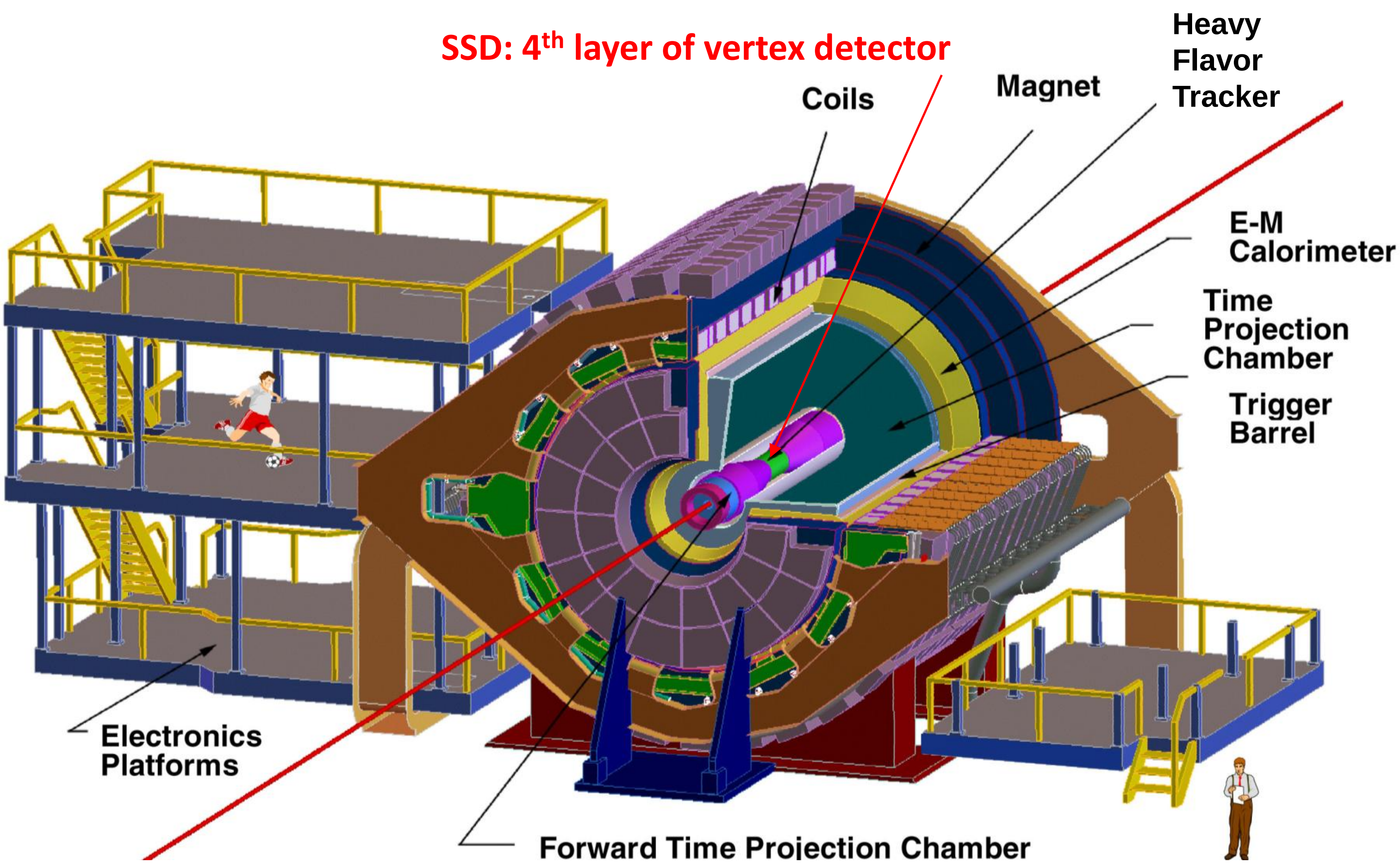
STAR SSD Safety Review

Something old, something new,
Something borrowed and something blue

Jim Thomas
Lawrence Berkeley National Laboratory
Gerard Visser
Indiana University

The STAR Detector at RHIC

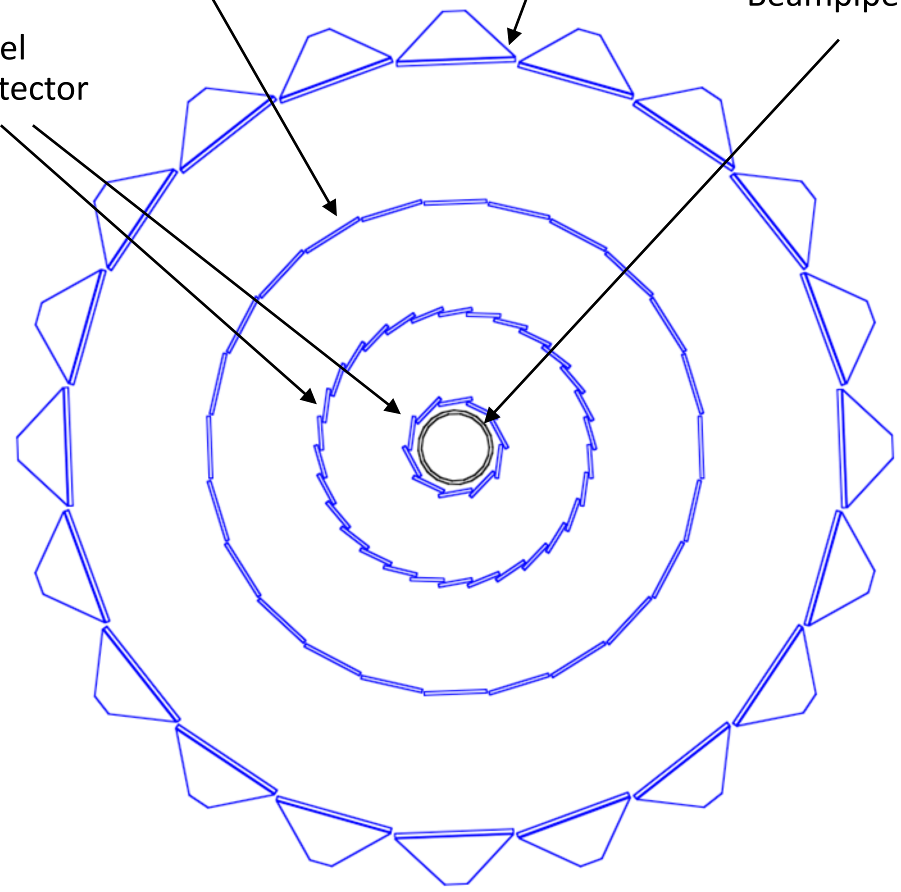
STAR HFT



Who, what, when, where, why & how

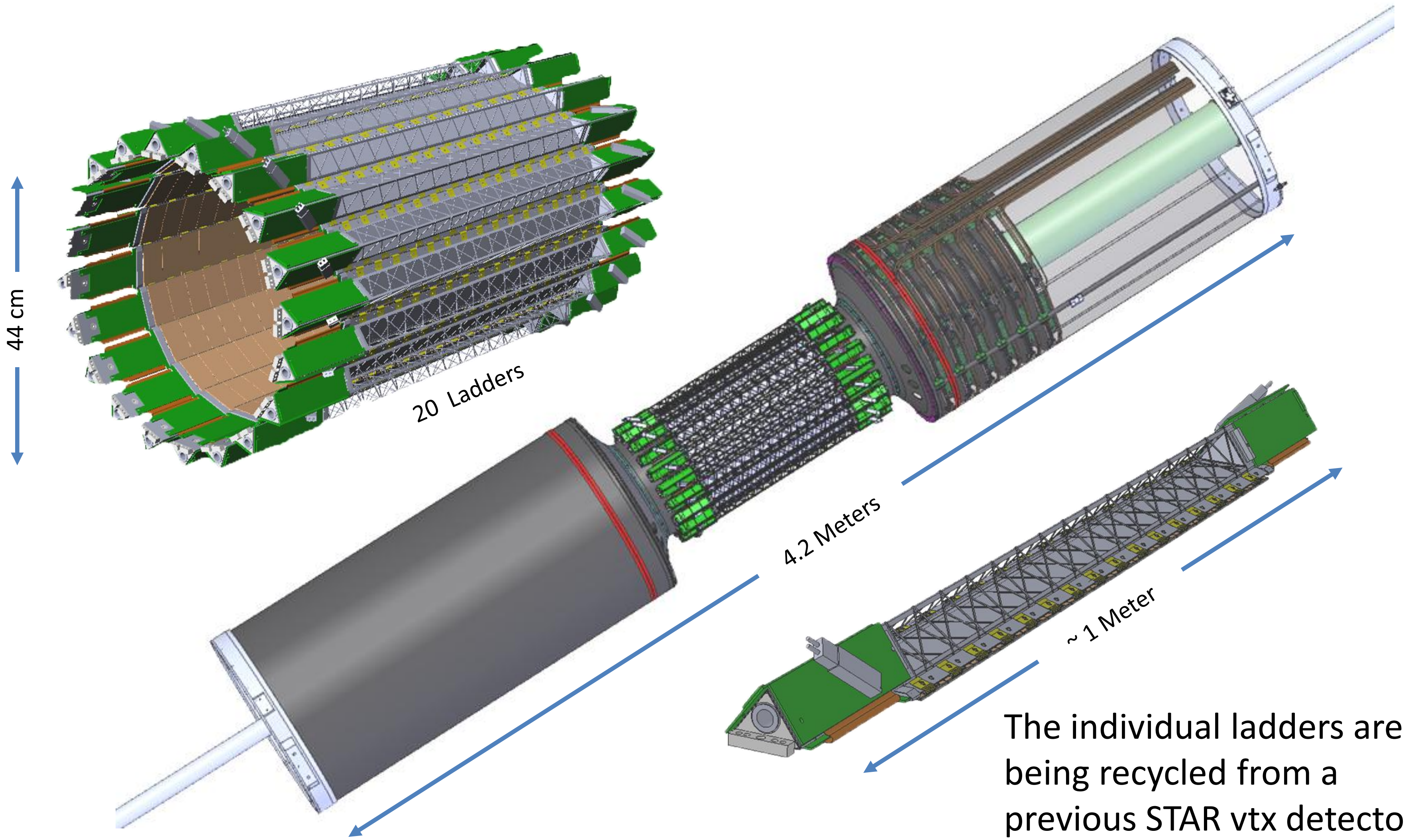
STAR HFT

- The Heavy Flavor Tracker provides exquisite resolution near the BP
- The SSD is the 4th layer in this system
- We are re-using the ladders from the old STAR SSD (SVT project)
- Radius is about the same as before (22 cm)
- Electronics are being upgraded to reach 1 kHz
- Mechanical mounting scheme is new
- Cooling scheme is similar but now more efficient



