EP Detector Seminar 3 June 2016:

Highlights from the Forum on Tracking Detector Mechanics held in Bonn 23-25 May 2016

http://www.forumbonn.org/

Antti Onnela and Bart Verlaat
CERN – EP – DT

Outline

- Intro to Forums on Tracking Detector Mechanics
- Forum 2016: Highlights on Mechanics
- Forum 2016: Highlights on Cooling

“Forums on Tracking Detector Mechanics”, why?

To bring together engineers, technicians and physicists working on the unique combination of requirements set on mechanics of tracking detector system:

- High-precision measurement of tracks
  - < 10 um level stability in multi-meter sized detectors
- Hermetic to tracks
  - ‘Closed’ onion-like geometry
- Very low mass (X0)
  - Minimise interaction with particles
- Radiation hard
  - Closest to the interaction points
- High heat load
  - A lot of channels → high power density per volume and per mass
- Often low temperature for improved radiation hardness
  - Below dew point = low enough to be quite problematic
- Long-term reliability
  - No, or at best limited, access for maintenance.
- Designed and constructed in multiple sites → transports

Such events – **for people from different experiments and institutes and also from outside HEP field (including companies)** – did not exist, until 2012.

Forums on Tracking Detector Mechanics

2012, CERN
http://indico.cern.ch/event/Forum_on_Tracking_Detector_Mechanics

2013, Oxford (UK)
http://www.physics.ox.ac.uk/forum2013/index.asp

2014, DESY (DE)
http://forum2014.desy.de/

2015, NIKHEF (NL)

http://forum2015.nikhef.nl

2016, Bonn (DE)
http://www.forumbonn.org/

universitätbonn

Local organization:
Carlos Marinas, Jochen Dingfelder, Jochen Kaminski, Bernhard Ketzer

Forum 2016

- ~2.5 days
- Format: Presentation 30 min + discussion 15 min. Works well.
- 26 talks
  - 3 industry talks
  - 8 talks on non-CERN activities
- 45 proposals for talks
  - First Forum with substantially more proposals than available slots.
  - Several proposals postponed/declined.
  - But also many combined talks – beneficial!

Topics

→ covered in Forum 2016

- → Mechanical design, advanced materials and construction technologies
- → Thermal management and cooling
- Humidity control, monitoring and sealing
- Installation, integration, disassembly and transportation
- Stability, alignment and adjustment systems; Requirements for future
- Quality control, failure and service management
- Radiation effects on materials and handling of irradiated structures
- → Structural and vibration analyses/measurements

Proposals (especially on alignment) received, but finally not fitting in the agenda

→ Organise specific event on alignment results/experience and future requirements, with participation expanded more to physicists?
In autumn 2016 at CERN?

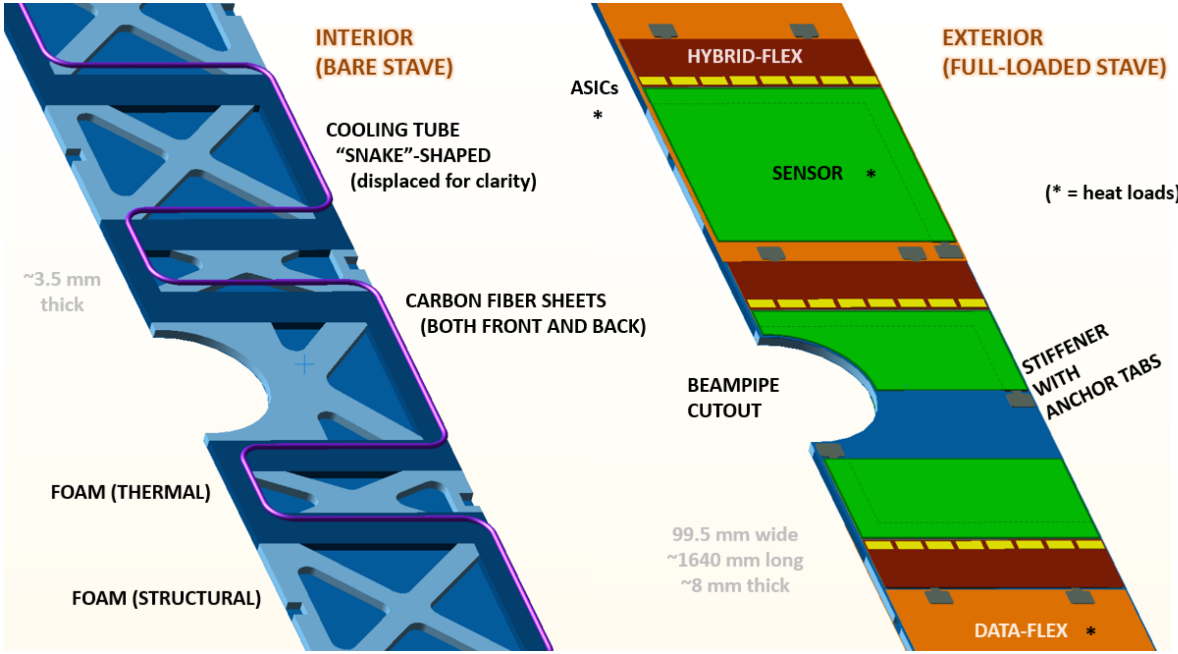
→ Consider for Forum 2017 specific themes on "Manufacturing/production phase" (e.g. current ALICE, LHCb upgrades), "Operational experience from existing Trackers"

Highlights on Mechanics

"Stave" concept widely used (Atlas, LHCb, CMS, …)

Mechanics and Construction of the LHCb Upstream Tracker Detector, *Ray Mountain*

LHCb UT



High-conductivity carbon-fibre/ polymer skins

Thermal foam core component

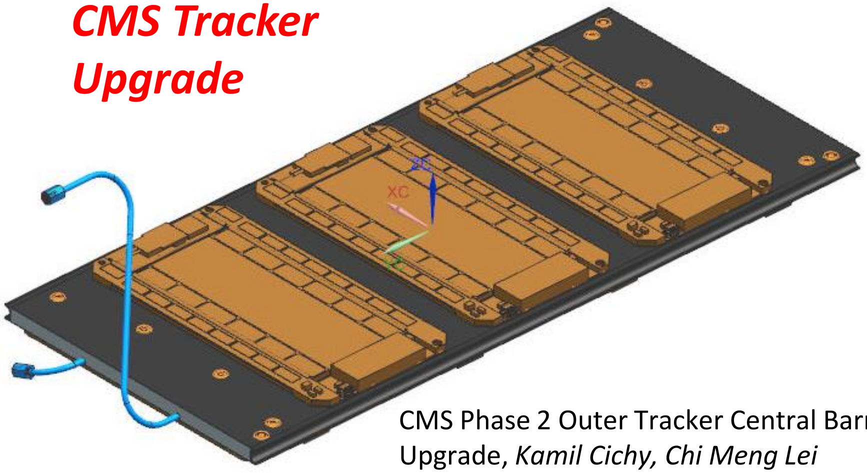
- Allcomp K-9 carbon foam
- High thermal conductivity (~35 W/m.K), low mass density (0.2 g/cm^3)
- Open cell foam
- Machinability is good

Ideal for spreading the heat transfer from a small tube to the large area required to cool the ASICs and sensors.

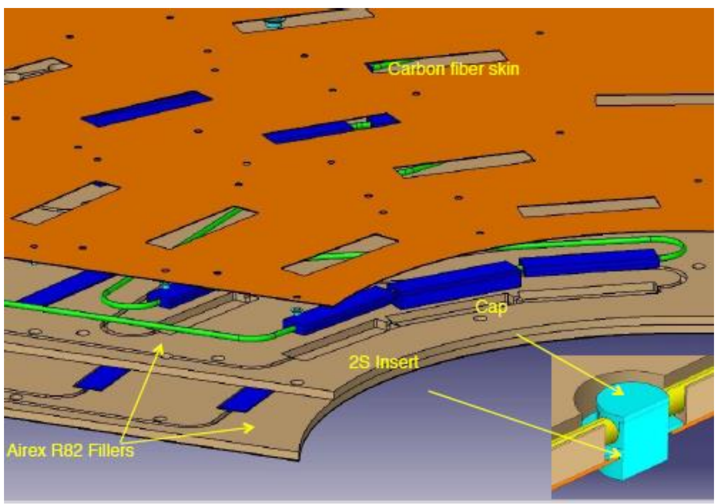
The machining of the foam is easy and the resulting surface can be made clean for epoxy.

Staves and Disks

CMS Tracker Upgrade

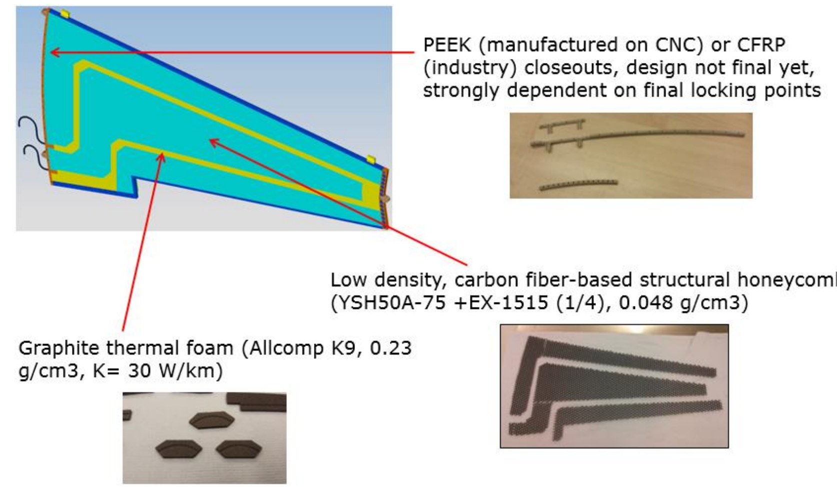


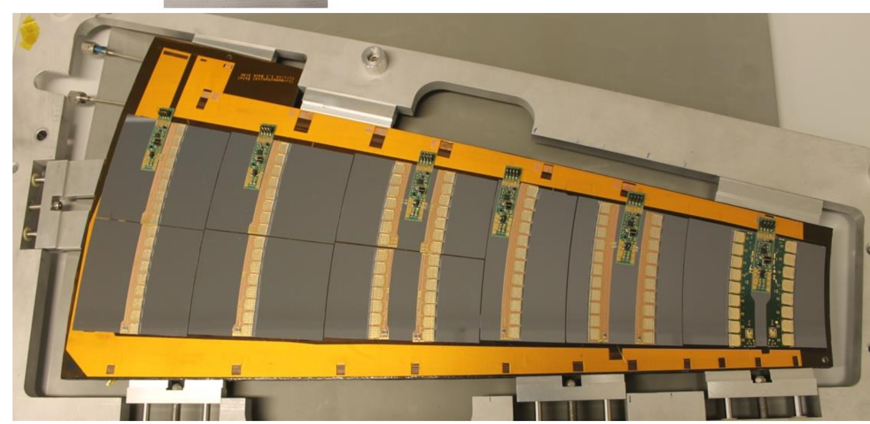
CMS Phase 2 Outer Tracker Central Barrel Upgrade, *Kamil Cichy, Chi Meng Lei*



Prototyping and R&D for the CMS Phase 2 Outer Tracker End Caps, *Andreas Mussgiller*

Atlas Tracker Upgrade

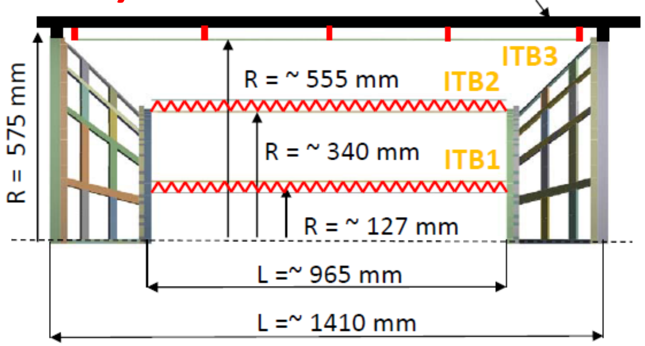


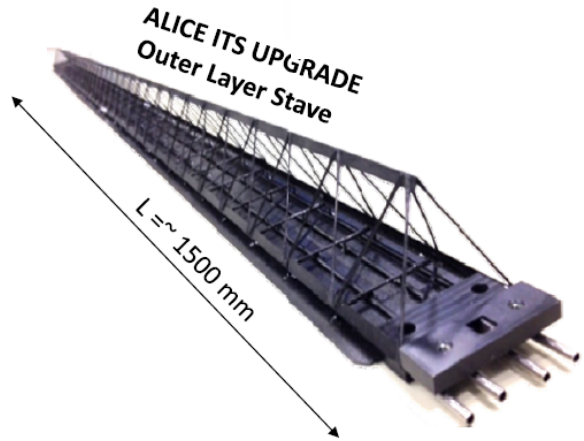


Module support structures and thermo-mechanical prototypes for the endcap of the ATLAS strips tracker, *Sergio Díez Cornell*

