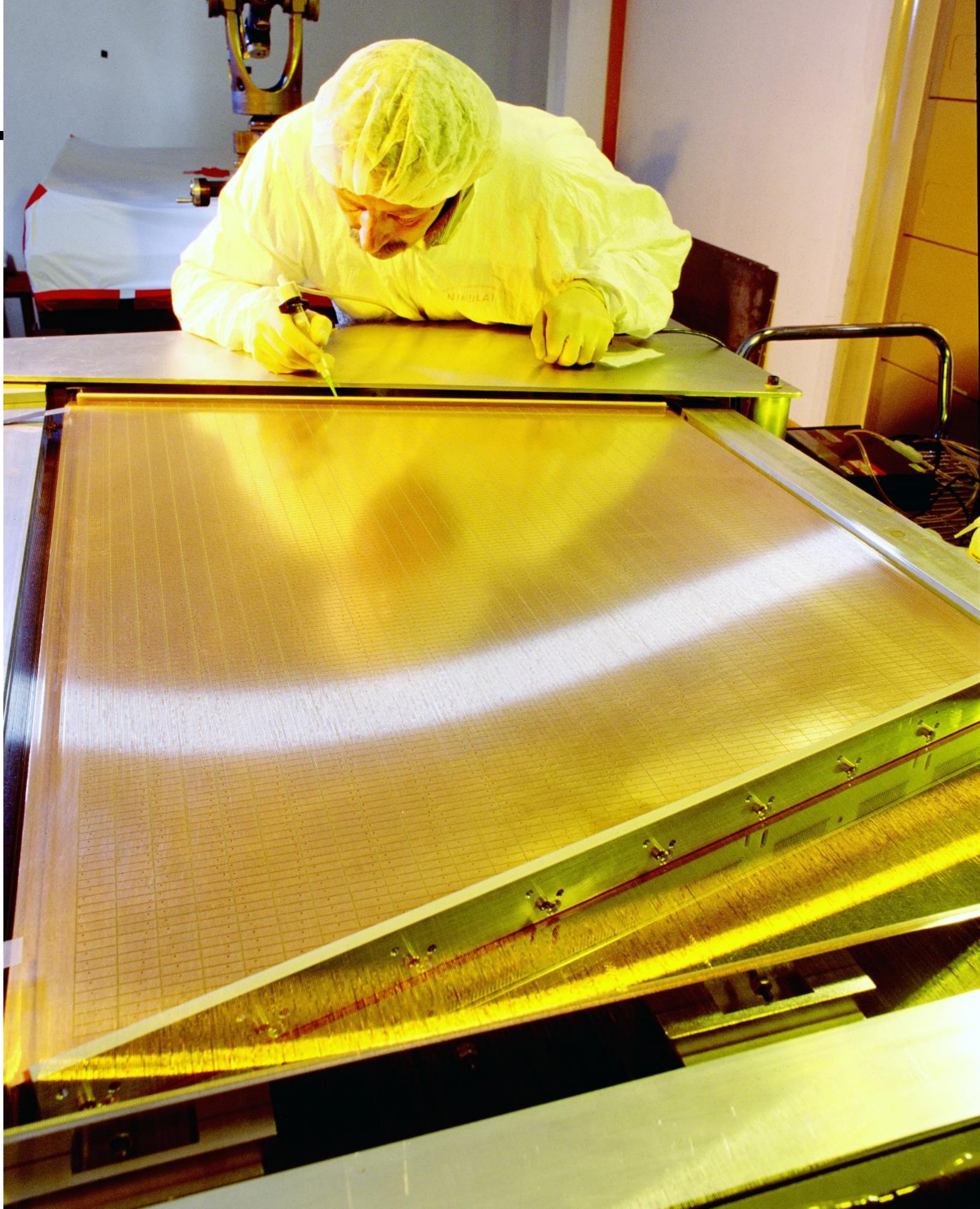




Platform Guards

- **The guards protect the wire planes, provide a hand-rest for gluing the wire planes and for soldering the gated grid**