- Previously reviewed by the RHIC Safety Committee Sept. 23, 2002

The (proposed) SSD Removed from STAR

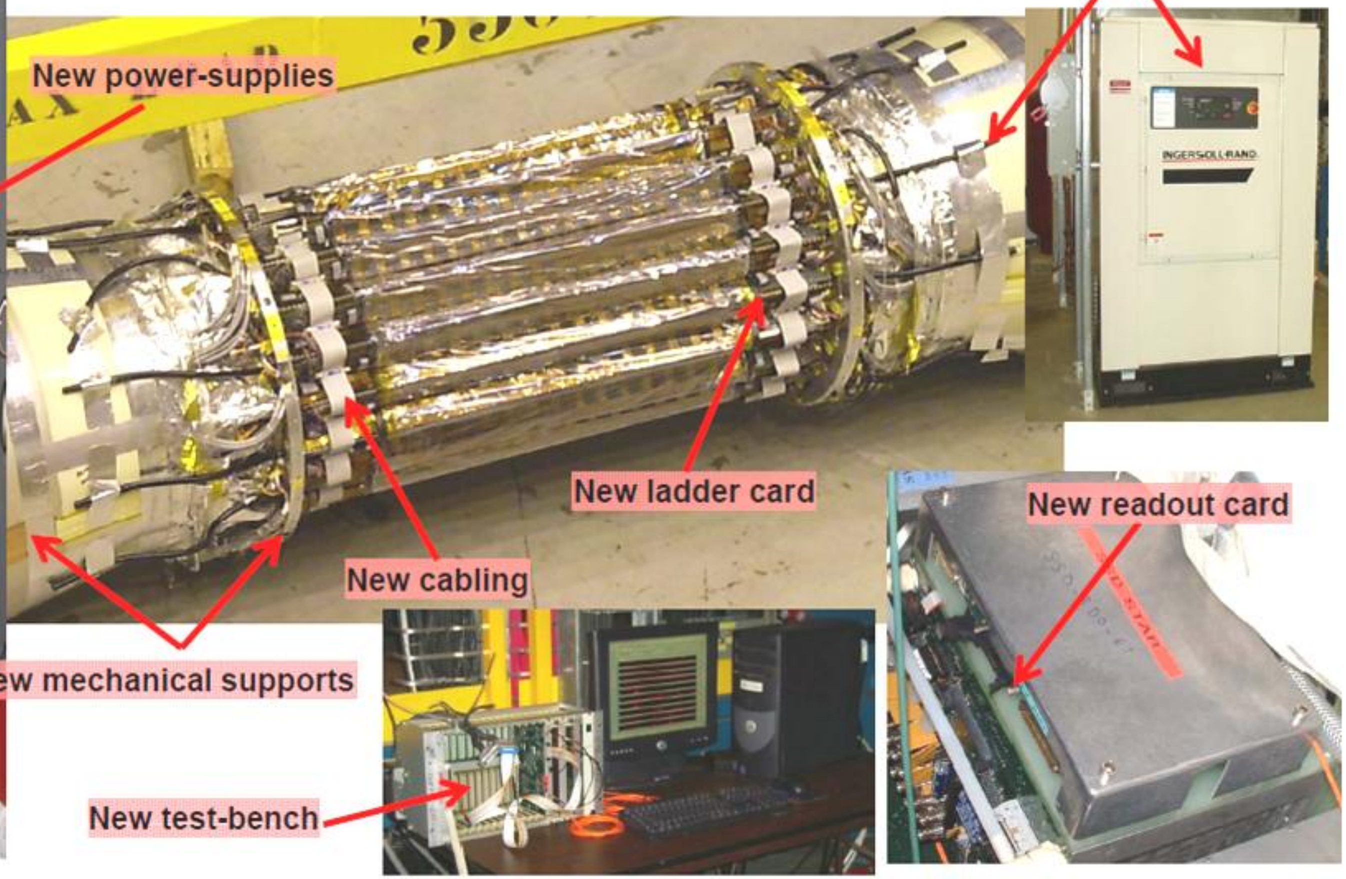


The individual ladders are being recycled from a previous STAR vtx detector

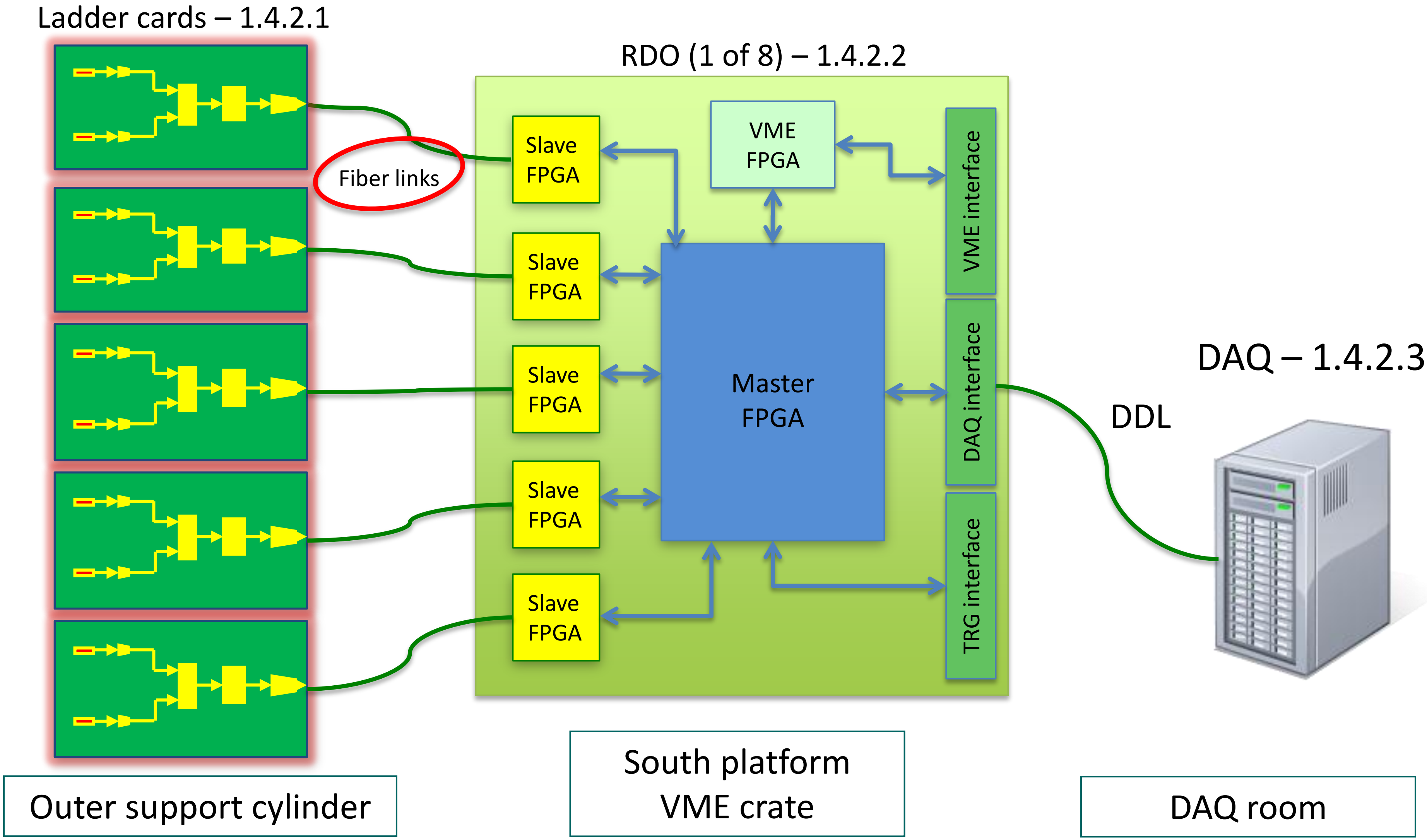
A Summary of Modifications to the old SSD

STAR HFT

- Use existing SSD silicon sensors
- Upgrade readout from 200 Hz to 1 kHz
- Improve reliability of sub-systems