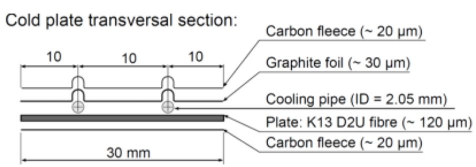
Long structures – more 3D

CLIC / ALICE





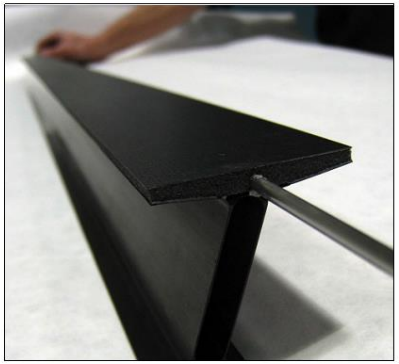
ALICE ITS UPGRADE

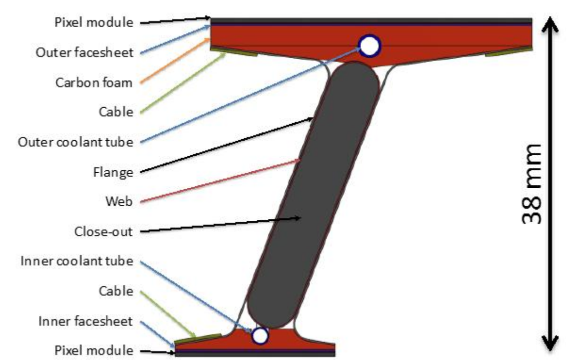


- **Total Radiation length:** ~1% X_0 (per layer)
- Room - operational temperature
- Max. sag < 100 μm

Developments on the mechanics and cooling for the CLIC tracking detectors, *Szymon Sroka*

ATLAS Upgrade Pixels

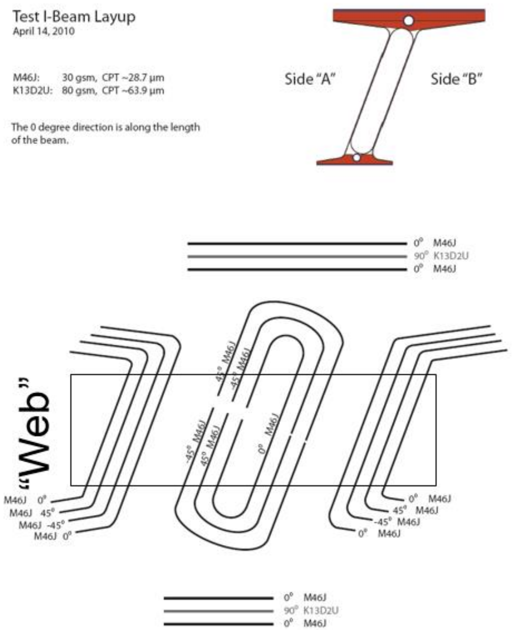


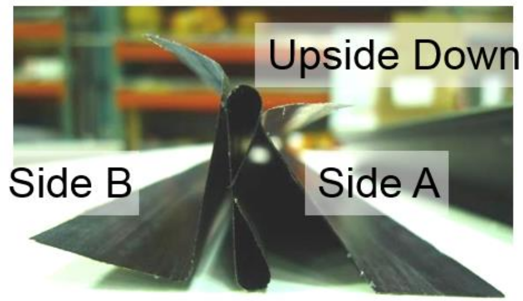


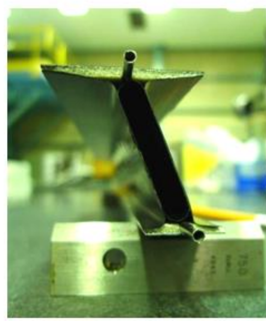
A Verified Thermo-Mechanical Prototype and Model for Integrated Local Supports in the ATLAS ITk Pixel Detector Upgrade, *Neal Hartman*

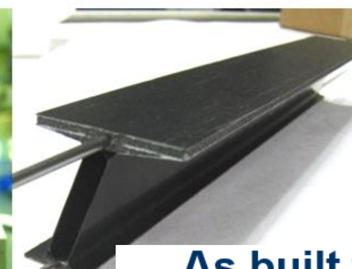
Manufacture to high final precision

The Ibeam



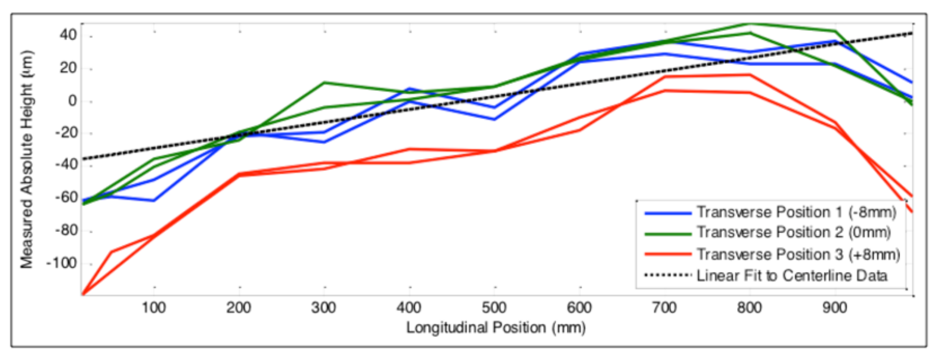




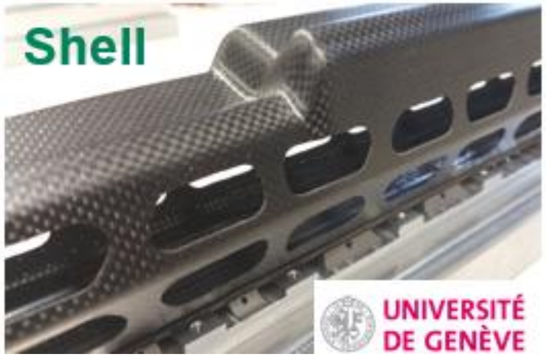


A Verified Thermo-Mechanical Prototype and Model for Integrated Local Supports in the ATLAS ITk Pixel Detector Upgrade, *Neal Hartman*

As built flatness on module mounting surface

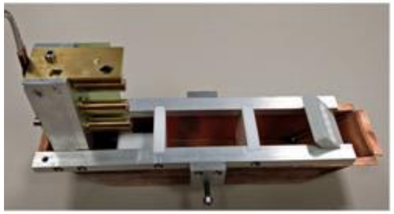


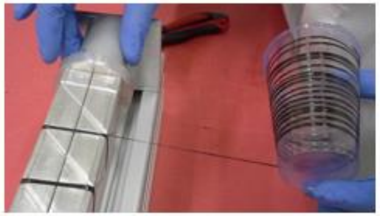
Further long structure alternatives

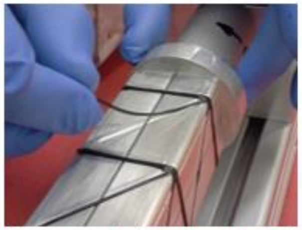


Lightweight support structures and thermal management materials for silicon tracker detectors featuring tilted modules, *Diego Alvarez Feito*

ATLAS ITK, etc.


0. Fibre Pre-impregnation


1. Winding 90˚ rings

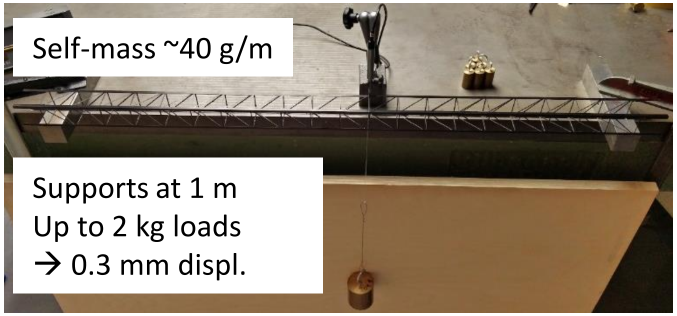

2. Placement of cross-members


3. Placement of longitudinal reinforcements

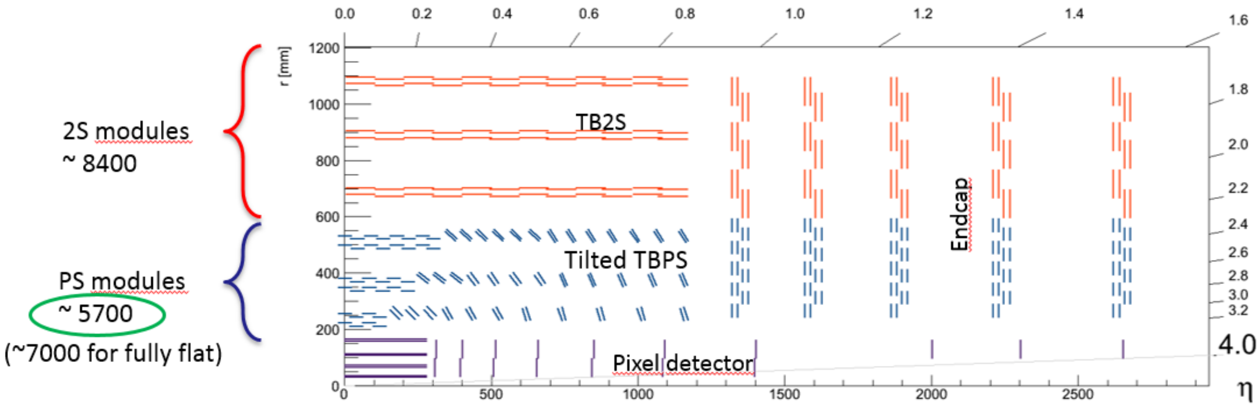

4. Placement of corner L-sections (UD prepreg)


5. Closure of mould


6. Co-curing (internal pressure via inflatable pipe)



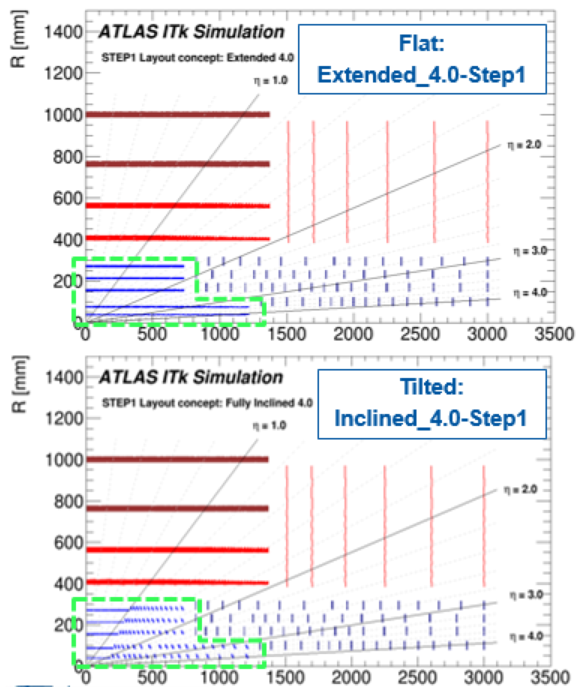
Tilted geometry



CMS Tracker Upgrade

CMS Phase 2 Outer Tracker Central Barrel Upgrade, *Kamil Cichy*

ATLAS Tracker Upgrade



ATLAS ITK*: Pixel Barrel (ONLY)				
Layer	Silicon Area (m²)		Services (Kg)	
	Flat	Tilted	Flat	Tilted
0	2	1.2	2.87	2.00
1			3.08	2.21
2	3.8	2.6	2.20	1.96
3			1.95	2.11
4	2.7	2.2	2.40	2.60
Total	**8.5**	**6.0**	**12.50**	**10.88**

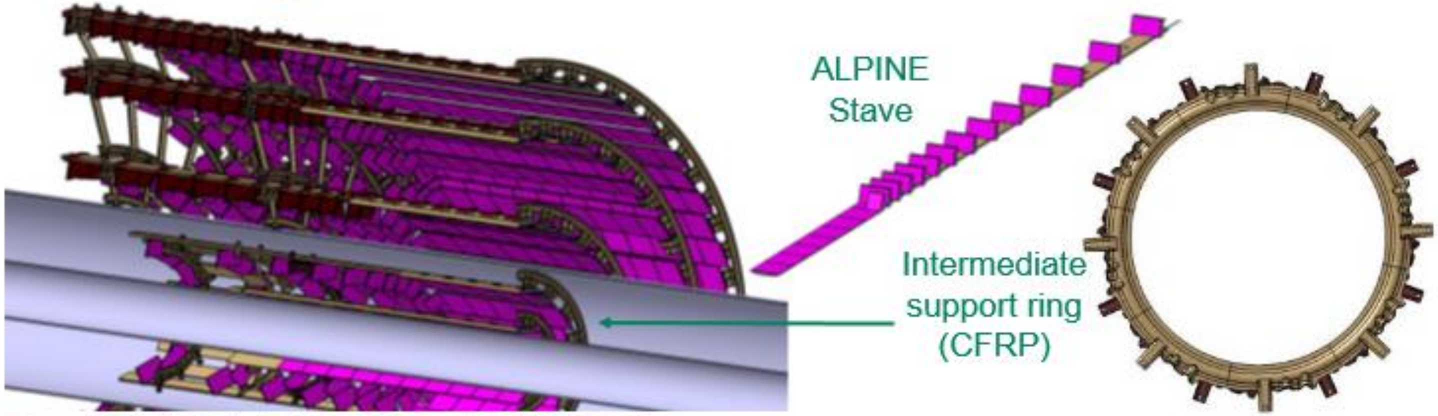
*Results shown ONLY include the Pixel Barrel, and are based on preliminary estimates by D.Giugni & P.Morettini

Lightweight support structures and thermal management materials for silicon tracker detectors featuring tilted modules, *Diego Alvarez Feito*

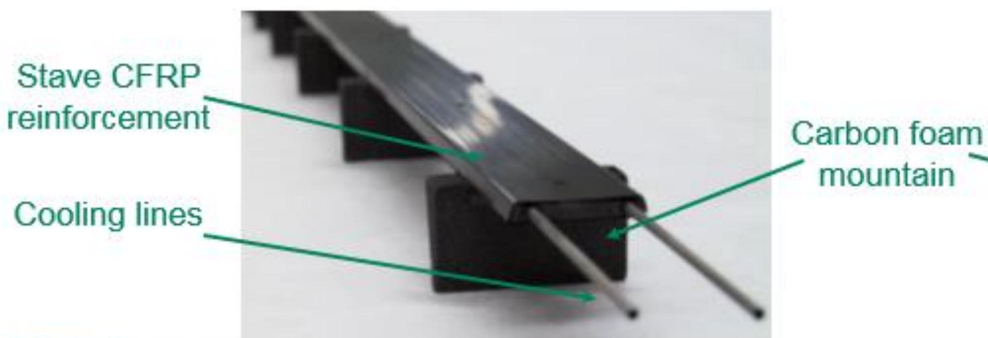
Tilted geometries

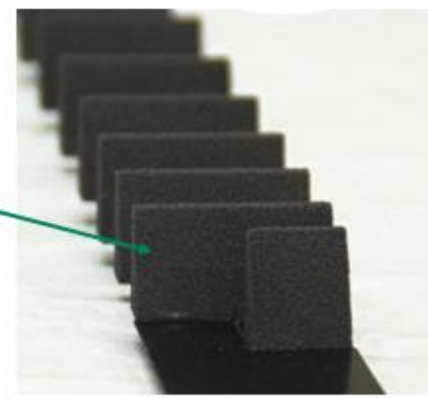
Mechanical Implementation: ATLAS Pixel ALPINE

- Support Structure: CFRP Staves + Intermediate rings
- Heat management of tilted cells: Carbon foam "mountains"



From: Kitézé ,D.et al., *Alpine Mechanics*, AUW, 2015.