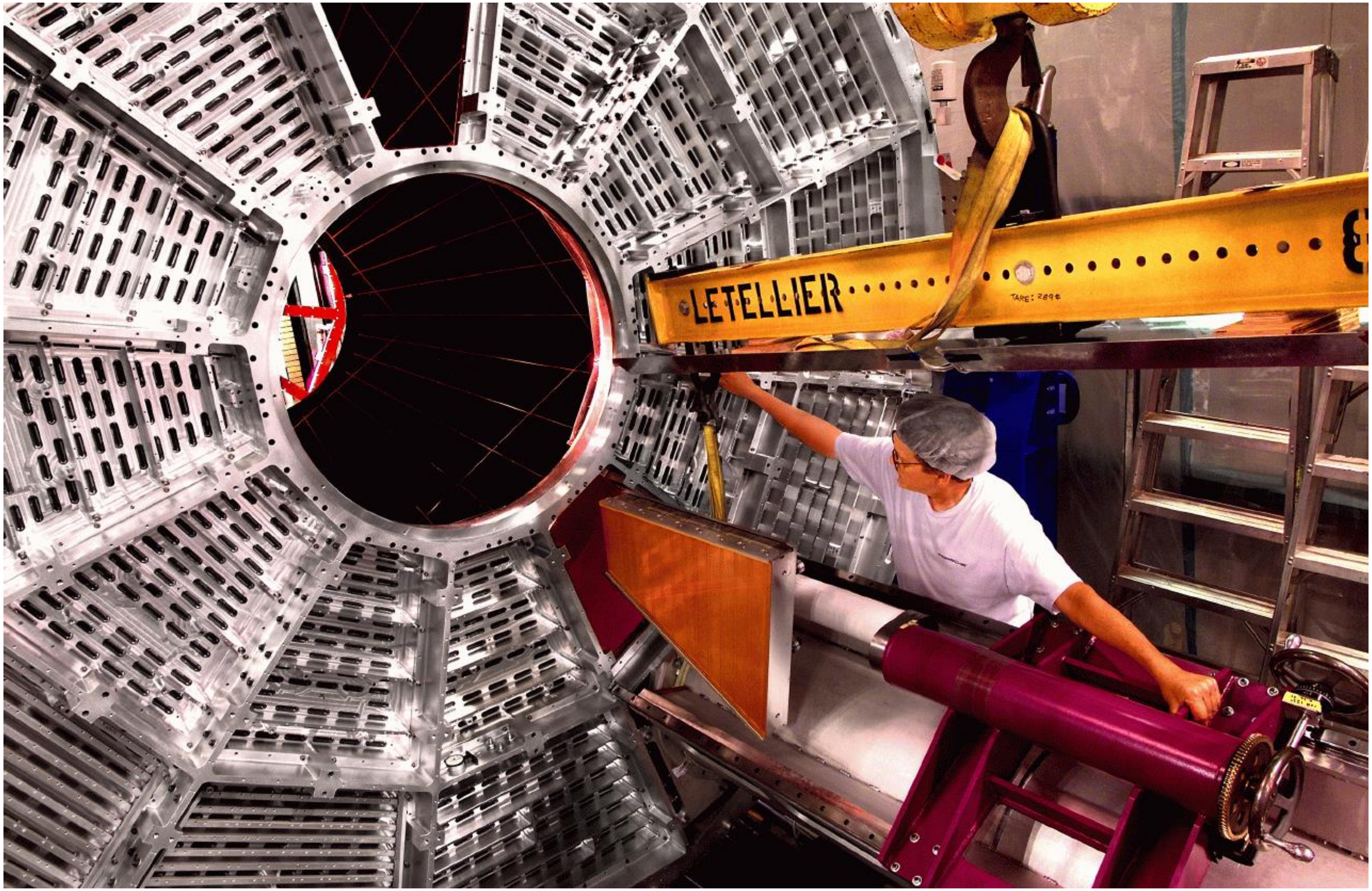
- **Comments**
  - **Plates are ¼ inch thick: the plates bend by about 2 to 3 mm when a person leans on them**
  - **2 inch diameter cylinders + washers were used to adjust the elevation of the platform guards.**
  - **There will probably be 3 different granite tables in use to build the iTPC sectors (one for each grid height). Each table may have different size spacers for the platform guards**