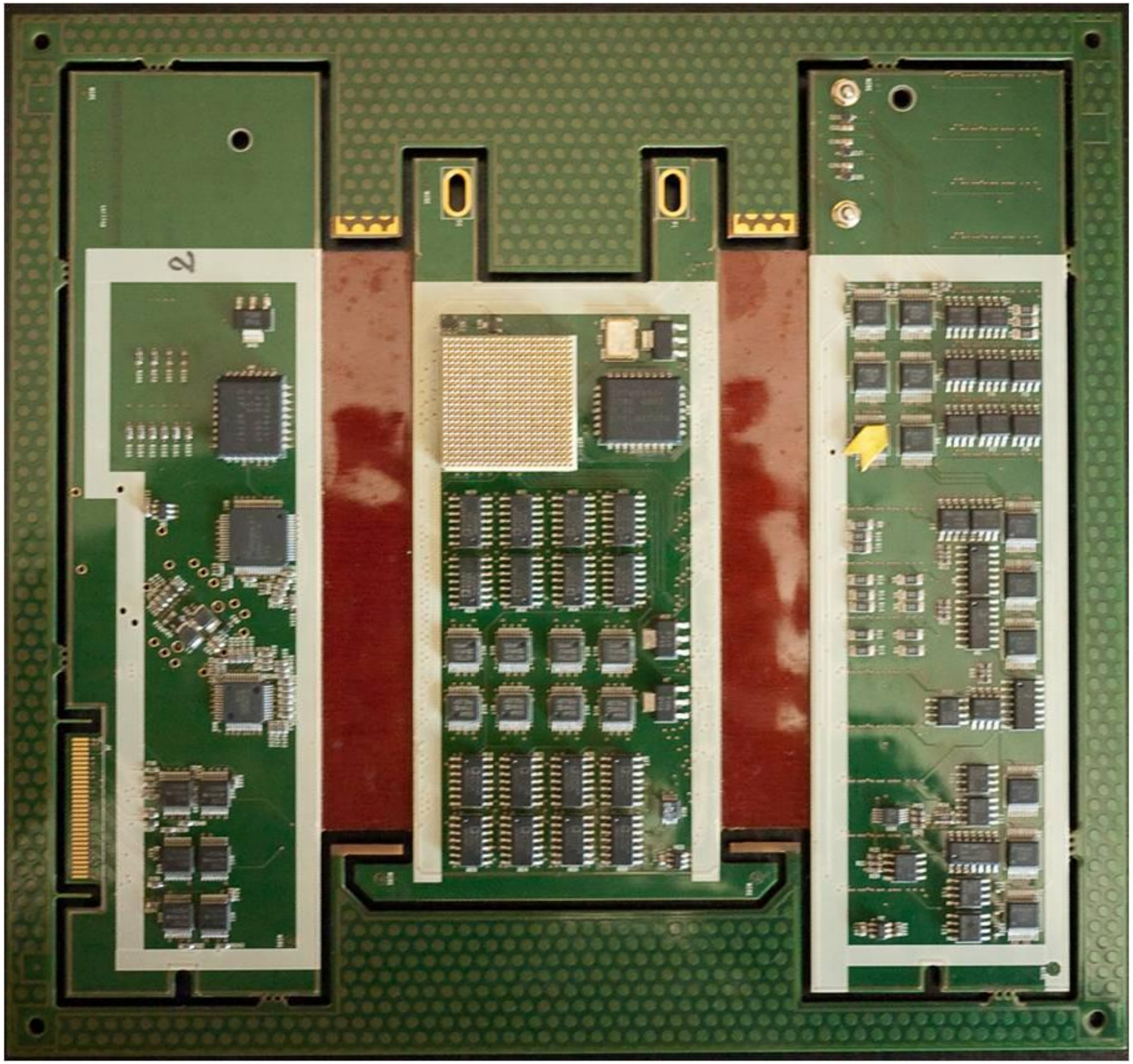


Readout Electronics – the heart of the upgrade



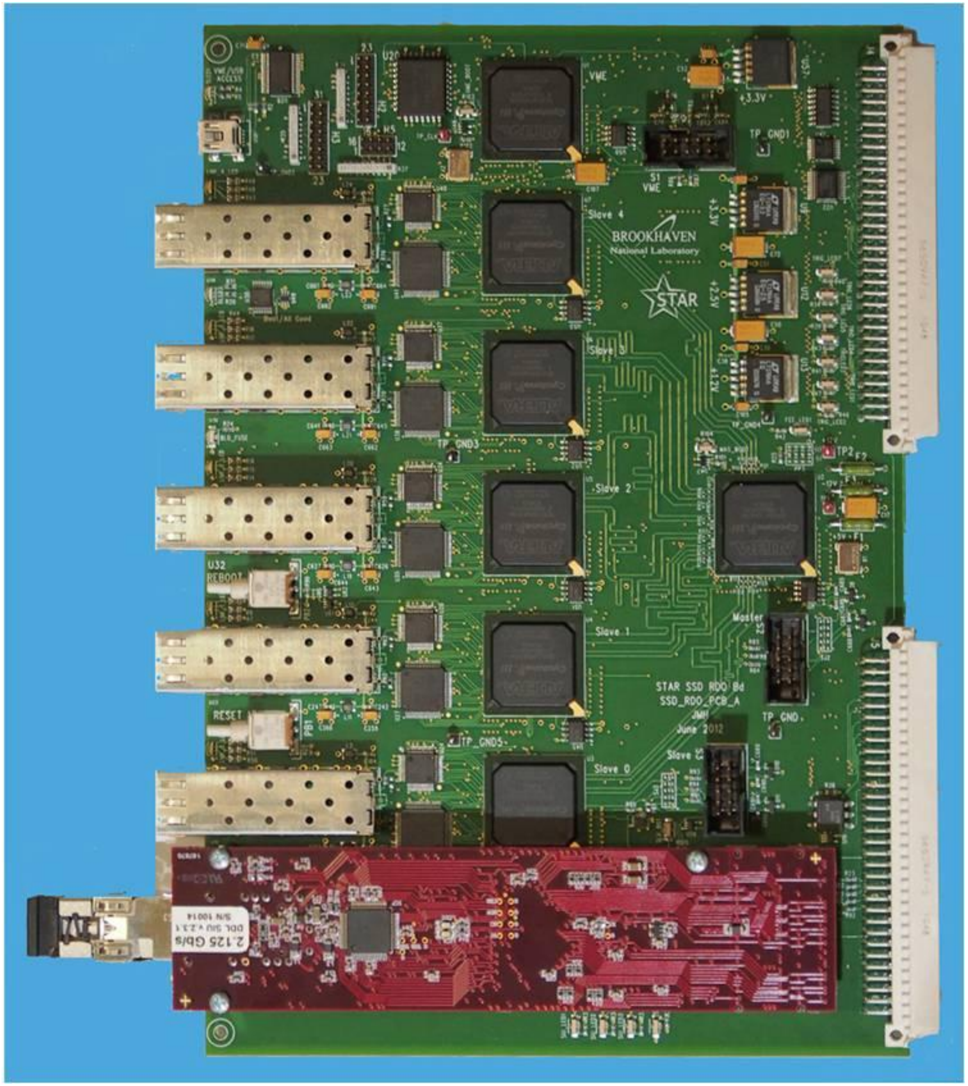
Ladder Card Prototype

STAR HFT



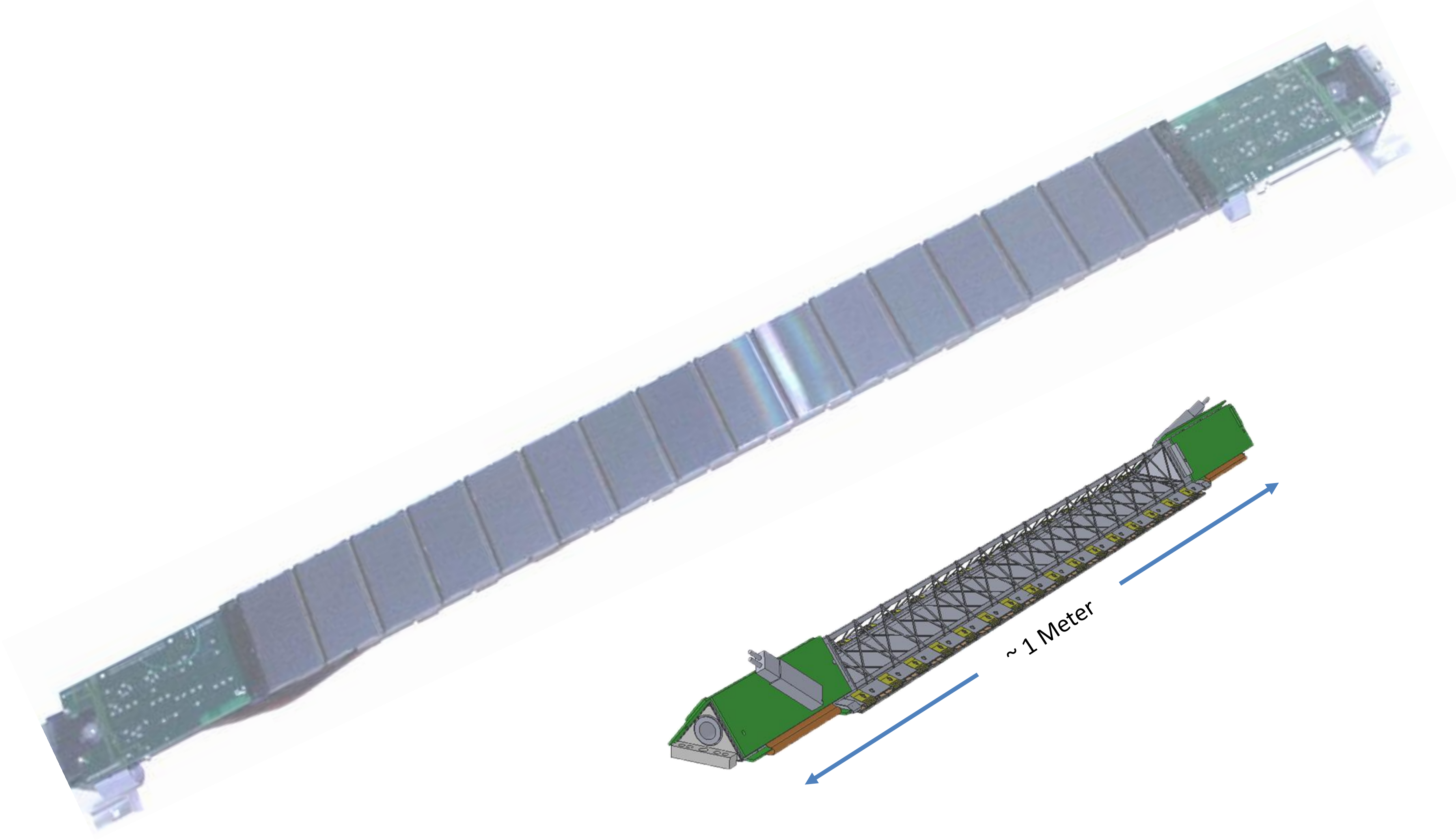
- A new layout with FGPA and ADCs
- Fast and efficient
- Power in:
  - Power in on Cu clad Al cables
  - Polyfuses (0.1 A) on ladderboard protect remote sense lines in cable (0603L010)
- Data out:
  - Fiber Optic connections to RDO, even JTAG goes over Fiber
- Use existing flex/ribbon cables connection to modules on ladder

Readout board



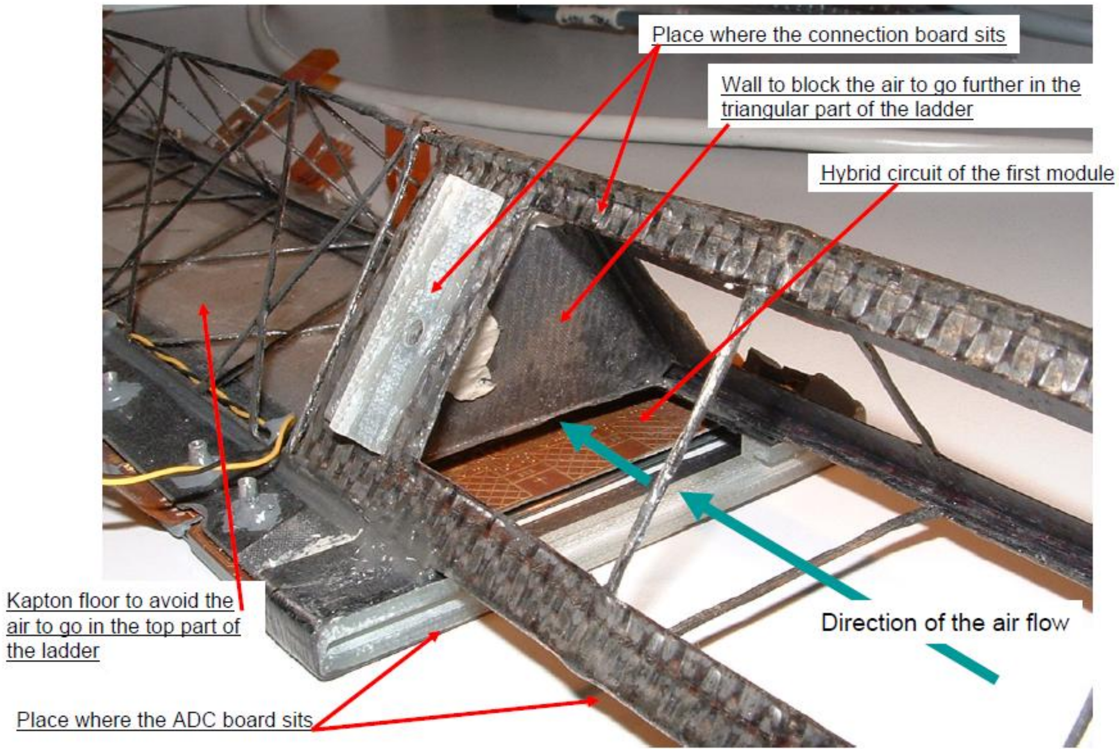
- Interface of the ladders to :
  - Slow control
  - Trigger
  - Daq
- One RDO services 5 ladders
- Located on the South Platform
- Rack mounted in a VME crate
- Air cooled

Focus on the Ladder

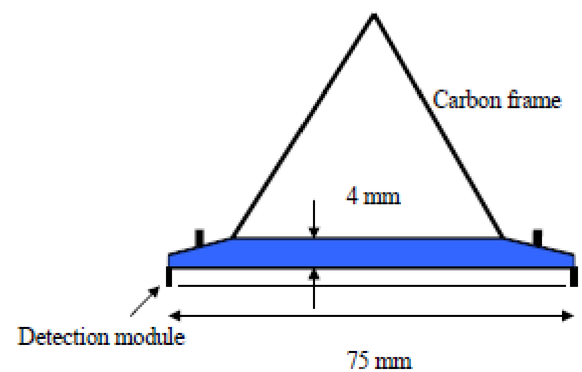


Ladder Structure

STAR HFT



- Mechanical parts of the ladders built of carbon fiber composite
- Shape is determined by location of Si module and path for air
- Air Cooling - Air enters the ladder through an ~ 1 cm orifice near LB
- The air flow is blocked by a 'wall' to force the air over the Si detectors

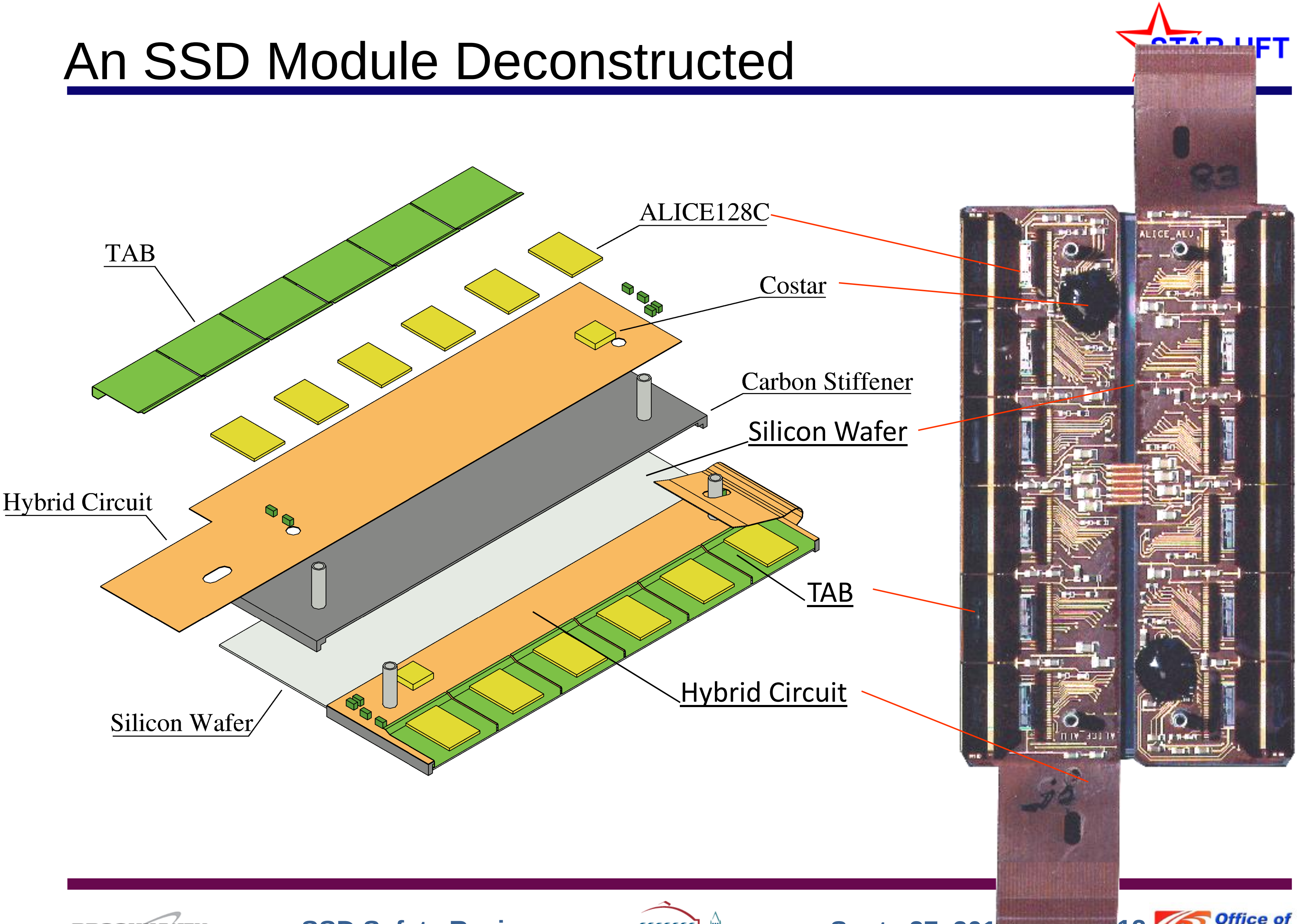


Ladder materials

STAR HFT

Module				*
Ladder	Upper part	Upper part		Carbon epoxy fiber
		Inside Deflector	Deflector	Carbon epoxy fiber
			Glue	Araldite 2013
		Inside stiffener	Stiffener	Carbon epoxy fiber
				Araldite 2013
		C2D2 board support		Glass epoxy fiber
	Base	Wings		Carbon epoxy fiber
		Central part		Kapton
		ADC board support		Carbon epoxy fiber/ Glass epoxy fiber
	Glue			Araldite 2013
Glue				Araldite 2013
Boards	ADC board			Glass epoxy fiber/Copper/ Standard electronic components and connectors
	C2D2 board			Glass epoxy fiber /Copper / Kapton / Standard electronic components and connectors
	Bottom Insulation foam			PVC
Cables	Module to C2D2 cable			Kapton/Aluminum
Cooling	Connectors			Polyacetal
	Shielding			Mylar

An SSD Module Deconstructed



Module materials

STAR HFT

Wafer				Silicon
Hybrid	Printed circuit	Flexible circuit		Kapton/Copper
		A128C chip	chip	Silicon
			A128C glue	Silver silled epoxy paste H20E
		Costar chip	chip	Silicon
			Chip coat	Namics G8345 (epoxy based)
			wire bonding	Aluminum
		Passive components	SMD components	
			Glue	Silver silled epoxy paste H20E
	Stiffener	Stiffener		Carbon fiber/Epoxy
		Pins		Aluminum
		Glue		Epoxy Araldite 2014
	Glue (flex on stiffener)			Epoxy Araldite 2014
TAB	TAB			Kapton/Copper
	Chip coat			Namics G8345 (epoxy based)
Glue (wafer on hybrid)				Silicon RTV 162