EP-DT
Detector Technologies

From: David,P.Y *et al.*, *Alpine Stave Update*, 2015.

From: *ATLAS Phase II Upgrade Scoping Document*, 2015.

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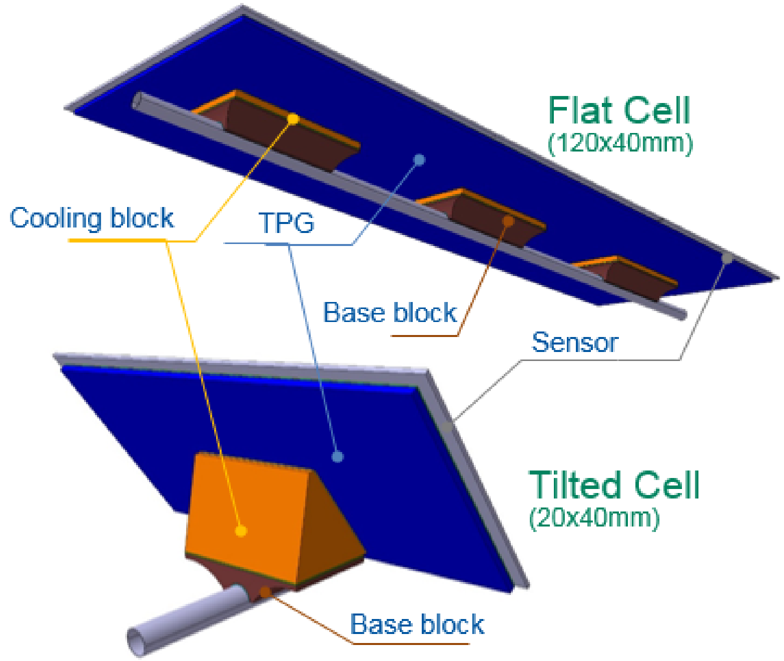
Tilted geometries

Mechanical Implementation: ATLAS Pixel SLIM

- Heat management: Module Cells (Modularity)
  - **Base block** with positioning pins soldered to CL
  - Bonded **cooling block** (phase-change material + **glue dots**)
  - TPG backing plate + loaded epoxy interfaces

Material tailored for TFM needs (e.g. Al-Carbon Al-Diamond)



Layer	TFM ($K \cdot cm^2 \cdot W^{-1}$)		
	Conductive	Convective	Global
0	11	4.3	15
1	16	8.6	25
2	12	8.6	21
3	15	8.6	24
4	18	8.6	27

D. GIUGNI

EP-DT Detector Technologies

S. MICHAL

UNIVERSITÉ DE GENÈVE

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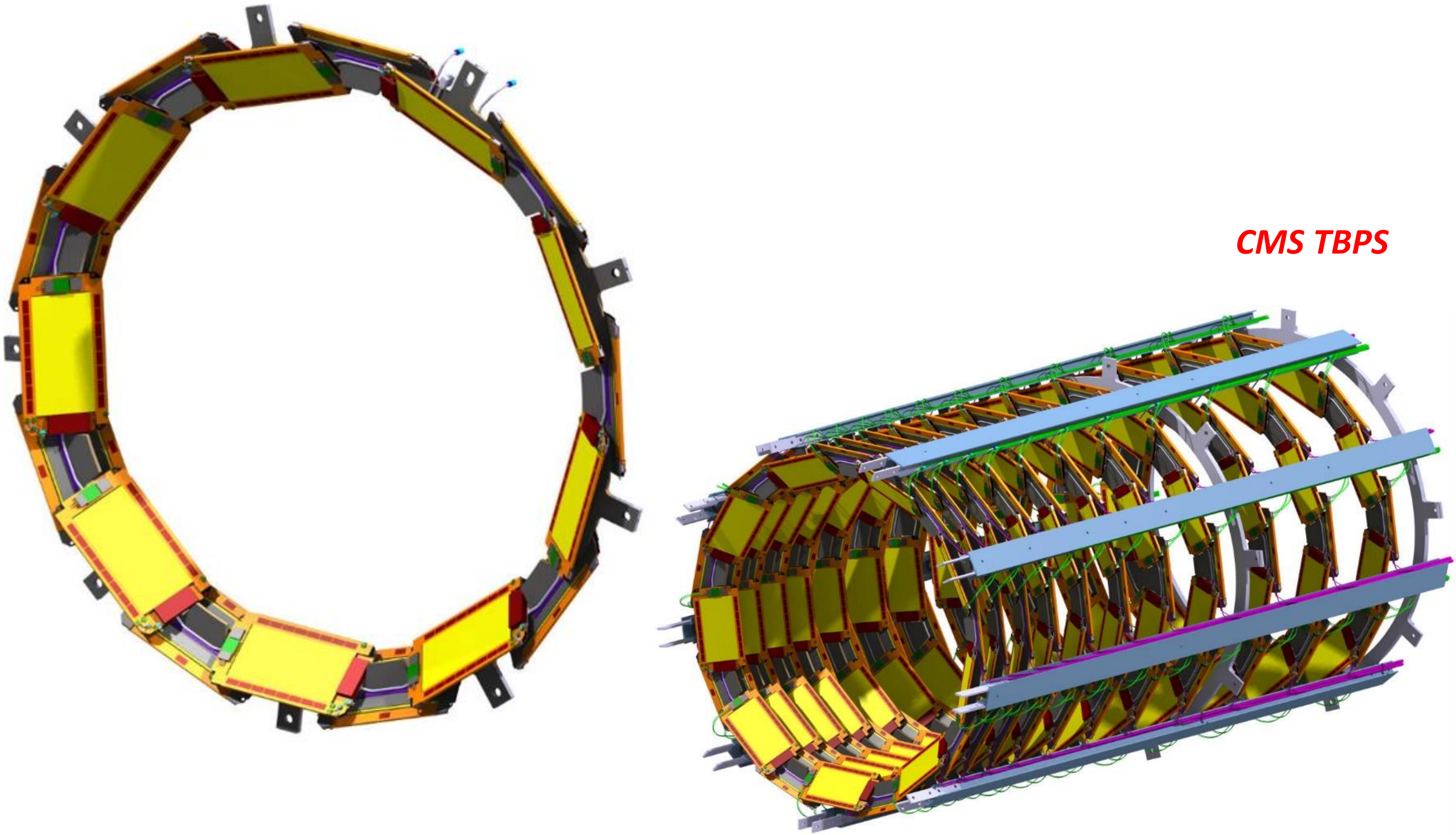
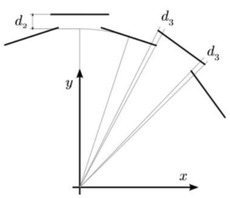
Tilted geometries

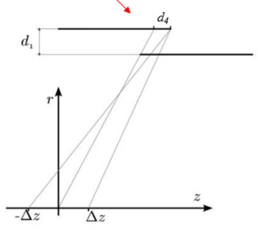


CMS TBPS

From physics layout model to 3D CAD

Flat geometry

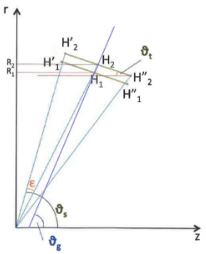




Input parameters:
- Δz
- d_1, d_2, d_3, d_4…
- numRods
- numModulesFlat

Z- positions computed automatically

Tilted geometry



Input parameters:
- numModulesTilted
- ϑ_t - tilt angle
- ϑ_g
- R_{inner}
- R_{outer}
- zOverlap

tilted layers with automatic placement : additional info

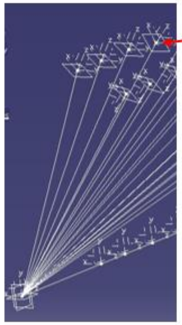
Layer 1 :

Flat part :

Ring	**1**	**2**	**3**	**4**
r_{Inner}	216.200	205.000	216.200	205.000
r_{Outer}	250.000	238.800	250.000	238.800
averageR (on Flat part)	228.800	228.800	228.800	228.800
bigDelta	16.900	16.900	16.900	16.900
smallDelta	5.600	5.600	5.600	5.600
z	0.000	40.351	86.339	121.212
phiOverlap	13.755	17.725	13.755	17.725
$zError_{Inner}$ (Ring i & i-1)		70.000	70.000	70.000
$zError_{Outer}$ (Ring i & i-1)		84.473	71.068	97.890

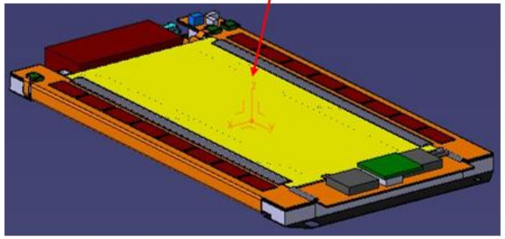
Tilted part :

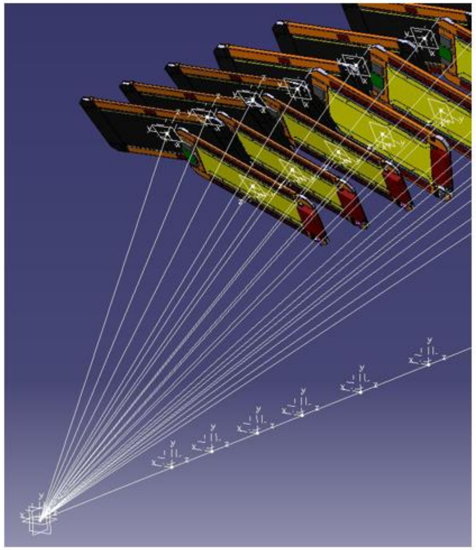
Ring	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
tiltAngle (°)	47.0	47.0	47.0	61.0	61.0	61.0	74.0	74.0	74.0	74.0
$tiltAngleIdeal_{Inner}$ (°)	34.5	42.4	49.4	54.8	60.2	64.9	68.6	71.9	74.5	76.7
$deltaTiltIdeal_{Inner}$ (°)	12.5	4.6	-2.4	6.2	0.8	-3.9	5.4	2.1	-0.5	-2.7
$tiltAngleIdeal_{Outer}$ (°)	34.8	42.2	49.0	54.9	60.1	64.7	68.6	71.8	74.5	76.6
$deltaTiltIdeal_{Outer}$ (°)	12.2	4.8	-2.0	6.1	0.9	-3.7	5.4	2.2	-0.5	-2.6
theta_g (°)	50.0	50.0	50.0	32.0	32.0	32.0	20.0	20.0	20.0	20.0
r_{Inner}	247.000	247.000	247.000	247.000	247.000	247.000	247.000	247.000	247.000	247.000
r_{Outer}	260.000	260.000	260.000	254.000	254.000	254.000	251.000	251.000	251.000	251.000
averageR (on Ring)	253.500	253.500	253.500	250.500	250.500	250.500	249.000	249.000	249.000	249.000
gapR	16.970	16.970	16.970	13.210	13.210	13.210	11.695	11.695	11.695	11.695
z_{Inner}	169.802	225.155	287.837	349.817	431.125	526.434	628.919	753.719	893.604	1045.792
z_{Outer}	180.710	236.063	298.745	361.019	442.328	537.636	639.909	764.709	904.594	1056.782
averageZ (on Ring)	175.256	230.609	293.291	355.418	436.726	532.035	634.414	759.214	899.099	1051.287
$deltaZ_{Inner}$ (Ring i & i-1)	48.590	55.353	62.682	61.980	81.309	95.308	102.485	124.800	139.885	152.188
$deltaZ_{Outer}$ (Ring i & i-1)	59.498	55.353	62.682	62.274	81.309	95.308	102.273	124.800	139.885	152.188
phiOverlap	0.635	0.700	0.700	0.585	0.585	0.508	0.667	1.006	1.345	1.854
$zError_{Inner}$ (Ring i & i-1)	106.836	19.162	27.335	82.518	27.072	33.888	78.618	63.153	113.733	197.394
$zError_{Outer}$ (Ring i & i-1)	7.143	20.685	26.182	33.570	27.975	32.482	40.443	63.970	113.226	195.877