Additional Homework

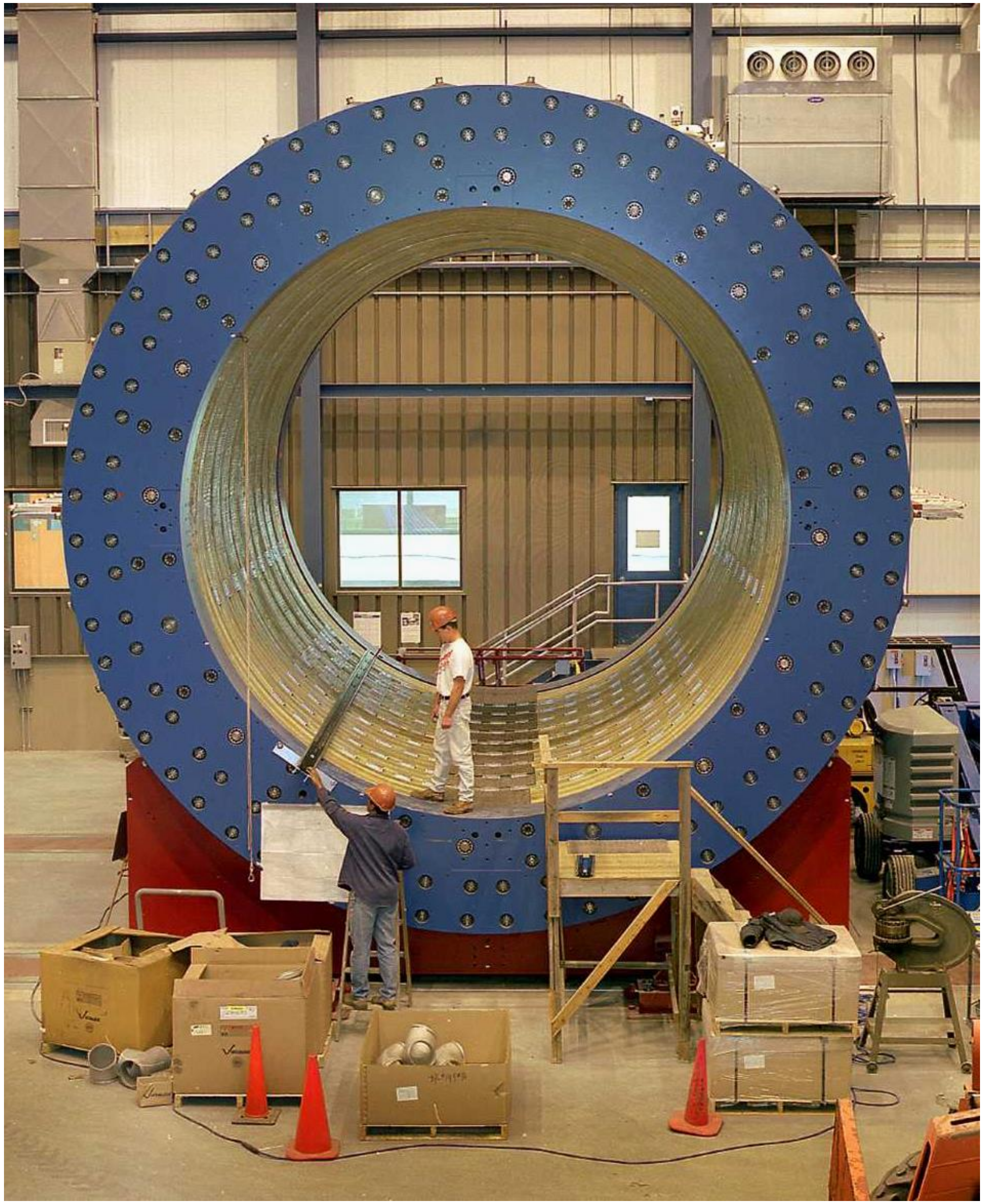
- Fixing the grid leak on the inner sector will change the mechanical design of the strongback
  - Not a problem … we just have to remember to do it and check that it is compatible with the clearance between sectors
- Hopefully, the fix for the grid leak does not affect the installation procedure … but we will have to check it carefully because the “wall” does change the shape of the sector
  - Installation is tricky and requires the sector to move in many odd directions before it is finally bolted into place.
- The Ground Wires are at the same elevation on the inner and outer sectors, ditto Gated Grid wires … have to keep it this way
- Tolerances for the flatness of the padplane and the height of the wires above the padplane are very demanding

Sector Insertion – special tools required



The STAR Magnet – life was simple and clean

- The old insertion tool was designed for use on the floor and required a crane to support the tool
- It is not practical to remove the TPC from the magnet for the iTPC upgrade
- The STAR TPC sits inside the magnet with an offset of 52 inches from the face of the magnet
- A new approach is needed
- See talk by Rahul



Summary

- **We can do this**
- **We have the drawings**
- **We have learned many of the secret ingredients**
  - **No doubt, a few of the most clever design features are still to be discovered**
  - **No doubt, a few of the most difficult fabrication techniques still need to be discovered**
- **We have made a good start on the design of the new sector**
  - **Final design requires analysis and input from professionals**
- **We need good hands**
  - **Unique, one of a kind, fabrications and assembly techniques**
- **We need time**
- **And we need money**