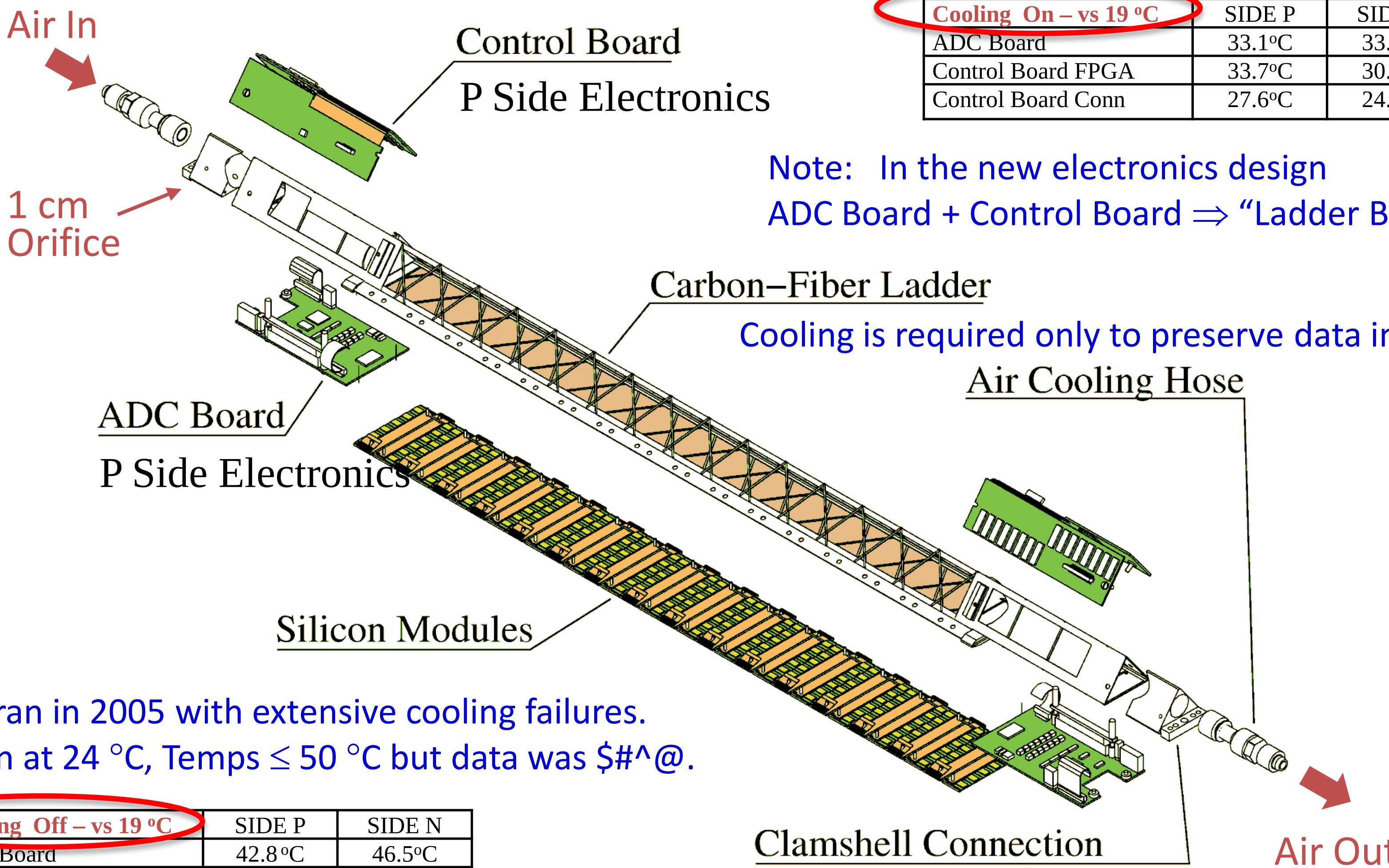
The SSD is air cooled (actually vacuum drawn)

STAR HFT

Cooling On – vs 19 °C	SIDE P	SIDE N
ADC Board	33.1°C	33.2°C
Control Board FPGA	33.7°C	30.7°C
Control Board Conn	27.6°C	24.5°C

Note: In the new electronics design
ADC Board + Control Board ⇒ "Ladder Board"

Cooling is required only to preserve data integrity

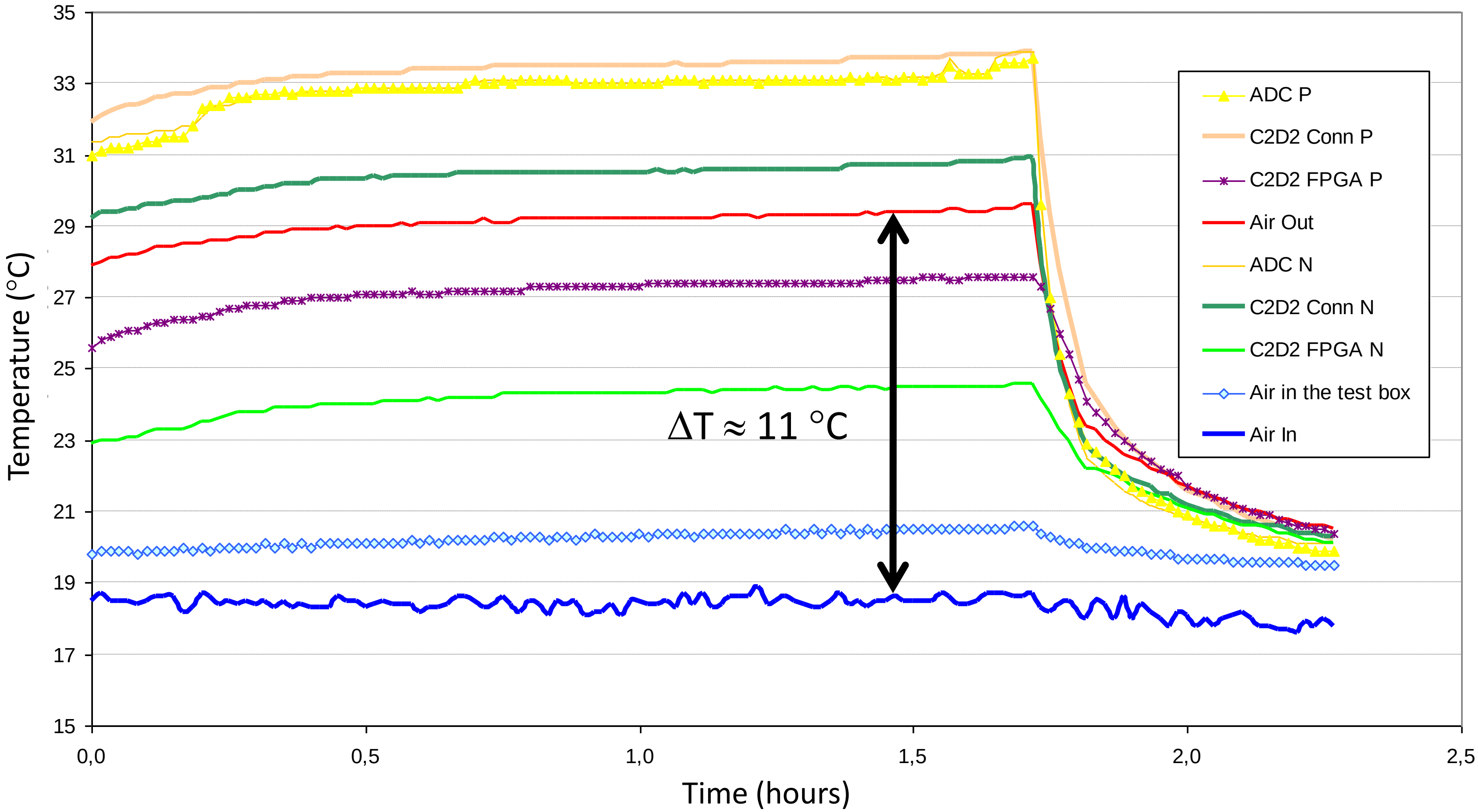


We ran in 2005 with extensive cooling failures.
Air in at 24 °C, Temps ≤ 50 °C but data was $#^@.

Cooling Off – vs 19 °C	SIDE P	SIDE N
ADC Board	42.8 °C	46.5°C
Control Board FPGA	34.8°C	36.5°C
Control Board Conn	45.2°C	45.4°C

Performance of Cooling System on Ladder #0

STAR HFT



Measurements confirm that the majority of heat from the ladder is transferred to the cooling air stream. The system is efficient; theory works.

New Electronics – New Expectations

STAR HFT

FEE POWER	Number of elements	Predicted Power	**Measured Power**
Detection Module w/ parallel readout	16 per 1adder	720 mW per module	
TOTAL FEE		**11.5 W**	

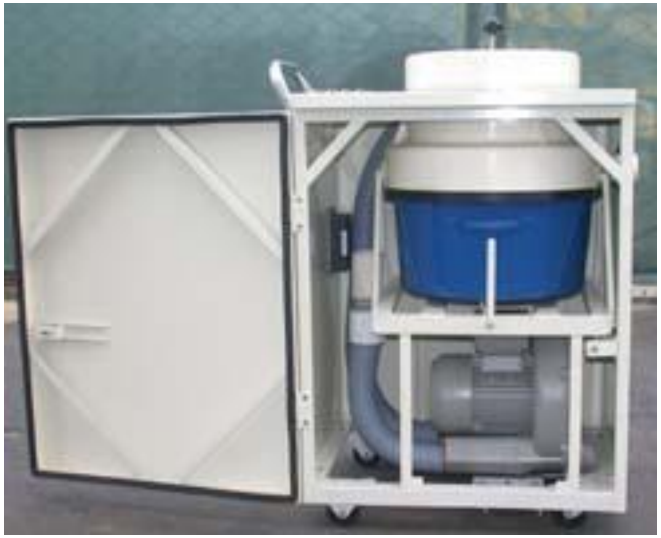
New Electronics Boards	Number of elements	Predicted Power	**Measured Power**
Ladder Boards	2 per Ladder	6.7 W per card	
Total Electronic Boards/Ladder		**13.4 W**	

Total Consumption: 25 Watts per Ladder
24 watts typical / 26 watts max. Previously 16 Watt average per ladders.

- 25 Joules into 1 liter of air suggests a ΔT of ~ 21 degrees °K at the old flow rate of 1 liter/sec (ambient air is 24° so total is 45°, which is in the danger zone).
  - Heat capacity of lab air is 0.0012 J / cm^3 / °K
- So to achieve the same ΔT as before, we need 1.6 liters/second of air flow with a velocity of 0.8 m/sec near the ladder boards and 5.4 m/sec over the Si detectors. Simple estimate of cooling failure $\Rightarrow$ 65 °C limit

We need more air than before, also careful about vibrations

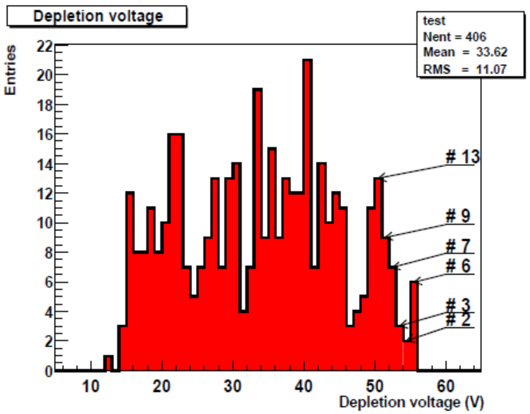
More Air … is available

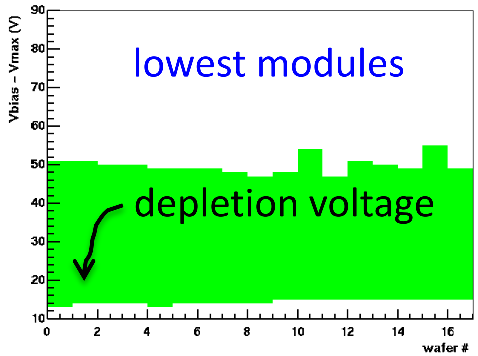


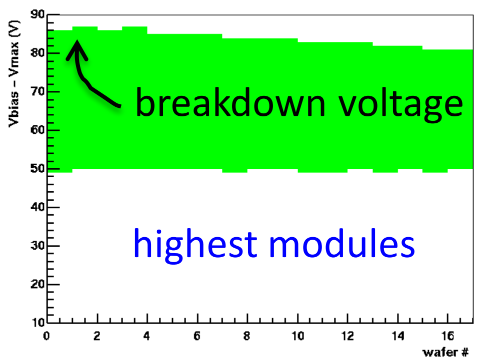
- The wood products industry uses high volume vacuum sources to clear wood chips from around saws and lathes. A commercial line of vacuum sources that provide vacuum with more flow and pressure than we need.
- Designed for continuous operation. Runs on 3 phase 240 VAC.
- We have tested the 1.2 kW model. It is ideal for our purposes. (Previously was 76 kW)
- Will be located on the North Platform at STAR
- Exhaust stream is easily accessible for sniffing, if it is useful.

http://www.dustcollectorsource.com

Bias Voltage for the SSD – grouped by ladder







name	depletion voltage (V)	breakdown voltage (V)
star_015	19	49
star_026	26	61
star_093	20	57
star_050	22	60
star_096	22	56
star_097	21	**39**
star_103	14	48
star_106	14	46
star_111	18	52
star_115	**32**	61
star_132	26	58
star_237	25	56
star_280	15	47
star_107		
star_108		
star_046	22	60

- The modules were sorted and grouped by operating point to form full ladders (16)
- The lowest depletion voltage (out of 406 modules) is 13 V
- The highest breakdown voltage is 86 V
- Typical operating voltage is < 50 V
- Low current, typically 20 μA