LOCATIONS

LOCATOR

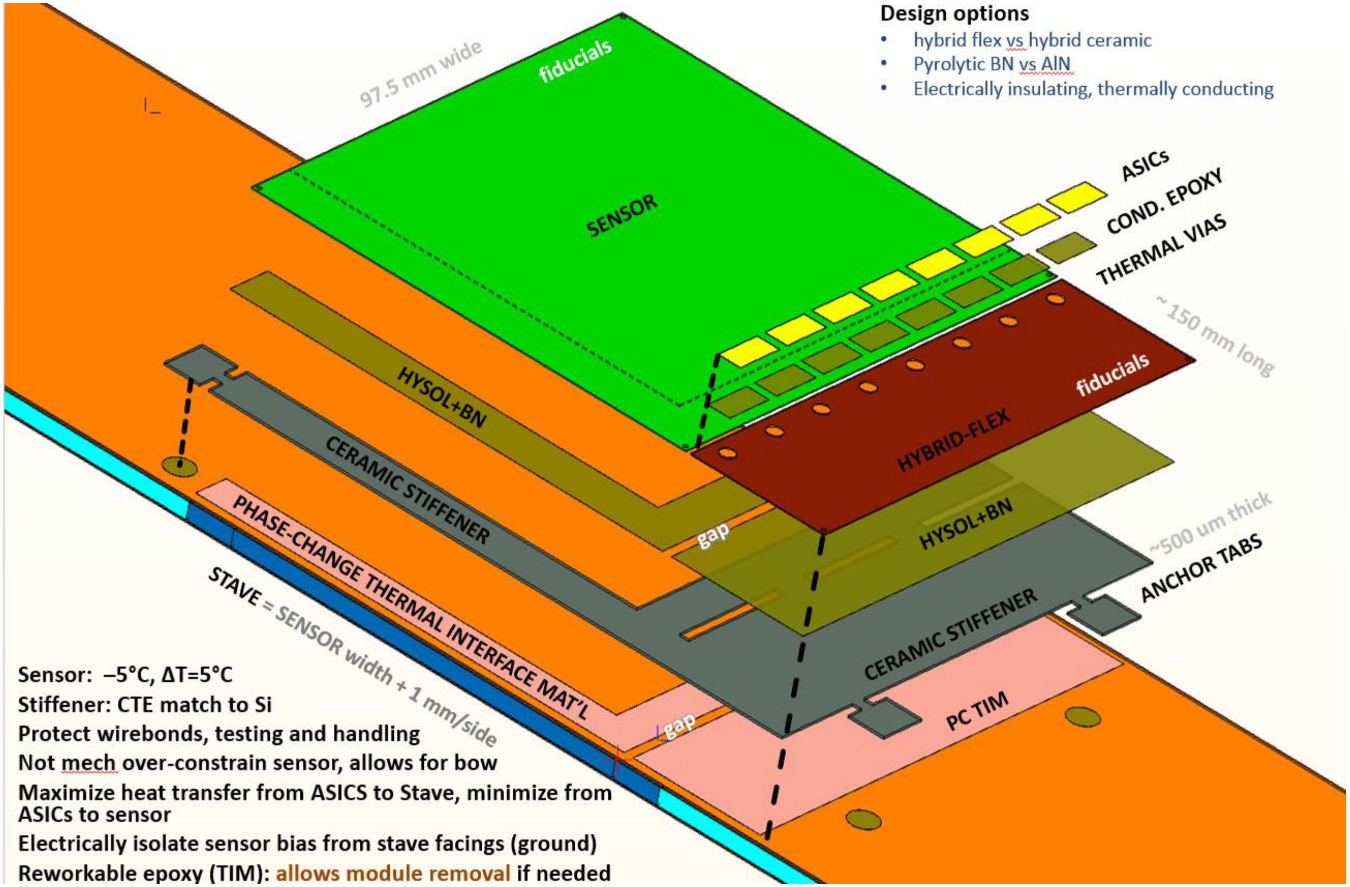




CMS Phase 2 Outer Tracker Central Barrel Upgrade, *Kamil Cichy*

Module mounted with phase-change adhesive

LHCb UT



Design options
- hybrid flex vs hybrid ceramic
- Pyrolytic BN vs AlN
- Electrically insulating, thermally conducting

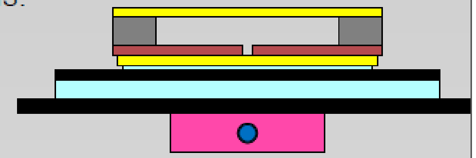
Sensor: −5°C, ΔT=5°C
Stiffener: CTE match to Si
Protect wirebonds, testing and handling
Not mech over-constrain sensor, allows for bow
Maximize heat transfer from ASICS to Stave, minimize from ASICs to sensor
Electrically isolate sensor bias from stave facings (ground)
Reworkable epoxy (TIM): allows module removal if needed

Mechanics and Construction of the LHCb Upstream Tracker Detector, *Ray Mountain*

Phase-change Thermal Interface Materials

Manufacturer	Glue	Thickness [mm]	Thermal conductivity [W/m/K]	phase change or burn-in temp.	Density [g/cc]	Operation range	Comment
Laird Technologies	Tpcm 905C	0.130	0.7	5 min @ 70°C	1.31	-25°C to +70°C	film
Laird Technologies	Tpcm 910	0.250	2.23	5 min @ 70°C	1.39	-25°C to +70°C	film
Laird Technologies	Tpcm 920	0.510	2.23	5 min @ 70°C	1.39	-25°C to +70°C	film
Laird Technologies	Tpcm 780SP		5.4	45°C to 70°C	2.48		printable paste
Laird Technologies	Tpcm 780	0.203 / 0.254 / 0.406 / 0.635	5.4	45°C to 70°C	2.48		film
Loctite	Isostrate 2000	-	0.45	60°C	-		on Kapton substrate
Honeywell	PCM45F	0.254	2.35	45°C	-		pad or tape
Parker Chomerics	Thermflow T725	0.125	1.41	55°C	1.1	-55°C to +125°C	film
Parker Chomerics	Thermflow T557	0.125	7.7	45°C / 62°C	2.4	-55°C to +125°C	film
Parker Chomerics	Thermflow T777	0.115	7.7	45°C / 62°C	1.95	-55°C to +125°C	film
Amec Thermasol	MPC 315	0.13	5.0	45°C	-	-40°C to 125°C	film
3M	5515	0.200 / 0.250	3.0	-	2.9	-	pad

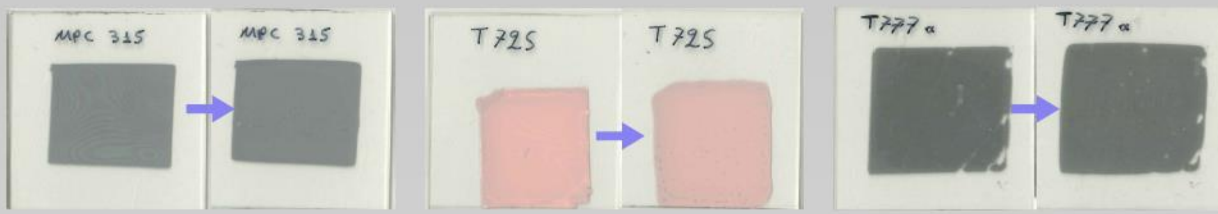
- materials were selected based on
  - small thickness (< 0.150 mm)
  - low transition temperature (< ~60 °C)
  - minimum operation temperature < -35 °C
  - high thermal conductivity
  - low density
- tested materials:
  - T725
  - T557
  - T777
  - MPC 315



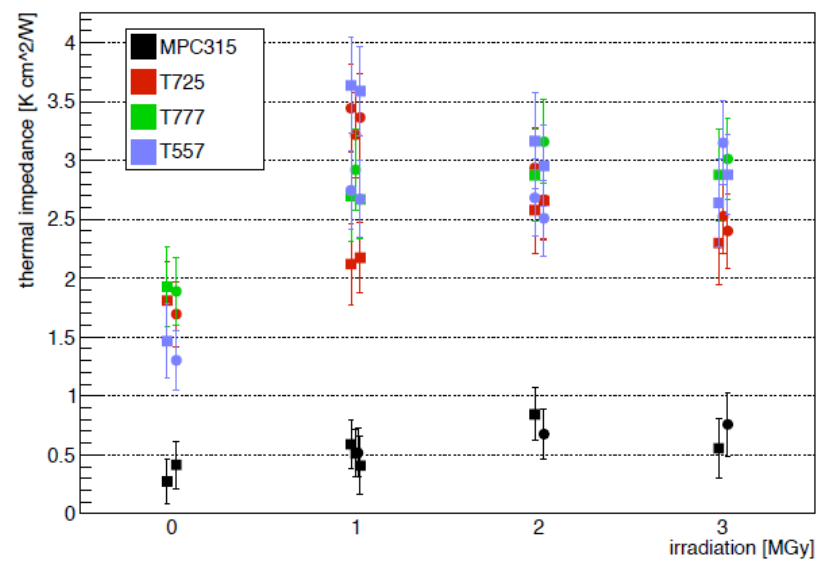
TIM handling and radiation resistance

Material	removal of first cover foil	stickness to glass	removal of second cover foil	number of trials
T777	very easy / easy / well	3 x well	2 x ok, tearing / well	2 / 2 / 1
T725	ok / easy / well / very easy	4 x well	4 x ok, tearing	2 / 1 / 1 / 1
T557	3 x easy / well	4 x well	4 x ok , some tearing	2 / 1 / 1 / 1
MPC315	easy / easy / well / very easy	well / well / well / well	ok / well / well / well	1 / 1 / 1 / 1

Material	softness of TIM after reheating	separability of glass plates	removal of TIM	residue
T777	very soft / very soft / gum	2 x hard / easy	very easy / very easy / ok	3 x no
T725	quite soft / very soft / gum / very soft	2 x easy / 2 x very easy	3 x hard / 1 x very hard	4 x sticky
T557	3 x soft / gum	2 x hard / 2 x easy	3 x ok / smeary	2 x sticky / 2 x no
MPC315	really soft / soft / plasticine / soft	easy / easy / easy / easy	very very easy / easy / easy / very easy	no / no / no / no

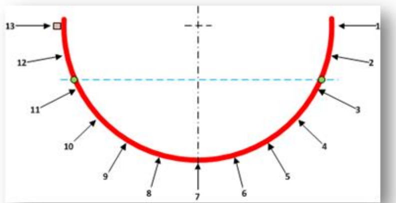


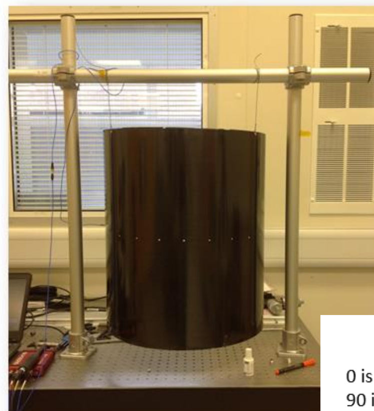
- handling-wise ranking is as follows
  1. MPC315
  2. T557
  3. T777
  4. T725
- handling becomes more tricky with rough surfaces (Al, CFRP)

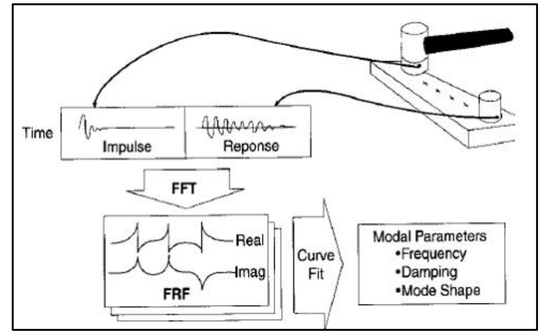


Characterisation of structures in composite materials

- Hang ½ cylinder from frame at 2 locations
  - Chosen to lie on centre-of-gravity so structure hangs vertically
- Mark out hammer locations at half-height at 15deg intervals
- Locate accelerometer at position 13







Mode frequency comparisons

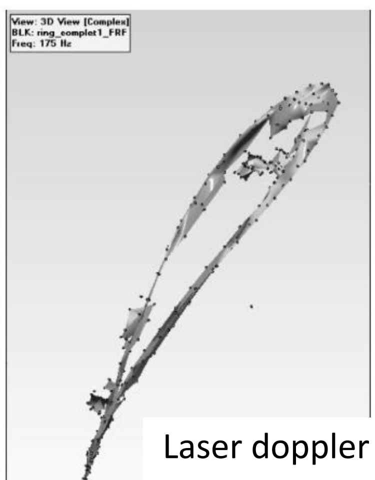
0 is along the centreline
90 is hoop

Layup	Layers	Thickness	Natural Frequency mode number					Simulation or Test
			1st	2nd	3rd	4th	5th	
0,45,-45,90,90,-45,45,0	8	0.62	3.49	10.075	21.103	36.079	55.565	*ANSYS*
			3.25	11.25	22.50	38.50	58.75	*TEST*
0,90,90,0,90,90,0	7	0.55	5.124	14.813	31.043	52.222	81.105	*ANSYS*
			5.00	14.50	31.20	52.75	81.50	*TEST*
90,0,90,0,90,0,90	7	0.55	7.105	20.540	43.043	60.581	112.45	*ANSYS*
			6.84	19.92	42.77	73.24	111.3	*TEST*
90,60,-60,0,-60,60,90	7	0.55	7.706	22.272	38.505	39.427	91.977	*ANSYS*
			7.42	21.68	46.09	79.30	123.0	*TEST*
90,45,-45,0,0,-45,45,90	8	0.62	7.930	22.926	48.035	68.514	125.50	*ANSYS*
			7.75	22.50	48.25	82.75	126.0	*TEST*
100GPa generic material comparison	1	0.55	5.533	15.997	33.525	57.433	87.606	*ANSYS*
100GPa generic material comparison	1	0.62	6.237	18.032	37.788	64.737	98.747	*ANSYS*

UNIVERSITY OF LIVERPOOL

The ATLAS Phase-II Upgrade Endcap Pixel Detector Support Structures, *J.Pater & P.Sutcliffe*

85,9	1,89	55,6	0,78
150	0.05	111	1,12
175	0.56	195	1,11
289	0,29	277	0,97
298	0,57	296	0,69



Laser doppler vibratometry

Vibration issues on particle detector components during transport and in operation – Experimental approach, *Michael Guinchard*

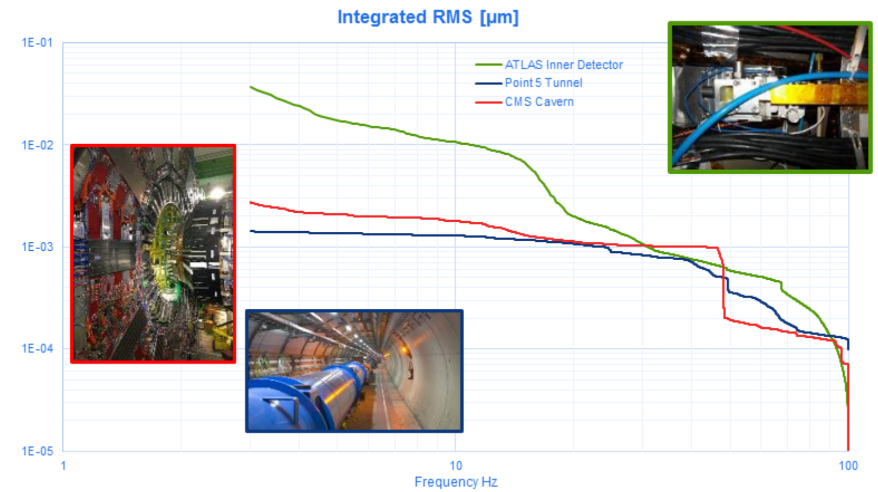
Better understanding of vibration loads

Vibration issues on particle detector components during transport and in operation – Experimental approach, *Michael Guinchard*

Overview from measurements done during LHC installation

Excitation sources	*Acceleration level*	*Frequency range*
Road transport without absorbers	around 0,5 g	Broadband (shock)
Road transport with absorbers	around 0,05 g	Broadband (shock)
Road transport : trailer suspension	around 0.2 g	Single frequency around 3 Hz
Lifting in the pit	around 0,1 g	Single frequency around few Hz depending the depth
Emergency stop in the pit	around 0,1 g	
Earthquake	see the graph	Low frequency excitation
Cavern excitation	see the graph	Broadband

Excitation sources – Ground motion
ATLAS Inner Detector – *EDMS 1403119*



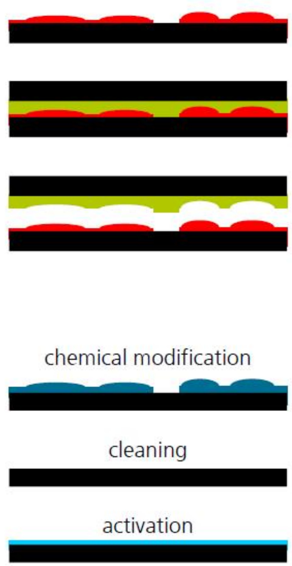
Continuous “ground” vibration at 3 Hz with 0.1 um amplitude measured inside Atlas detector

Preparing CFRPs for adhesive bonding

Pre-Treatment for adhesive bonding:

- Residues of release agents
- → Low adhesion forces

- Development of combined processes
  - Conversion of contaminations
  - Cleaning (abrasive and non-abrasive)
  - Surface activation



Klebtechnik und Oberflächen

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Increasing use of thermoplastic matrices

- variation of wetting properties of matrix-polymers

surface energies (untreated)

Polymer	Surface Energy [mN/m]	Water Contact Angle [°]
PP	31	102
PE	32	96
PPS	38	80
Epoxy	45	76

source :https://www.accudynetest.com/polytable_03.html?sortby=number%20ASC

Methods

Pretreatment of CFRP for improved adhesive bonding performance,
Joerg Ihde / Fraunhofer institute

PRE-TREATMENT OF CFRP -
MECHANICAL ACTIVATION

GRINDING

- removal of contamination and substrate material
- manually or automatically
- Hard particles or fibers as abrasive

- formation of dust / particles
- Release of fibers / deterioration of substrate
- Pre- and Post-Cleaning with organic solvents needed

Manual grinding with abrasive paper and solvent cleaning is the actual process for CFRP pre-treatment in aircraft and wind power industry.

Klebtechnik und Oberflächen

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Technologies and Fields of Application

Technologies:

- Low pressure plasma
- Atmospheric pressure plasma
- VUV-excimer technology
- Laser surface treatment
- Blasting. CO_2-Snow, VacuBlast
- Flame treatment
- Bath processes (e.g. ultrasonic)

Applications:

- Cleaning and activation
- Functional coatings

Klebtechnik und Oberflächen

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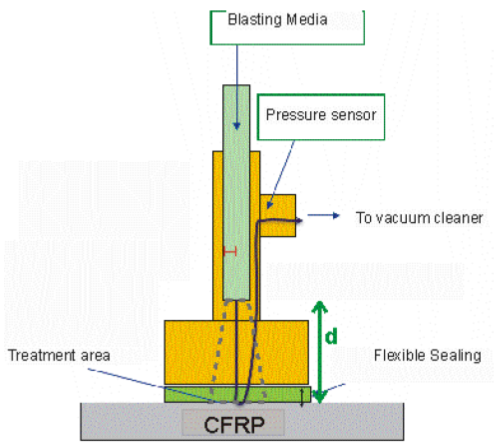
Vacuum blasting



Principle:

- Industrial vacuum cleaner is used to generate a reduced pressure in the treatment chamber
- Blasting media is injected by the pressure differences
- The reduced pressure prevents the emission of blasting media and dust

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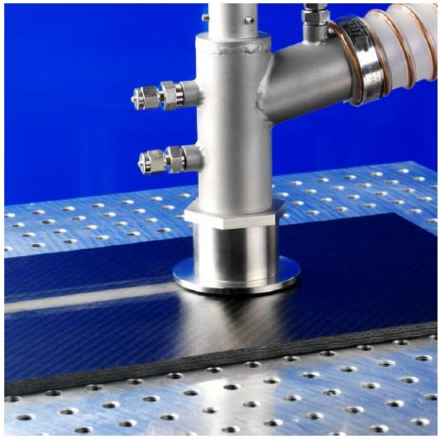


Advantages:

- Emission-free cleaning methode
- moderate noise emission
- Automated and manual use possible
- Line, local and area treatment

Disadvantages:

- Limited usability for complex shapes

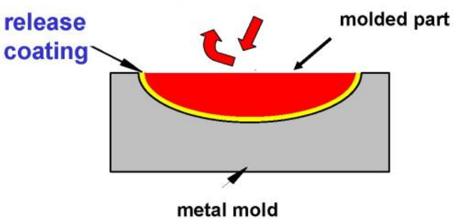
Or avoid surface treatment completely?

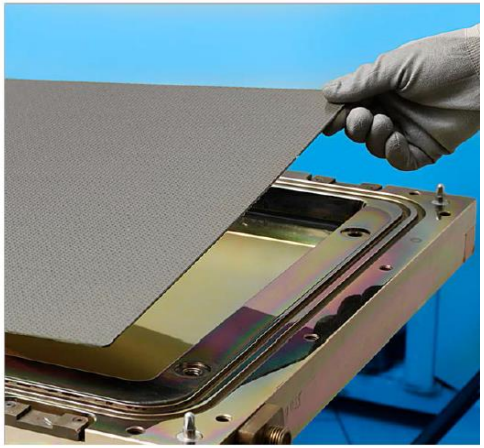
Hydrophobic Coatings

1. Permanent Release Layers

Plasma polymer coatings for the substitution of release agents

- process cost & effort
- cost & effort for surface cleaning
- quality controll





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Flexible Release Film for CFRP Production

- Thermoset Materials
- Direct release with filn
- No transfer of release agent
- Mechanical Protection by film
- Combination with In-Mould:
  - Paints
  - Function Coatings
  - …

Klebtechnik und Oberflächen

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New applications for CFRPs

Carbon Fibre Reinforced Polymers in High-End Applications – Potentials and Limitations,
Fabian Preller, INVENT GmbH

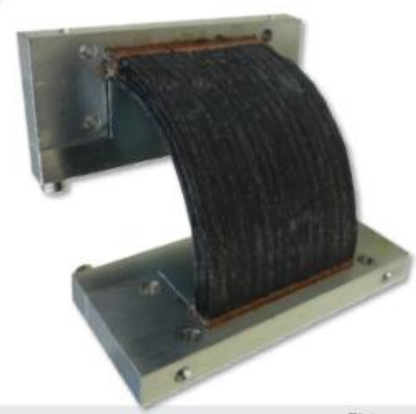
High Thermal Conductivity Applications

INVENT

Example: Thermal link made of CFRP

Material	Density ρ	Thermal Conductivity α	Ratio ρ/α
Aluminium	2 770 kg/m³	~ 160 W/mK	17.3 kgK/Wm²
Copper	8 867 kg/m³	~ 400 W/mK	22.2 kgK/Wm²
Carbon Fibre*	2 200 kg/m³	800 W/mK	2.8 kgK/Wm²

* pitch-based ultra high modulus (UHM) carbon fibre Mitsubishi K13D2U



Pictures: Airbus; INVENT

New applications for CFRPs

Carbon Fibre Reinforced Polymers in High-End Applications – Potentials and Limitations,
Fabian Preller, INVENT GmbH

Electrical Conductivity Applications

INVENT

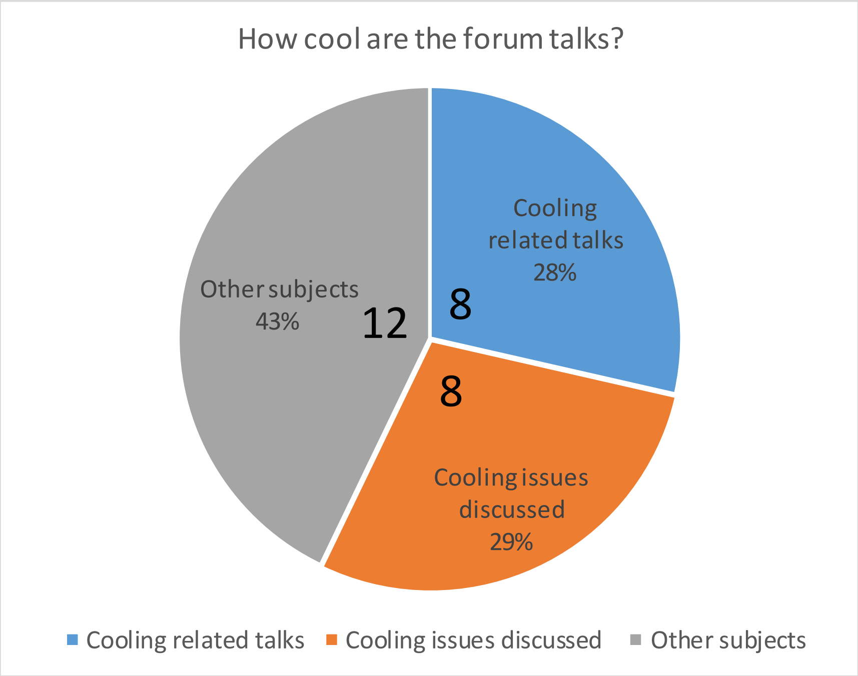
Example: Heating of moulds

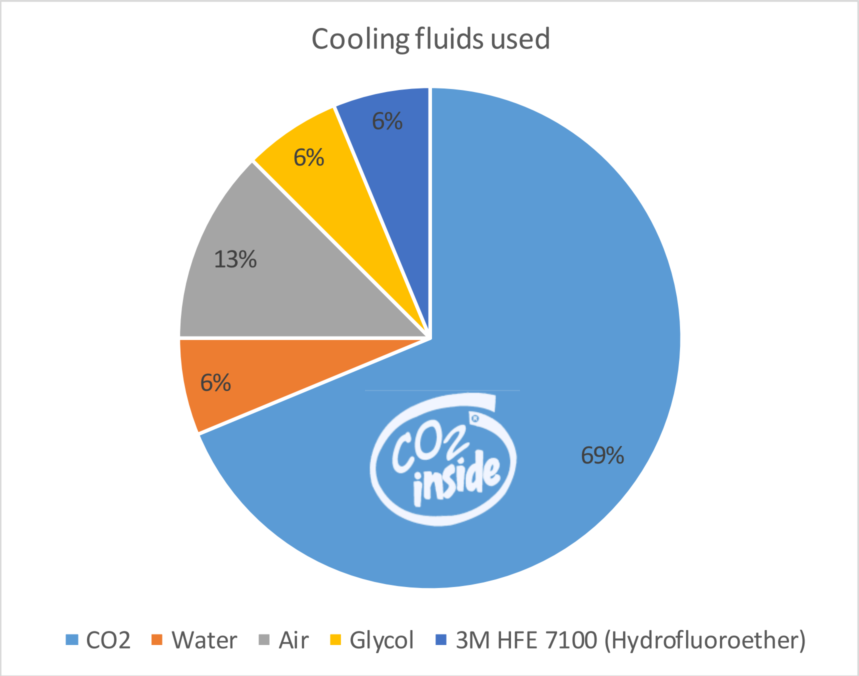
- Mould for composite parts is made of composite itself
  - A CFRP layer is used as heating element
- Parts with large dimensions, complex shapes, e.g. boats or wind turbine blades
- Temperatures of the mould up to 150°C
- Easy and precise adjusting of temperature
- Little heating power required (500 W / m²)
- Fast cooling down caused by low heating capacity of the mould itself
- Efficient manufacturing of moulds