We will exceed 50 V on a few ladders … but always < 100 V

Please excuse the interruption …

while we change speakers

Power Requirements & Cable Design

STAR HFT

	-2 V	+2 V	+5 V
typical	870 mA	2172 mA	909 mA
max	883 mA	2186 mA	1357 mA

Current for one ladder end (each Nicomatic Connector) from “star_ssdU_v14” (C. Renard)

	Bias
typical	16*5 μA
max	16*10 μA

Bias current for one ladder

SSD Cable Design Calculator (G. Visser)

				INSUL_T=	0.014 inch						INSUL_T=	0.011 inch					
				LENGTH=	13.9 feet						LENGTH=	85 feet					
				Inner cable							Outer cable						
Service	Vload	Iload	Pload	strand	nStrands	cond, in2	total, in2	R	IR	I2R	strand	nStrands	cond, in2	insul, in2	R	IR	I2R
-2	2.5	2.2	5.5	28CCAW	7	0.000873	0.002955	0.200557	0.441226	0.970697	26CU	7	0.00139	0.003224	0.497857	1.095286	2.409629
+2	2.2	0.9	1.98	28CCAW	7	0.000873	0.002955	0.200557	0.180501	0.162451	26CU	7	0.00139	0.003224	0.497857	0.448071	0.403264
+5	5	1.4	7	28CCAW	7	0.000873	0.002955	0.200557	0.28078	0.393092	26CU	7	0.00139	0.003224	0.497857	0.697	0.9758
BIAS	200	0	0	28CCAW	1	0.000125	0.001295	1.4039	0	0	32CU	7	0.000352	0.001463	1.967143	0	0
+2 sense	2	0	0	28CCAW	1	0.000125	0.001295	1.4039	0	0	32CU	7	0.000352	0.001463	1.967143	0	0
-2 sense	2	0	0	28CCAW	1	0.000125	0.001295	1.4039	0	0	32CU	7	0.000352	0.001463	1.967143	0	0
+5 sense	5	0	0	28CCAW	1	0.000125	0.001295	1.4039	0	0	32CU	7	0.000352	0.001463	1.967143	0	0
		POWER=	28.96			DIA=	0.189103		POWER=	3.05248			DIA=	0.198832		POWER=	7.577386

Connectors at ladderboard

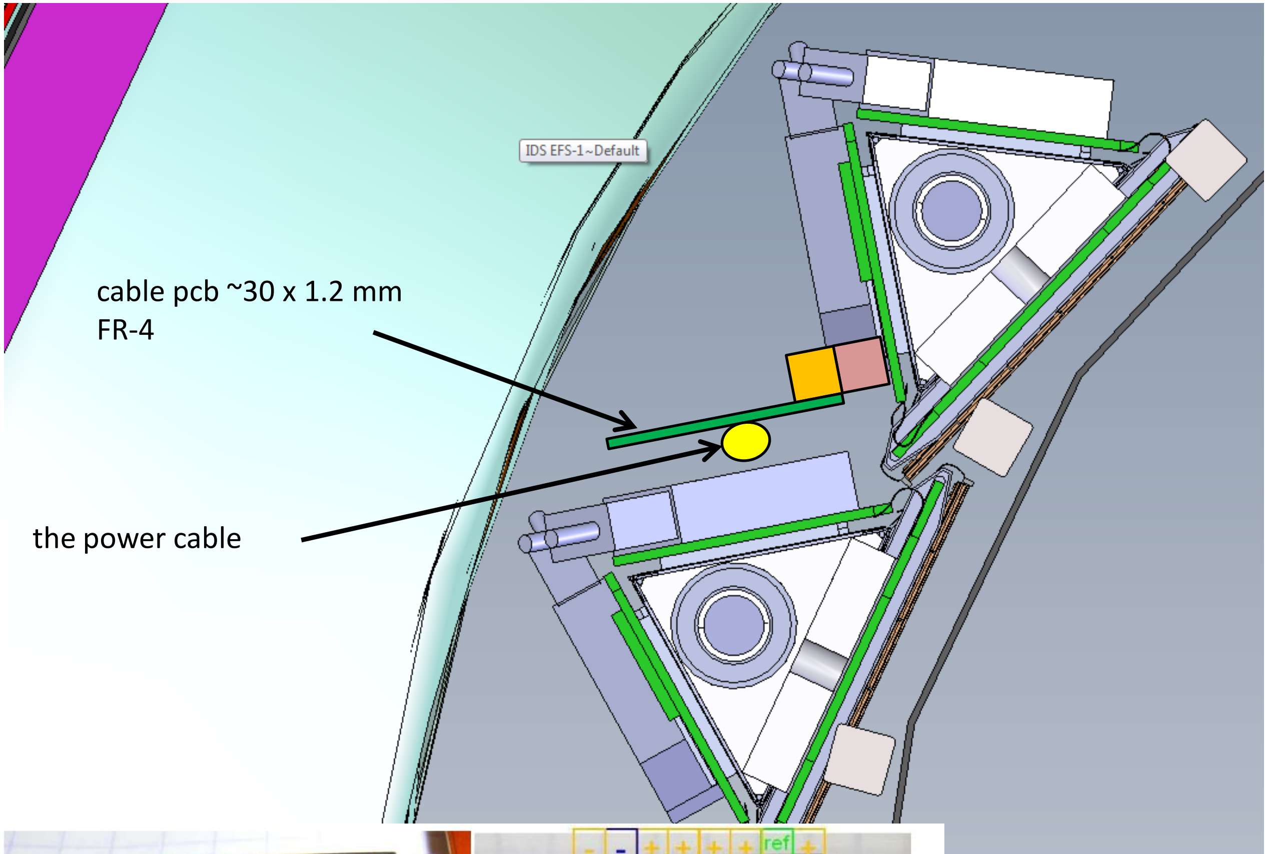


Figure 17: *Nicomatic power connector cabling*

Nicomat Connectors and auxiliary card
Note that Bias supplied to one ladder end, only, due to jumper across ladder

Connectors at ladderboard

STAR HFT

MICRO-CONNECTOR CMM SERIES

- Miniature, low mass connector is a key requirement for the SSD
- Operating at 2.2 A 100 V, well within ratings 3 A 800 V

CMM Specifications (with LF contacts)

MATERIALS

INSULATOR: Special PPS (Polyphenylene Sulfide Fiberglass filled thermoplastic) UL 94-V0

- Radiation resistance
- No humidity absorption
- Oxygen free

Note : PPS characteristics are recognized for space applications

P.C. LF CONTACTS :

Male:
Tail : copper alloy / Ni + Au flash 0,1 μ
Contact area : copper alloy / Ni + Au > 1 μ

Female:
Body : copper alloy / Ni + Au 0,2 μ
Socket : beryllium copper / Ni + Au > 1,25 μ

CRIMP LF CONTACTS :

Male:
Body : copper alloy / Ni + Au > 1 μ

Female:
Body : copper alloy / Ni + Au > 0,2 μ
Socket : beryllium copper / Ni + Au > 1,25 μ

FIXING HARDWARE:

- Jackscrew: Stainless steel.
- Latch : Beryllium copper/plated nickel (CMM 100/200 series only)

ELECTRICAL

• All contacts	3 A max. @ 25°C 2.2 A max. @ 85°C
• Working voltage (sea level)	Tested at 800 V DC
• Proof voltage	Tested at 1 200 V DC
• Contact resistance (initially)	max. 10 mΩ
• Insulation resistance	1 000 MΩ min.

Power cables (inner)

CALMONT Wire & Cable

3007-5267-06-12
Composite cable consiting of 15 primary wires. Primary Wires 1-7:
20 AWG 7/28 Copper Clad Aluminum insulated with Silicone to a nominal OD of 0.062" (Color: All Black). Primary Wires 8-15:
28 AWG Solid Copper Clad Aluminum insulated with Silicone to a nominal OD of 0.033" (Color: All Black). Cabling: 15 Primary wires cabled together with a 20 AWG 7/28 Copper Clad Aluminum drain wire using a left hand lay, and wrapped with an Aluminum/Mylar Tape. Jacket: Silicone to a nominal wall of 0.020", and a nominal OD of 0.270" (Color: Yellow).

- Construction similar to FGT inner cable, except all silicone (FGT used FEP on signal wires for low loss signal transmission, not relevant to SSD), and stranded 20AWG wire (FGT used solid 22AWG wire, which was hard to work with)
- Sample will be submitted for burn test, as was done for FGT, we expect no problems owing to similar construction
- Power dissipation 7mW/cm under normal condition, 46 mW/cm at 100% fuse rating current (4A).
- Length 4.2 m

Power cables (outer)

STAR HFT

- Virtually identical to FGT outer power cable, Alpha # 518050, except 2 more 18AWG conductors are needed in SSD case
- Sample will be submitted for burn test, as was done for FGT, we expect no problems owing to similar construction
- Power dissipation 3mW/cm under normal condition, 18 mW/cm at 100% fuse rating current (4A)
- Length 26 m

ALPHA WIRE
CUSTOMER PRODUCT SPECIFICATION

Part Number: 518050	**Issue:** 1
Page 1 of 2 Pages	**Issue Date:** 3/29/2010
	Effective Date: 3/29/2010

A. Construction — Diameters (In)

1) Component 1 — 4 X 1 PAIR
   a) Conductor — 24 (7/32) AWG TC — 0.024
   b) Insulation — 0.009" Wall, Nom. PVC, Semi Rigid — 0.042
      (1) Color Code — Alpha Wire Color Code B

Pair	Color	Pair	Color	Pair	Color
1	WHITE-BLACK	3	WHITE-RED		
2	WHITE-BROWN	4	WHITE-ORANGE		

   c) Pair — 2/Cond Cabled Together
      (1) Twists: — 9.6 Twists/foot (min)
2) Component 2 — 4 X 1 COND
   a) Conductor — 18 (7/26) AWG TC — 0.048
   b) Insulation — 0.011" Wall, Nom. PVC, Semi Rigid — 0.070
      (1) Color Code — Alpha Wire Color Code D

Cond	Color	Cond	Color	Cond	Color
1	BLACK	3	WHITE		
2	RED	4	GREEN		

3) Cable Assembly — 8 Components Cabled
   a) Twists: — 4.4 Twists/foot (min)
   b) Core Wrap — Clear Mylar Tape, 25% Overlap, Min.
4) Shield: — Alum/Mylar Tape, 25% Overlap, Min.
   a) Foil Direction — Foil Facing In
   b) Drain Wire — 20 (10/30) AWG TC
5) Jacket — 0.025" Wall, Nom.,PVC — 0.290 (0.306 Max.)
   a) Color(s) — SLATE
   b) Print — ALPHA WIRE-* P/N 518050 4PR 24 AWG 4C 18 AWG EXXXXXX 75C SHIELDED CMG (UL) C(UL) FT4 ROHS
      * = Factory Code
      [Note: Product may have c(UL) or CSA markings depending upon plant of manufacture.]

B. Industry Approvals

1) UL — CMG — 75°C
2) CSA International — CMG — 75°C
   FT4
3) CE: — LVD 73/23/EEC Amendment 93/68/EEC

E. Electrical Properties — (For Engineering purposes only)

1) Voltage Rating — 300 V_{RMS}
2) Component 1
   a) Mutual Capacitance — 26 pf/ft @1 kHz, Nominal

Connectors at patch panel

STAR HFT

851

Current rating per contact

Size 20 = 7.5 A / ~~Size 16 = 13 A~~

Dielectric withstanding voltage

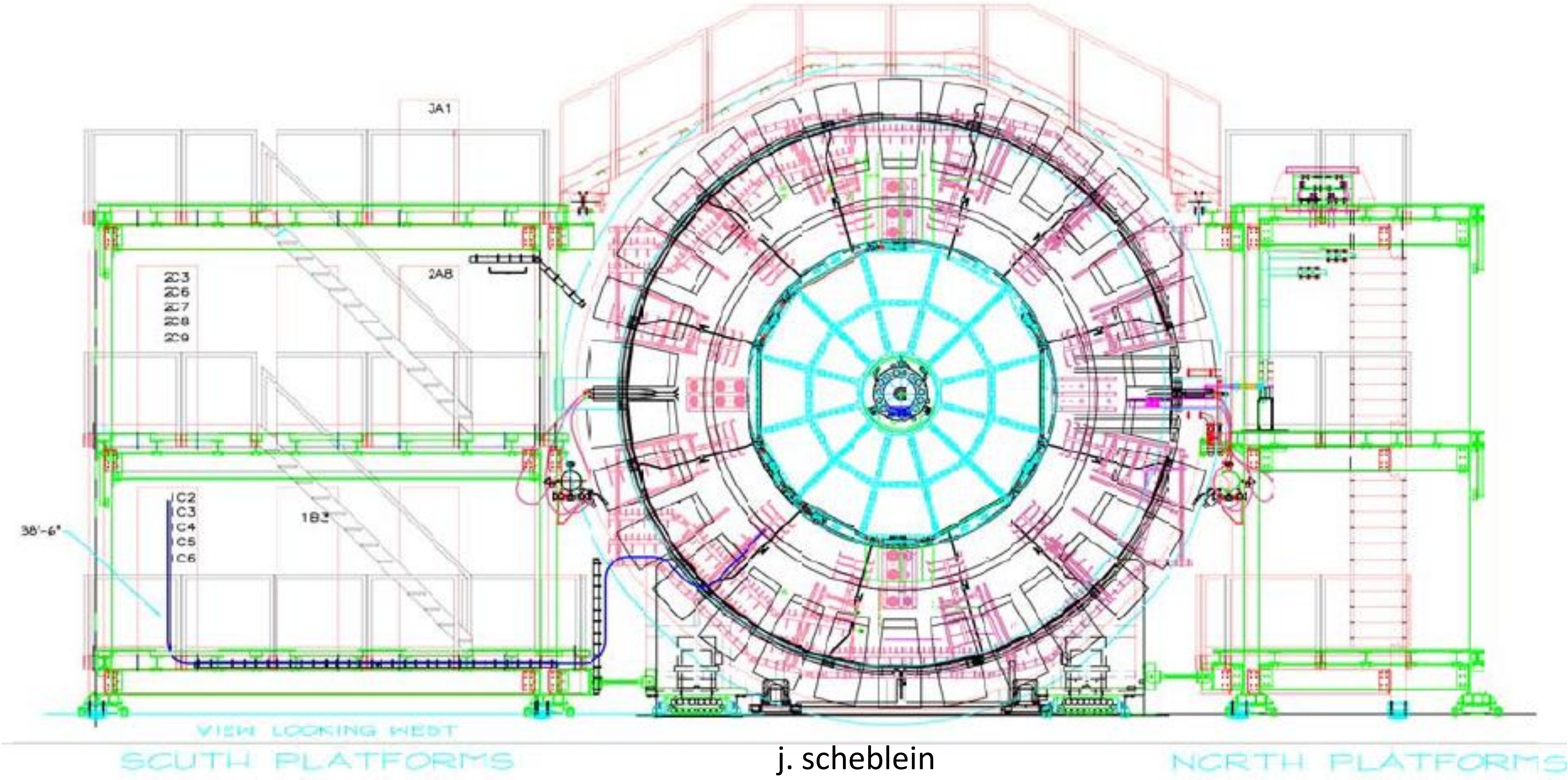
- *At standard pressure : mated and unmated connectors*