Pictures: Fibretemp

Highlights on Cooling

Cool talks at the forum

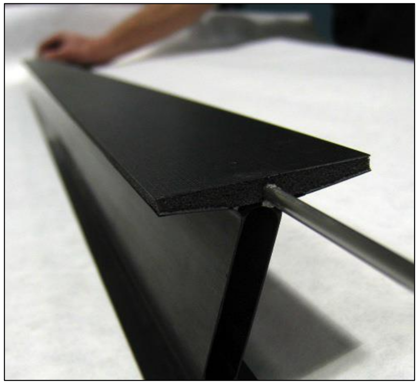


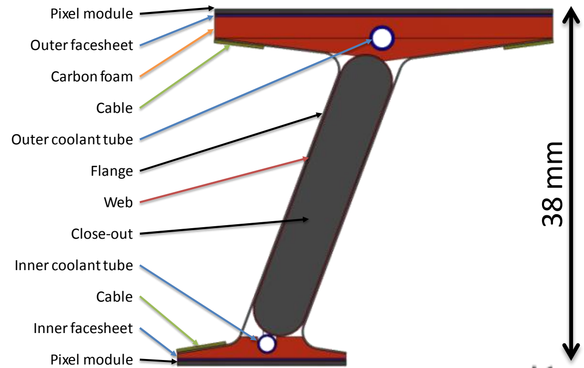


The average cooling temperature of the presented talks: -16.3°C

Thermal/ mechanical integrated structures (1)

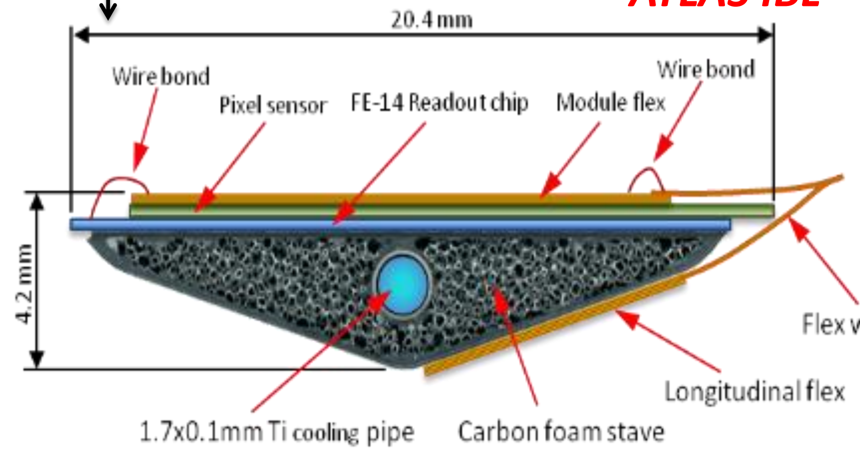
ATLAS Phase2 Pixel

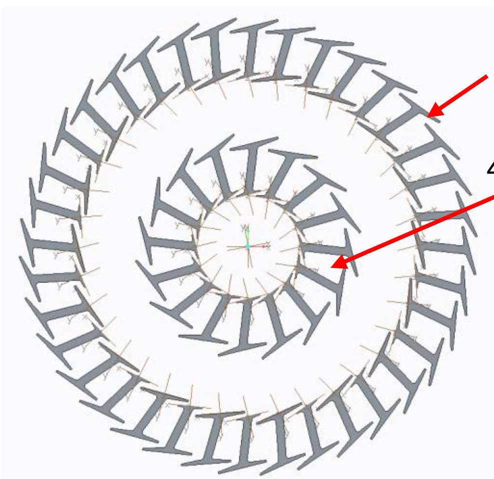




The full support structure is used as a thermal conductor to the integrated cooling pipe

ATLAS IBL





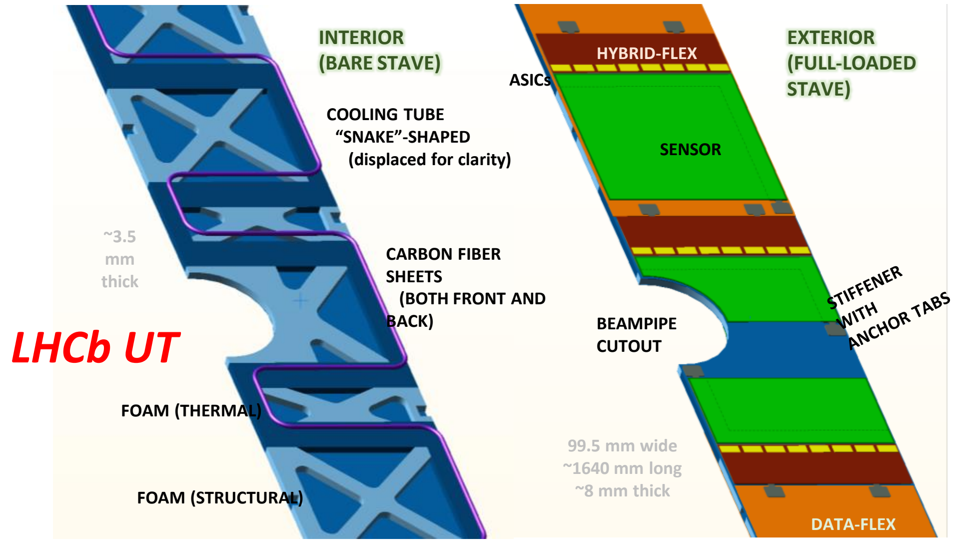
Alternating 4x2 and 4x4 Ibeams

4x2 Ibeams 16x

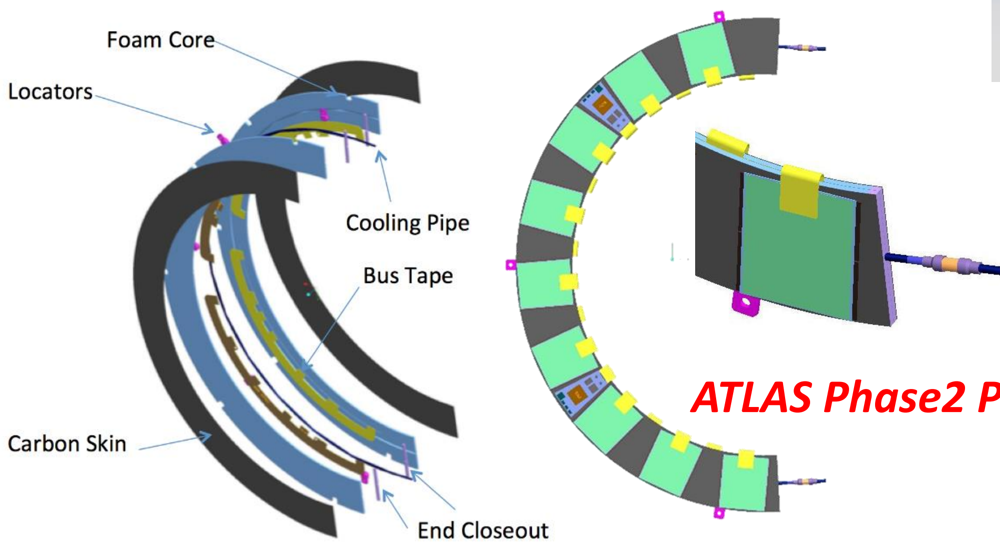
A Verified Thermo-Mechanical Prototype and Model for Integrated Local Supports in the ATLAS ITk Pixel Detector Upgrade, *Neil Hartman*

Commissioning and operational experience of the ATLAS IBL CO2 cooling system, *Bart Verlaat, CERN*

Thermal/ Mechanical integrated structures (2)



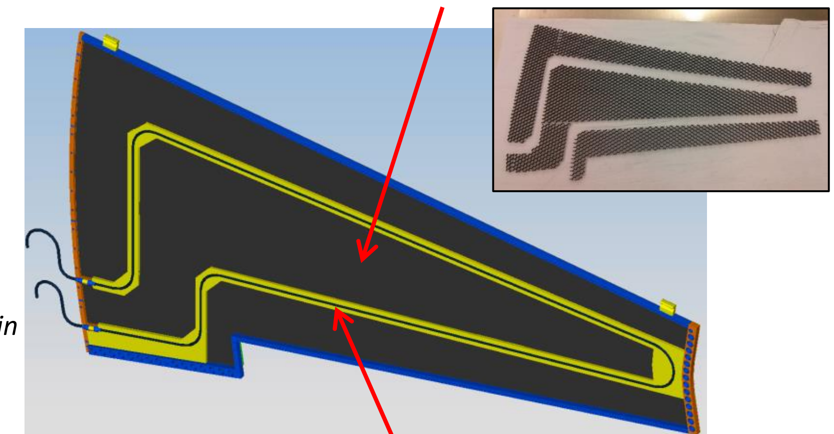
Mechanics and Construction of the LHCb Upstream Tracker Detector, *Ray Mountain*



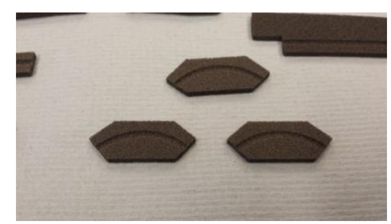
ATLAS pixel endcap upgrade, *Jo Pater*

ATLAS Phase2 Strip EC

Low density, carbon fiber-based structural honeycomb (YSH50A-75 +EX-1515 (1/4), 0.048 g/cm3)

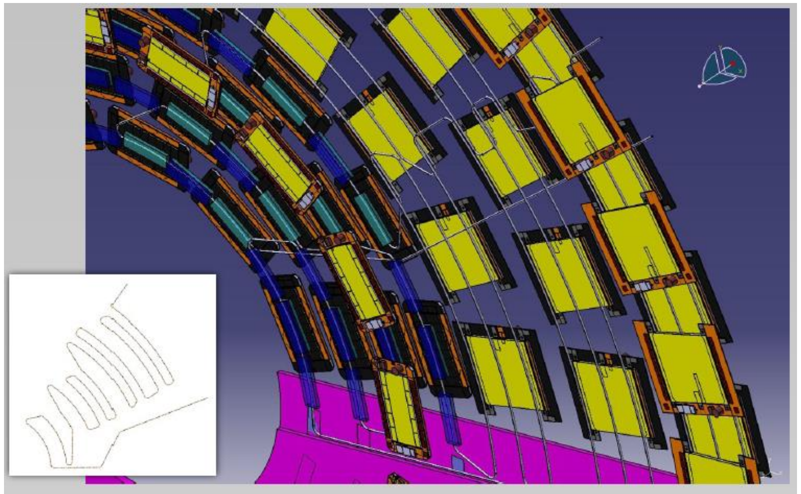


Graphite thermal foam (Allcomp K9, 0.23 g/cm3, K= 30 W/km)

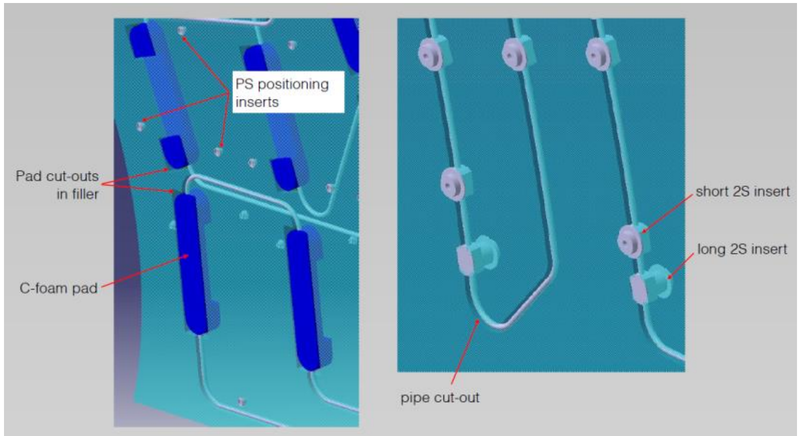


Module support structures and thermo-mechanical prototypes for the endcap of the ATLAS strips tracker, *Sergio Cornell*

Partial separation of cooling and structure

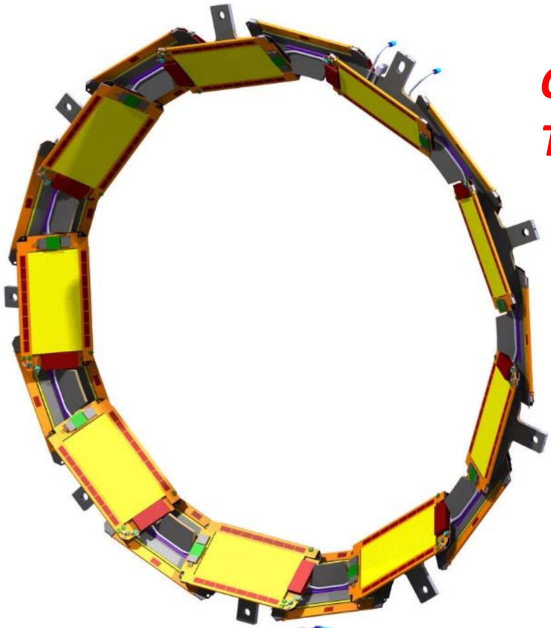


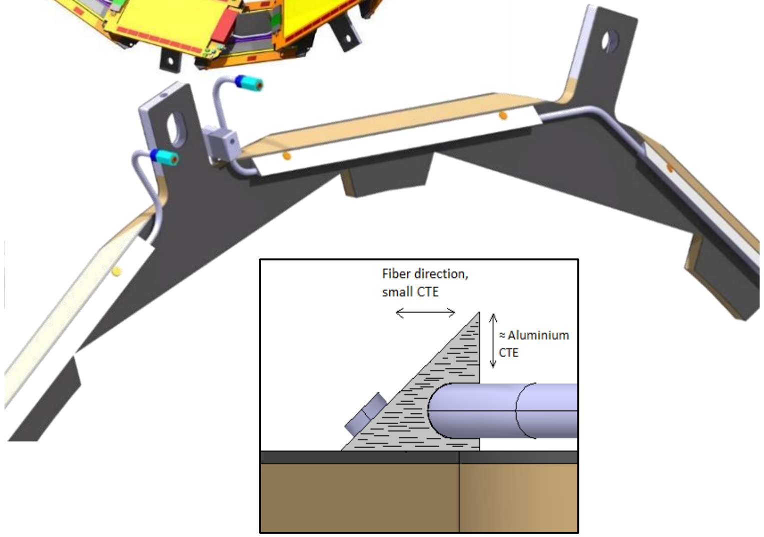
CMS Phase 2 Tracker EC



Prototyping and R&D for the CMS Phase 2 Outer Tracker End Caps, Andreas Mussgiller

CMS Phase 2 Tracker barrel

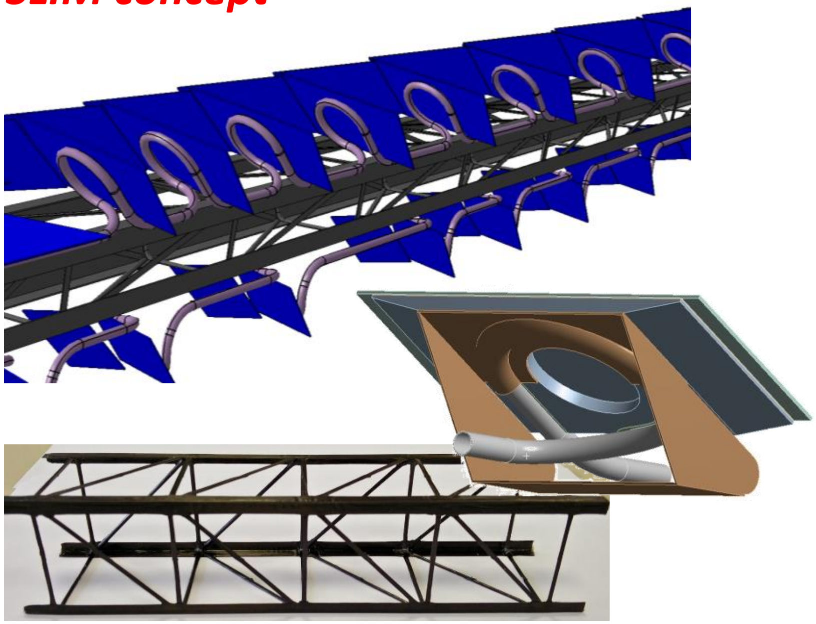




CMS Phase 2 Outer Tracker Central Barrel Upgrade, *Kamil Cichy*

Full separation of cooling and structure
(Bring the tube to the sensor, it is a CO_2 cooling pipe after all)

ATLAS Phase2 Pixel
SLIM concept

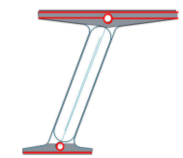


Lightweight support structures and thermal management materials for silicon tracker detectors featuring tilted modules, *Diego Alvarez Feito*

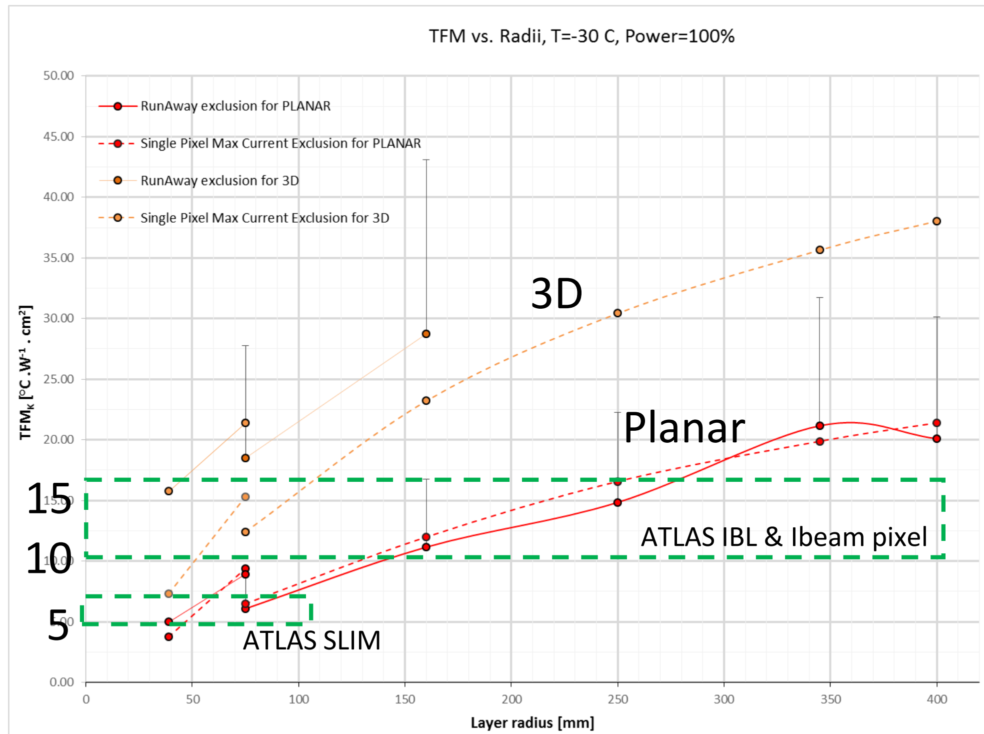
Backing Material	Conductive TFM (°C·W^{-1}·cm^{-2})	Mass* (g)
Al-Diamond	5.2	3.0
Iso-graphite	7.0	2.5

ATLAS Phase2 Pixel

		TFM [K cm^2 W^{-1}]			
I-Beam side	CO_2 [C]	NTC default		IR camera	
Wide	-19.5	16.8	0.7	11.7	0.7
Narrow	-19.5	11.2	0.9	10.4	1.0

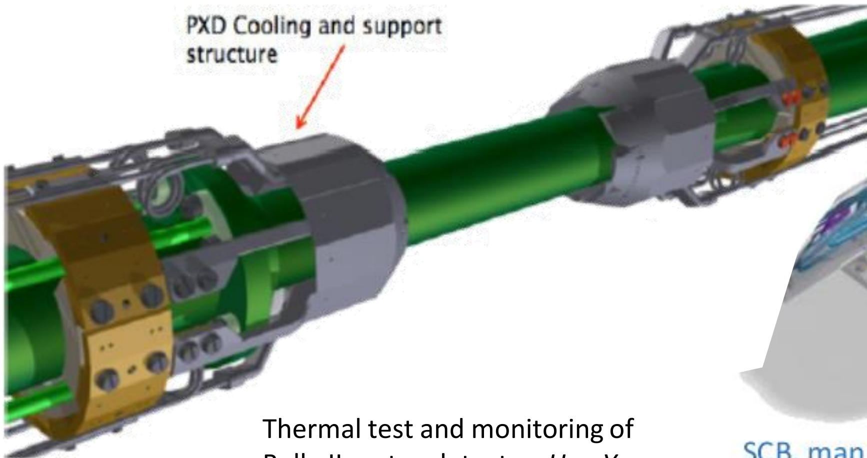


*ATLAS IBL TFoM=13 K*cm^2*W^{-1}*

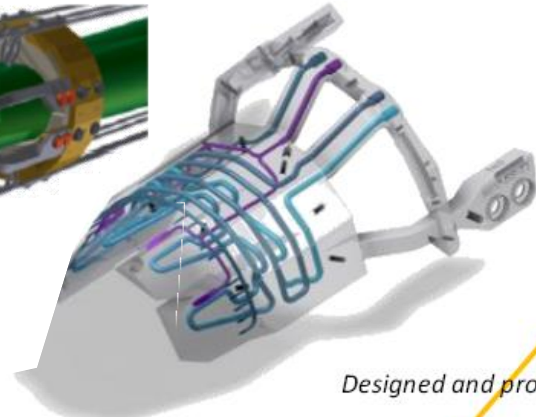


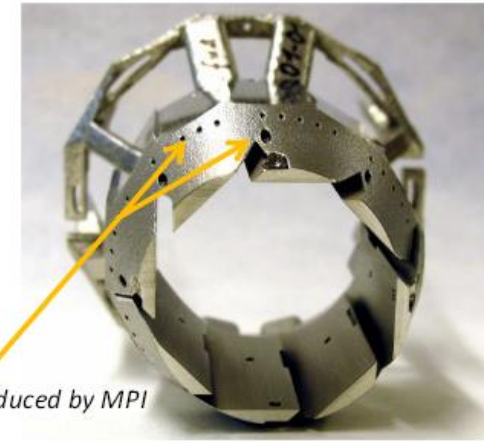
Alternative cooling solutions

KeK Belle-2 PXD



Thermal test and monitoring of Belle II vertex detector, *Hua Ye*



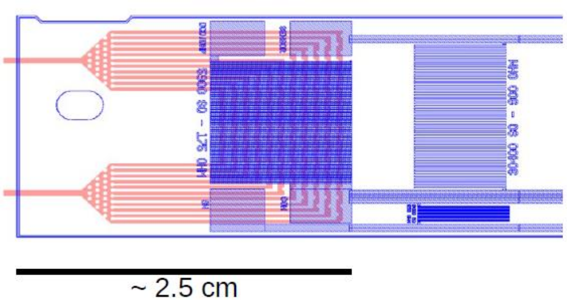


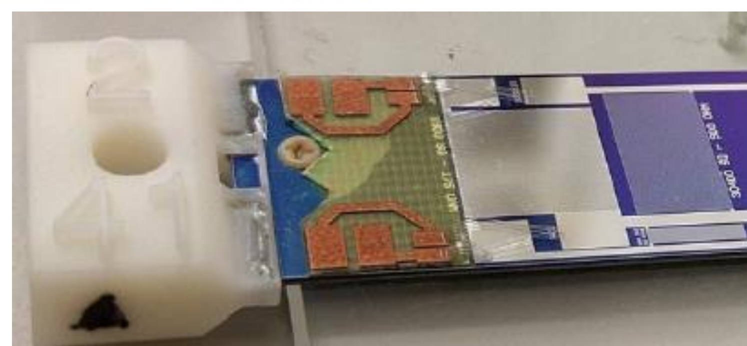
Designed and produced by MPI

SCB, manufactured using 3D printing technology, with enclosed CO_2 and open N2 channels inside.

AIDA-2020 Depfet

Micro-channel cooling for silicon detectors, *Miguel-Angel Villarejo Bermudez*



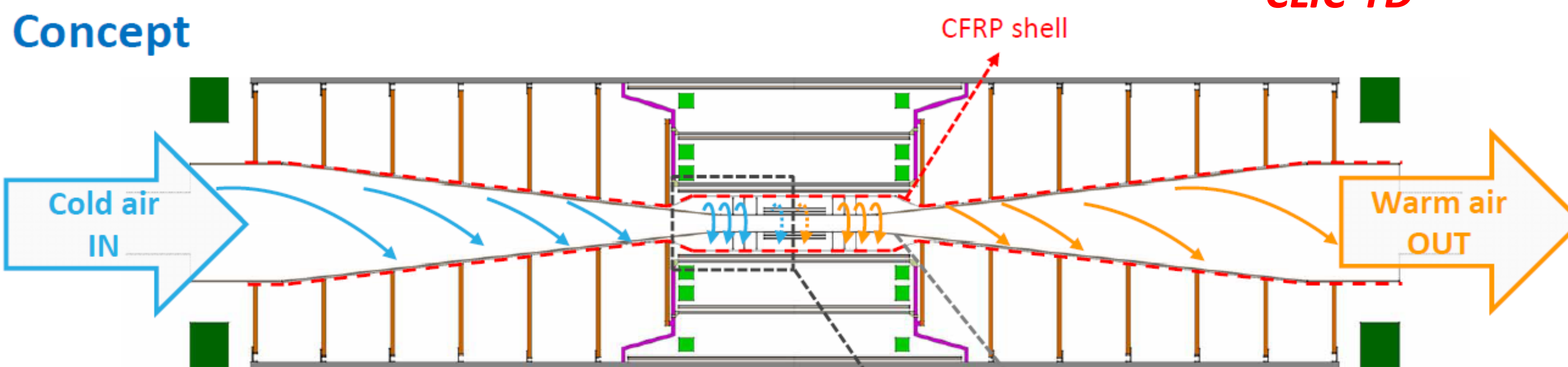


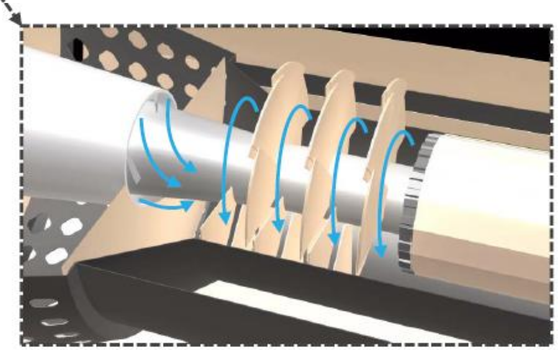
Air cooling solutions for low power CMOS, MAPS and Depfet sensors