- 1500 Vrms between size 20 contacts (service 1)

Souriau # 85106EC1214S50

Souriau # 85100T1214P50

SSD Cable pathways on the platform



j. scheblein

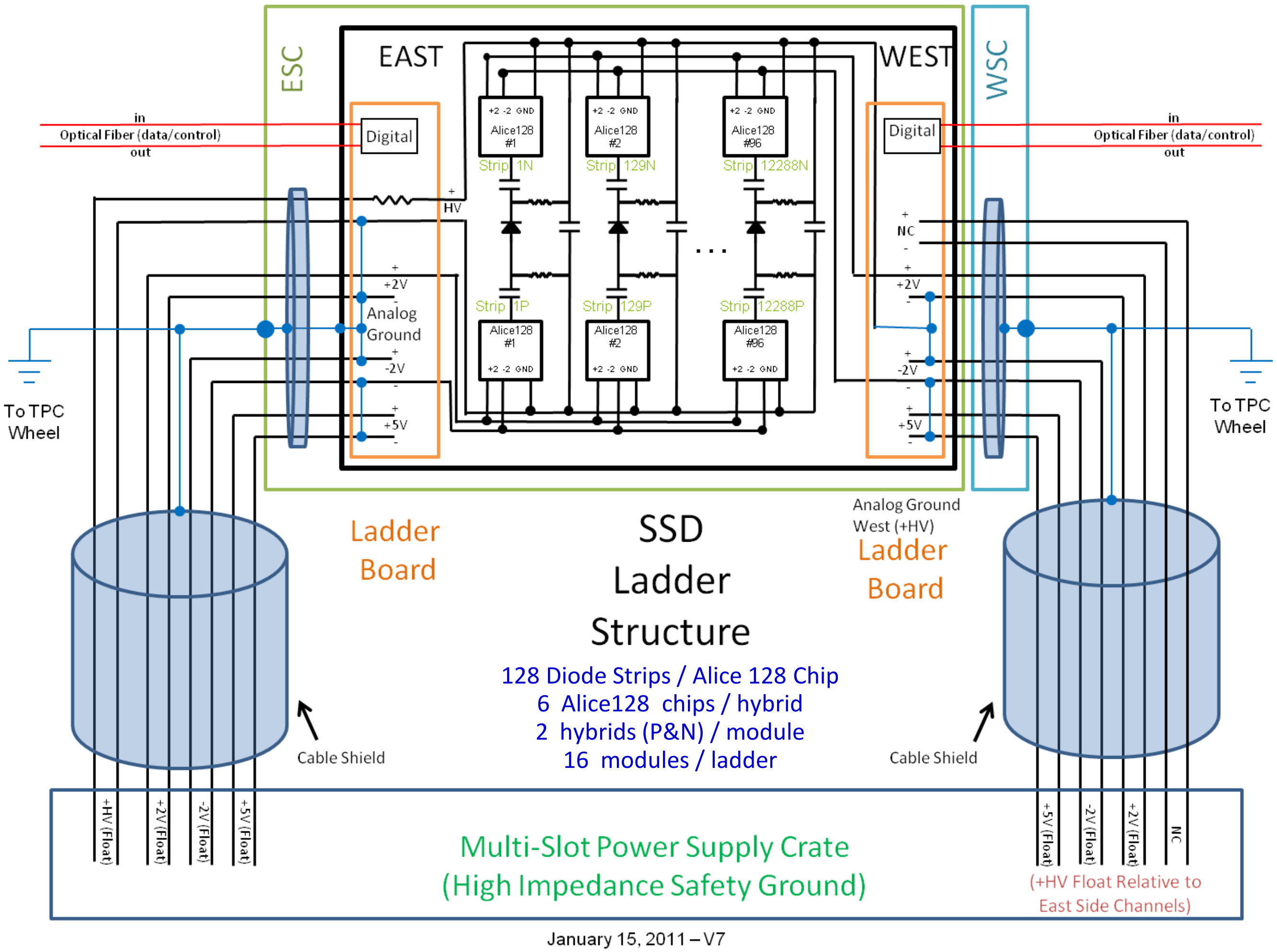
- Cable path from Rack 1C6 to PXL patch panel is 70 feet via shortest route
- This autumn, we must verify that there is space in these racks (and reserve!)
- Next most desirable path is longer … on the order of 100 feet

Power Supplies

- Wiener MPOD system selected for compatibility with FGT, IST, and MTD
- We will use rear facing MPOD crates with facilities for vertical cooling and fans (8U+1U)
- Choice for LV supply is
  - Wiener #MPV8008LI : 8 channels, 8 V, 5 A
- Choice for Bias supply is
  - ISEG #EHS F2 01-F: 16 channels, 100 V, 10 mA
- Cables connect through patch panels (not yet designed)
  - Mounted in rack with short connecting cables to power supplies
  - 4A fuses on all power lines, (Littelfuse #0451004, rated interrupt 300 A @ 32 VDC)
  - Connectors TBD

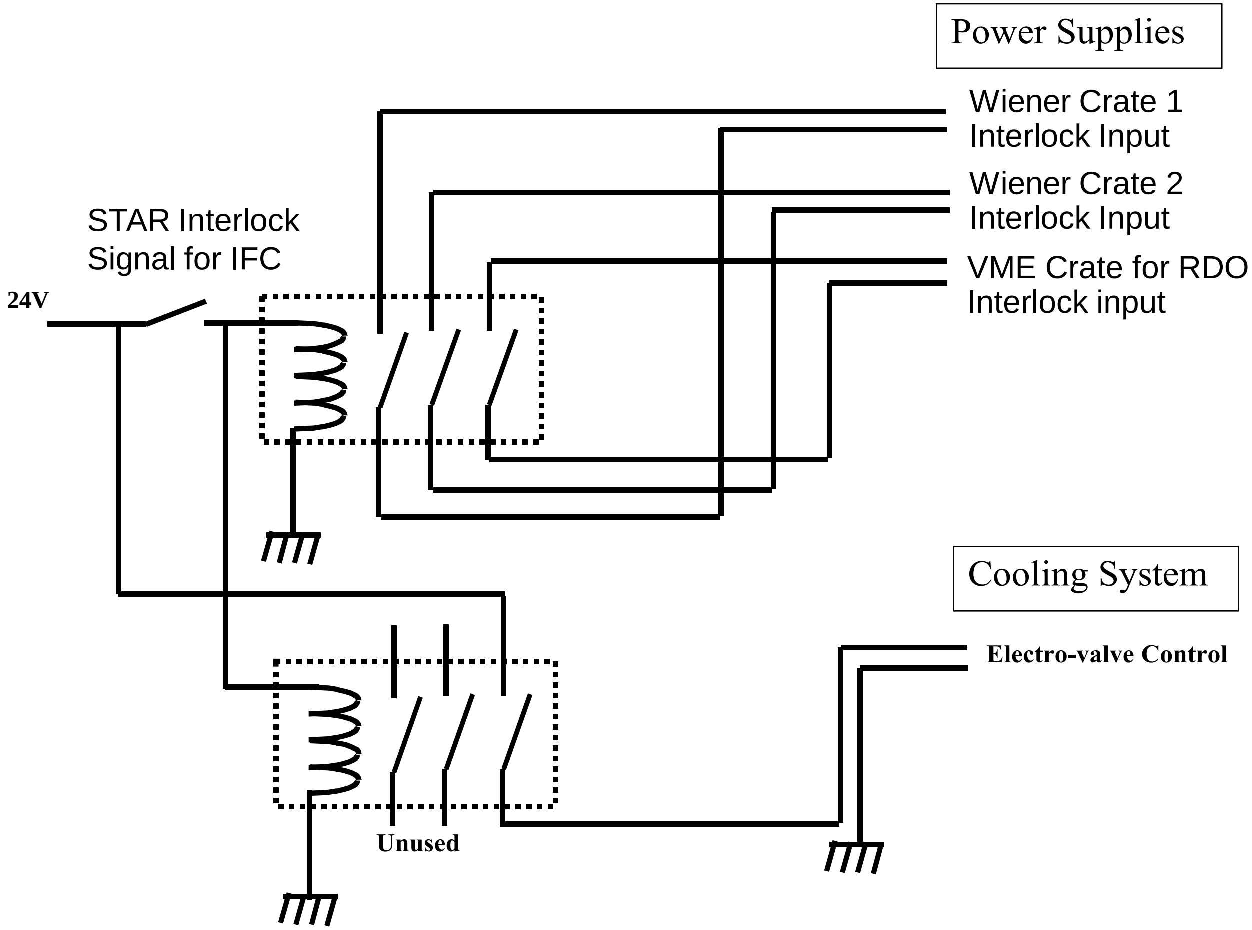
Grounding Plan

STAR HFT



- Digital signals over optical fiber
- Si modules biased to ~50 V
- Single point ground on East
- Ladderboard “ground” at west end held at bias potential (+50V typ.)
- Power supplies for +2, -2 and +5 are floating PS

Interlocks



24V generated by OMRON 24 V 100 W, UL508 (listing)/1950

Mechanical Engineering … much is done

Still To Do:

Split the shroud so it is easier to install the SSD ladders

Ladder Mounts

Air in and out for SSD vacuum

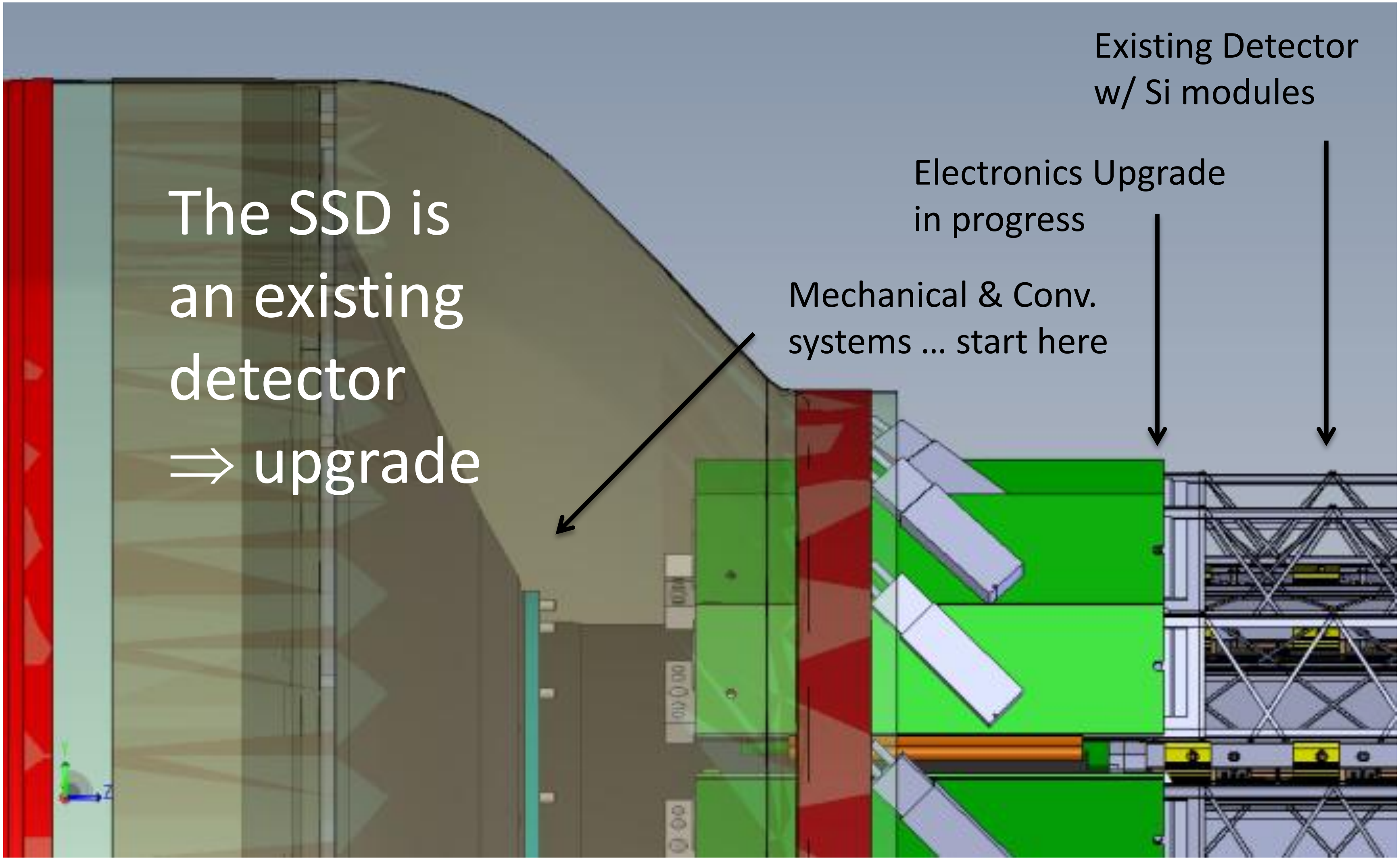
Cable routing under the shroud & ESC/WSC

The HFT Carbon Fiber Support Cylinders

OSC with shroud and mylar E&M shield installed in STAR

SSD (of course) not installed but this is where it will go

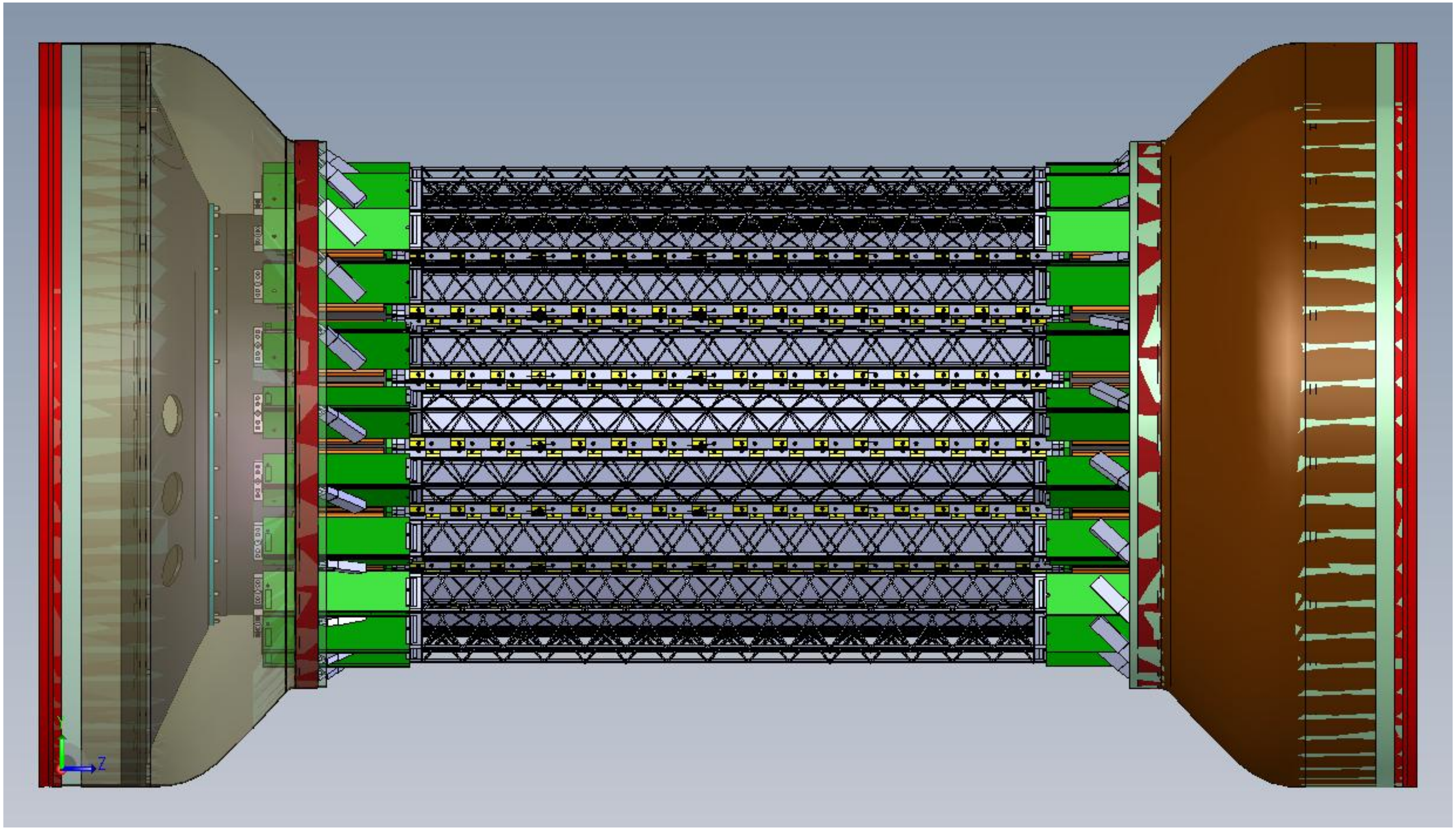
Summary



The SSD is an existing detector ⇒ upgrade
Existing Detector w/ Si modules
Electronics Upgrade in progress
Mechanical & Conv. systems … start here

Backup Slides

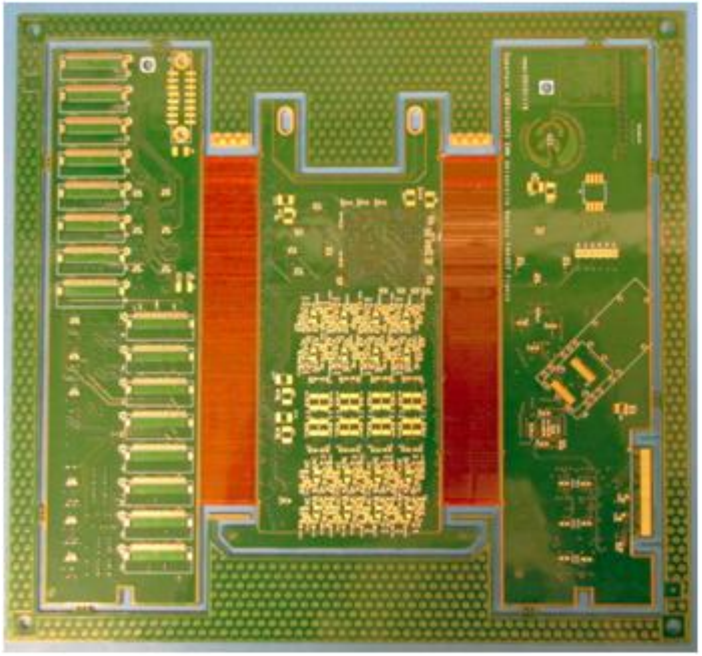
Schematic View of the SSD



Ladder Board Mechanical Detail

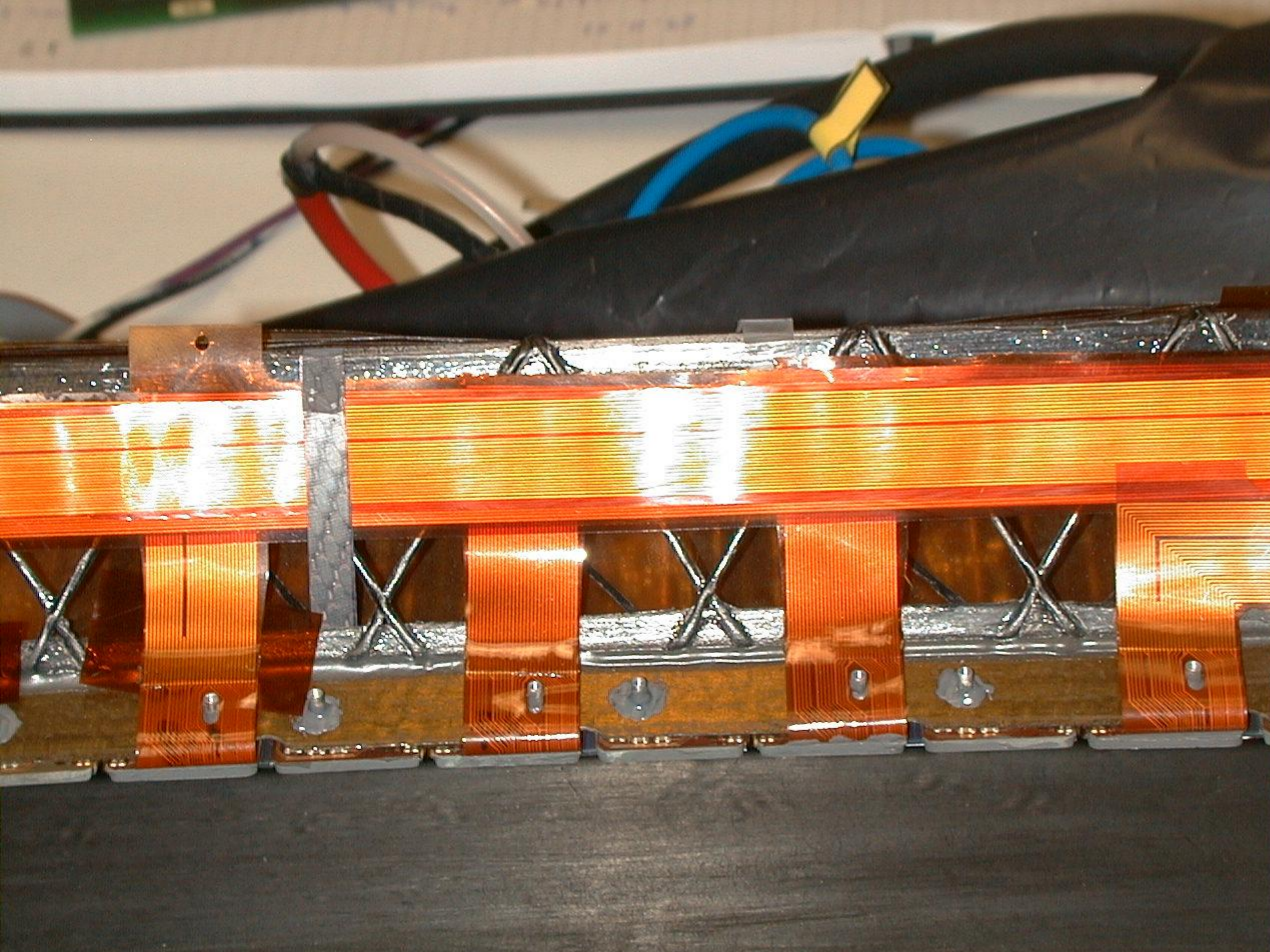
STAR HFT

- ✓Mechanical prototype
- ✓Electrical prototype
- In process of testing prototype Ladder Board
  - Problems were found which are being repaired

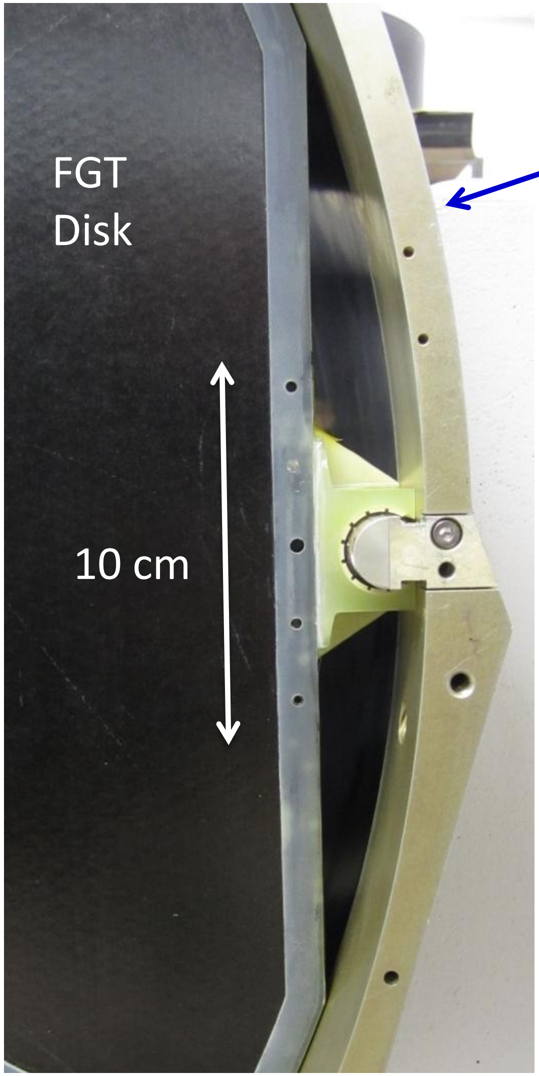


Prototype Ladder Board

Mechanical Dummy – Board is cut loose from its frame, then folded around the ladder end to form a triangle



Cable Trays

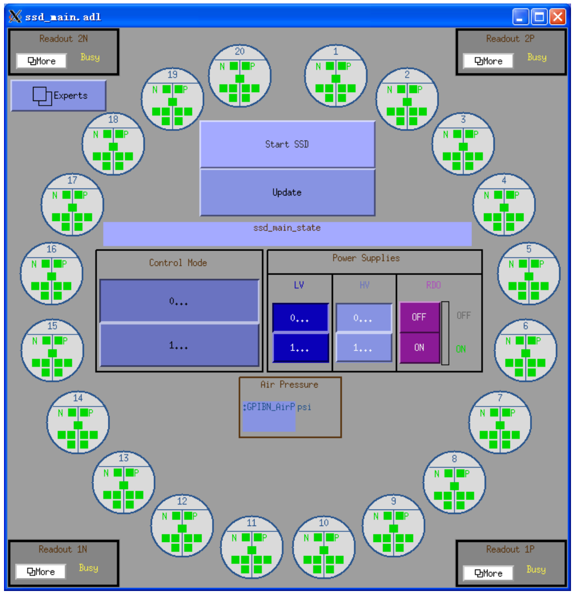


West Support Cylinder

- Cable tray needed above and below the FGT rail to hold 5 cables and 5 fiber pairs (5 ladders per tray, 10 ladders left, 10 ladders right, 20 total)
- Cable tray mounted to WSC
- Can only be installed after the FGT has been removed from STAR … part of summer 13 installation activities
- Not designed yet

Progress: Slow Controls and Conventional Systems

STAR HFT



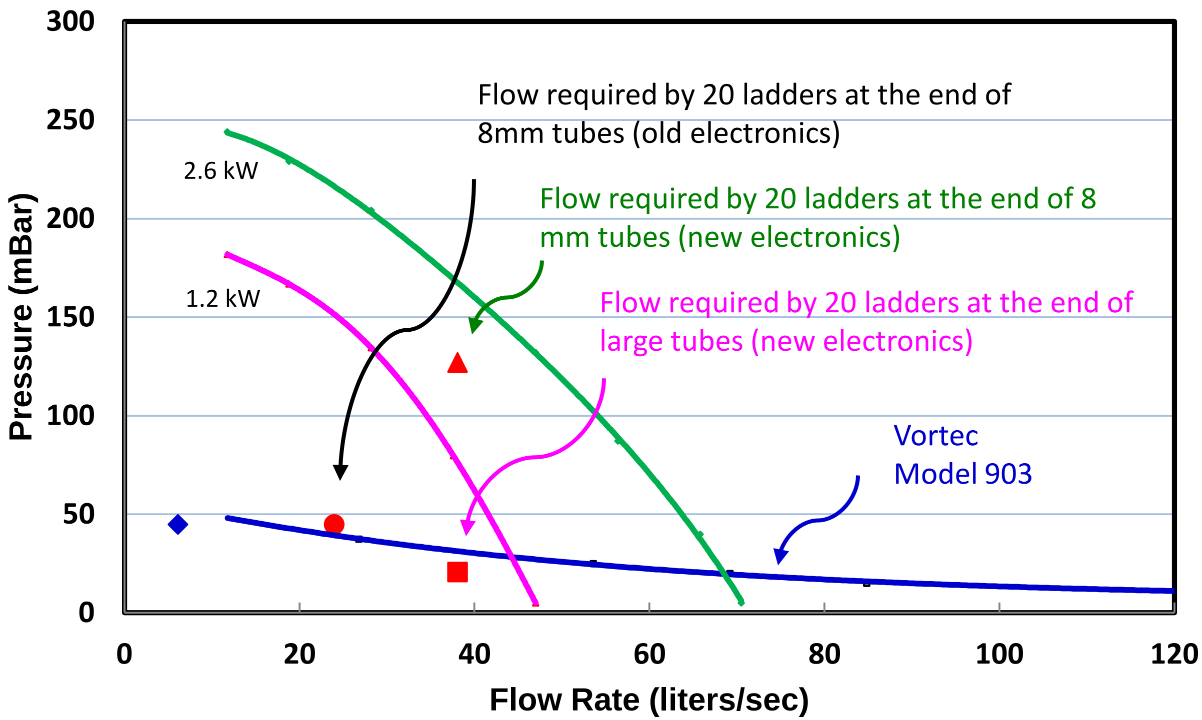
- Weihua Yan has developed a slow controls interface to the new Power supplies
- Working on the more complex problem of JTAG communication to the ladders
- Prototype quantities of PS and Power modules are in-house

Cooling system – vacuum

Instrumentation for cooling

Dust Collector Vacuum Sources

STAR HFT



'Large tubes' means 4 long tubes with 2.5 cm (ID) each, then distributed locally to 20 ladders without additional pressure drop

- A wide variety of options are available. Shown above are the vacuum curves for a 1.2 kW and a 2.6 kW vacuum system from a company in California. (Old system was 76 kW)

The airflow can be increased ~2x by using a bigger pump and larger tubes

Old Safety Review Slides

Sept. 23, 2002

Characteristics of the Cables: on the detector

STAR HFT

Cable name	AWG	Operating current	Operating Voltage	Manufacturer & part numb.	material	Voltage rating	Operating Temperature	Flammability rating
Power cables low volt. side	20	2 A	5 V	Alcatel Lyflex	PVC Copper	500 V	-10 C to +60 C	NF C 32-070 C2 CEI 332-1
Power cables high volt. side	20	2 A	35 V	Alcatel Lyflex	PVC Copper	500 V	-10 C to +60 C	NF C 32-070 C2 CEI 332-1
Sense cables low volt. side	24	0 A	5 V	Alpha wire 5599/5	PVC Copper Aluminium	300 V	-20 C to +80 C	UL VW1
Sense cables high volt. side	24	0 A	35 V	Alpha wire 5599/5	PVC Copper Aluminium	300 V	-20 C to +80 C	UL VW1
Signal & power cable	28	300 mA	0-5V	3M KU-KM PVV-SB	PVC Copper	300 V	-20 C to +60 C	UL VW1
High voltage cable	24	1mA	0-50V	Alpha wire 5092	PVC Copper	300 V	-20 C to +80 C	UL VW1

Characteristics of the connectors: on the detector

Taitek : power cable and HV cable

- number of pins — 8
- housing material : — Nylon
- temperature rating : — -40 C to +105C
- flammability rating : — UL 94V-2
- Voltage rating — AC 250 V rms
- current rating — 5 A

FCI : sense cable

- number of pins : — 6, double row
- temperature rating — -55C to +125 C
- flammability rating — UL 94V-0
- voltage rating — AC 1000 V rms
- current rating — 3 A

AMP : M series 14 position

- housings material : — phenolic
- temperature rating : — -55C to +150C
- flammability rating : — UL94V-0
- voltage rating : — AC 900 V,rms
- current rating : — 13 A

Characteristics of the cables: platform to the TPC wheel

STAR HFT

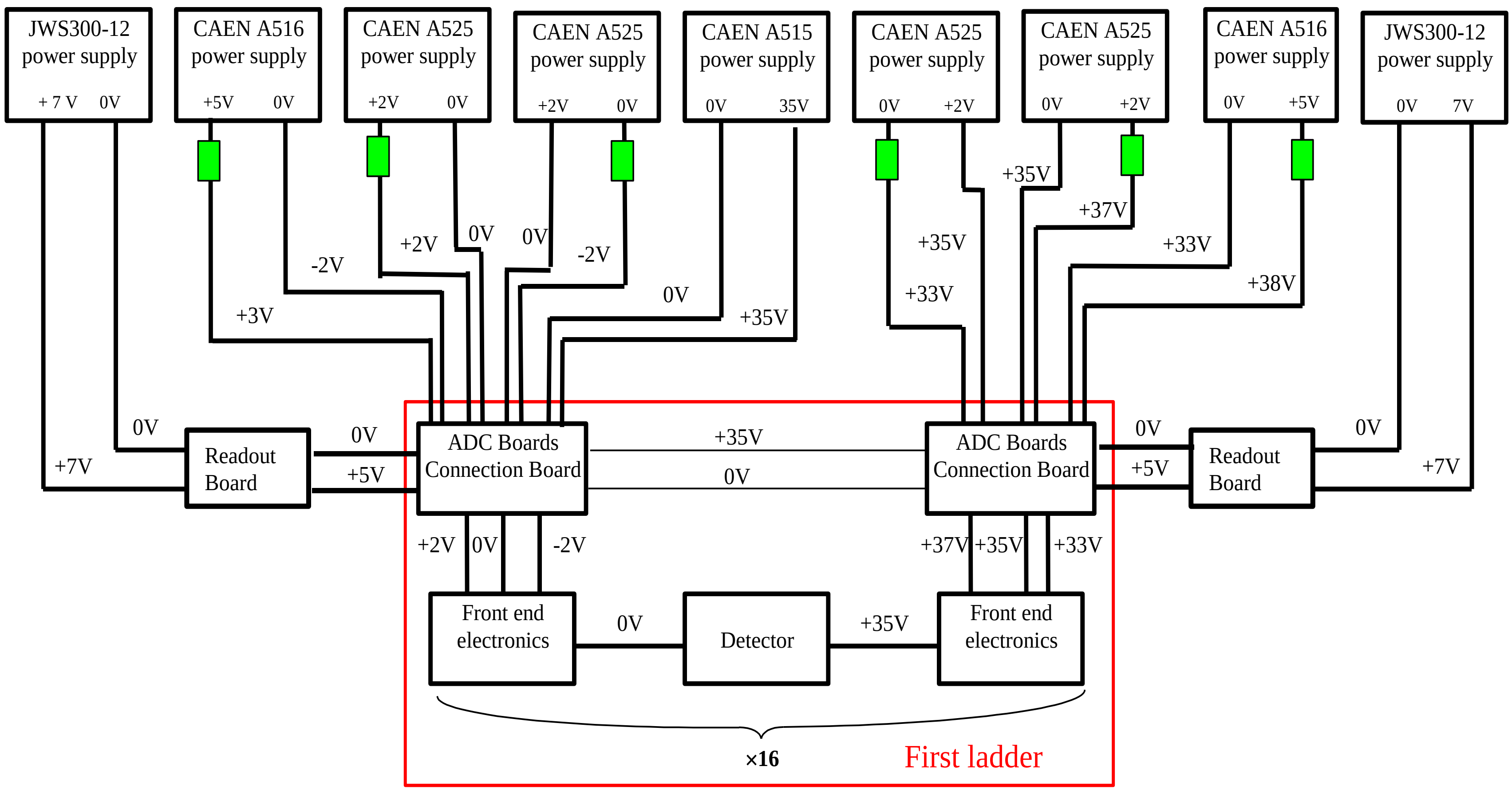
Cables	Nb cond	AWG	Manufacturer Part Number	Material	Operating Current	Operating Voltage	Voltage/ current Rating	Temperature Rating	Flammability Rating
Inside Rack Low & High Voltage	27	22	HELUKABEL LiY-CY 20070	Copper PVC	LV : 1A HV : 1mA	LV: 5V HV : 35V	300V / ?	-30°C 105°C	IEC 332-1
Readout board power supply	12	16	Hi-Flex-CY	Copper PVC	2A	5V	300V / ?	-30°C 70°C	IEC 332-1
Ladder power supply	12	16	Belden 8622	Copper PVC	LV : 2A HV : 1mA	LV : 5V HV : 35V	600V / 2A	80°C	UL 1581 VW1
Ladder power Sense	8	22	Belden 9421	Copper PVC	-	35V	300V / 2A	80°C	CSA FT4
Control	27	22	HELUKABEL LiY-CY 20070	Copper PVC	-	5V	300V/ ?	-30°C 80°C	IEC 332-1
Trigger	20	24	Belden 8170	Copper PVC	-	5V	300V / 1A	60°C	UL 1581

Characteristics of the connectors

STAR HFT

Connectors	Cable / Location	Manufacturer Part Number	Material	Operating Current	Operating Voltage	Voltage Rating	Temperature Rating	Flammability Rating
Inside Rack Cable Low Voltage	RKLVxx PS, Distr Crate	Amphenol 777-RR-B25P	glass-filled thermoplastic	2A	5V	500V	-55°C 105°C	ULV94V-0
Inside Rack Panel Low Voltage	RKLVxx PS, Distr Crate	Amphenol 177-RR-B25S	glass-filled thermoplastic	2A	5V	500V	-55°C 105°C	ULV94V-0
Inside Rack Cable High Voltage	RKHVxx PS, Distr Crate	Amphenol 777-RR-C37P	glass-filled thermoplastic	1mA	35V	500V	-55°C 105°C	ULV94V-0
Inside Rack Panel High Voltage	RKHVxx PS, Distr Crate	Amphenol 177-RR-C37S	glass-filled thermoplastic	1mA	35V	500V	-55°C 105°C	ULV94V-0
Inside Rack Panel Mixed Voltage	FMVxx,SMVx x Rack	AMP CPC 206838-1	glass-filled thermoplastic	2A	35V	1500V	-55°C 105°C	ULV94V-0
Cable Mixed Voltage	FMVxx,SMVx x TPC Wheel	AMP CPC 206837-1	glass-filled thermoplastic	2A	35V	1500V	-55°C 105°C	ULV94V-0

First ladder: power distribution plan



4 amperes fuse