Air cooling

Concept

CLIC-TD



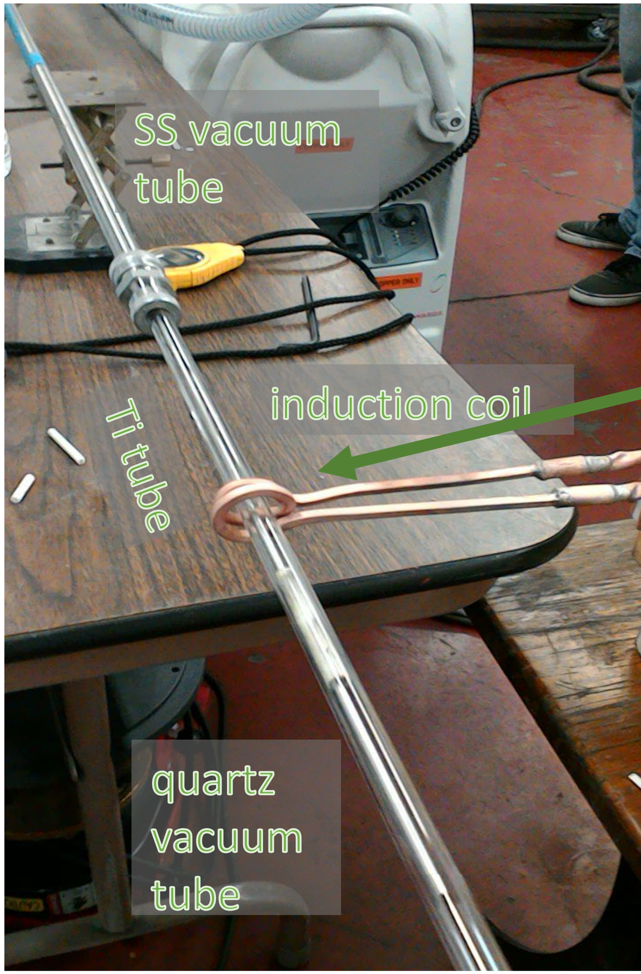


Developments on the mechanics and cooling for the CLIC tracking detectors, *Szymon Sroka*

STAR PXL

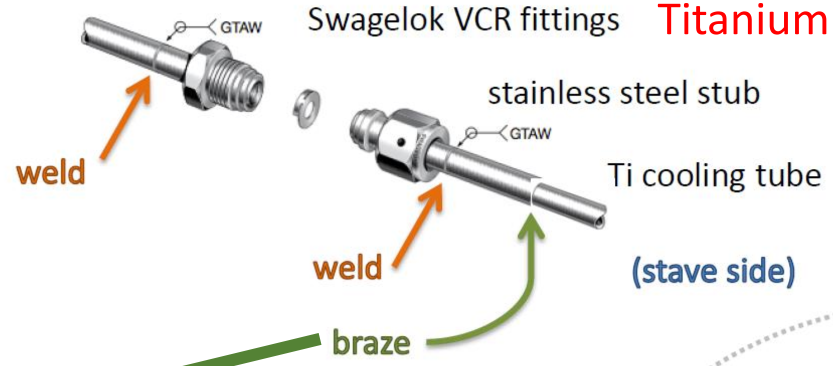
The STAR PXL detector cooling system, *Eric Anderssen*

Reliable cooling connections for high pressure CO_2



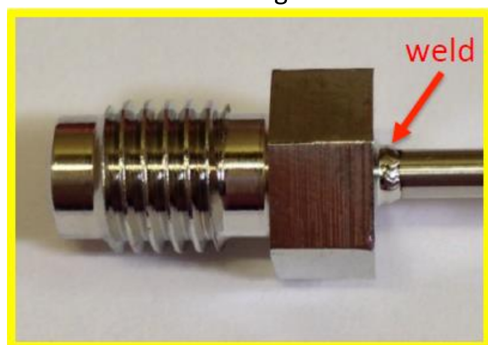
Mechanics and Construction of the LHCb Upstream Tracker Detector, *Ray Mountain*

Titanium to SS brazing

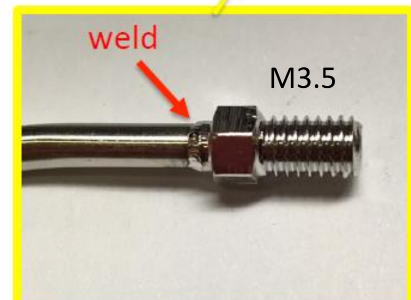


Super small connector (VCR like)

Laser Welding of the CMS FPIX Phase 1 Upgrade Cooling Pipes, *Stephanie Timpone*



VCR

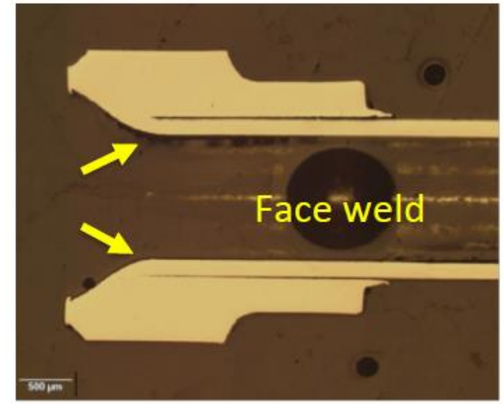


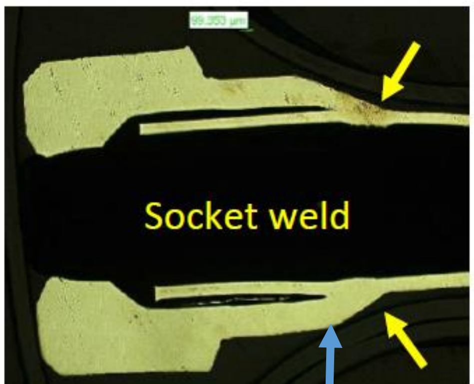
Male Nut

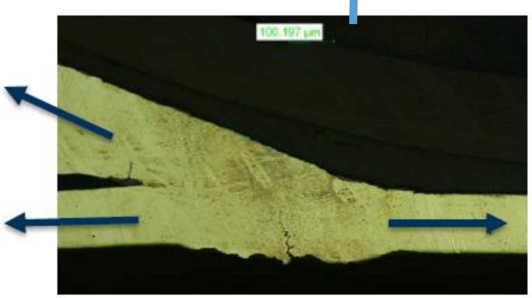
Welding SS tubes

A very nice material science lesson by Stephanie Timpone about hot cracking

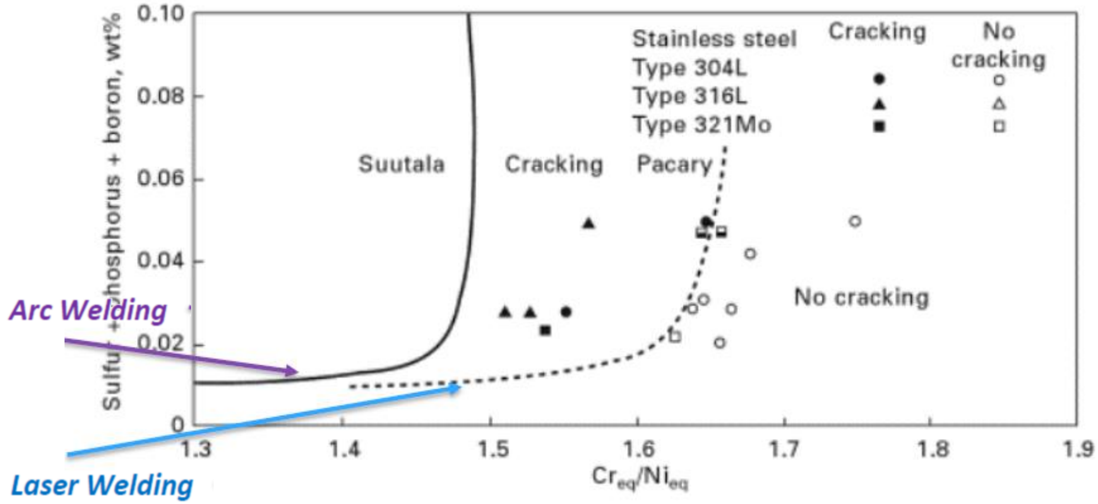
Both samples taken from a HD assembly that passed hydrostatic pressure testing at 157 bar for 1 hour







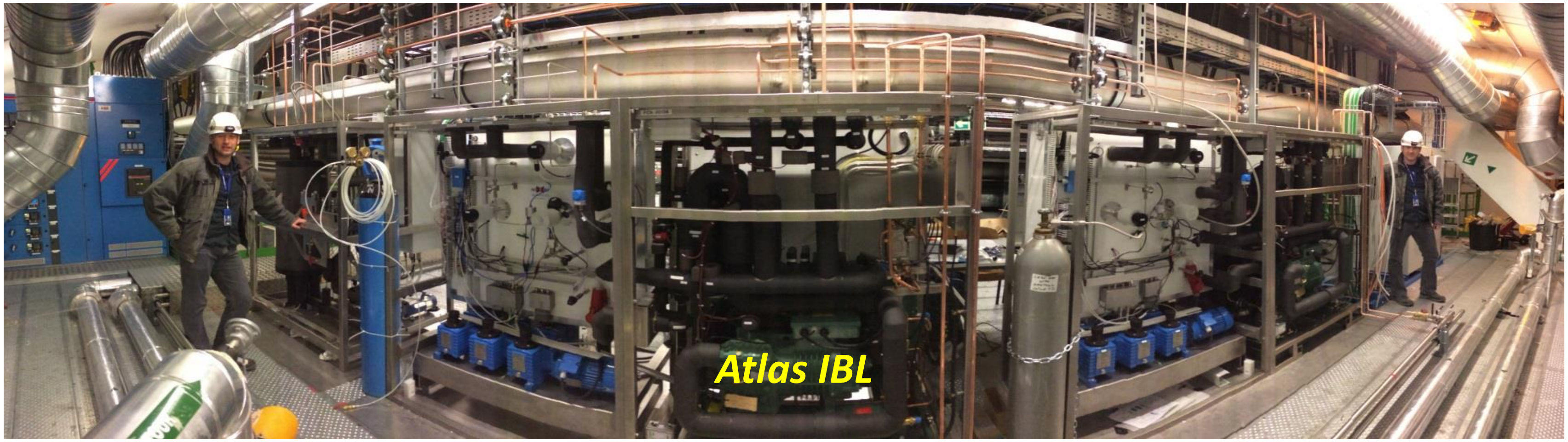
Laser Welding of the CMS FPIX Phase 1 Upgrade Cooling Pipes, *Stephanie Timpone*



1.12 Cracking susceptibility diagram of stainless steels under laser beam processing conditions.

CO_2 Cooling system commissioning

The CMS PIXEL Phase 1 CO2 cooling system: Commissioning and operation of a large scale CO2, *Jerome Daguin*



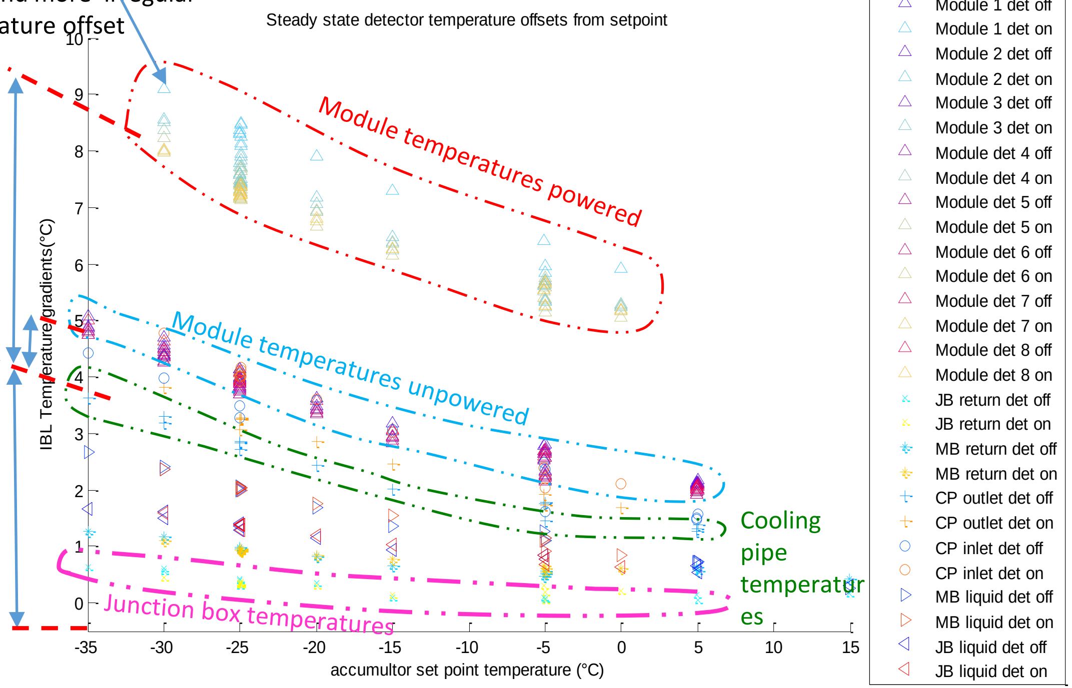
Commissioning and operational experience of the ATLAS IBL CO2 cooling system, *Bart Verlaat*

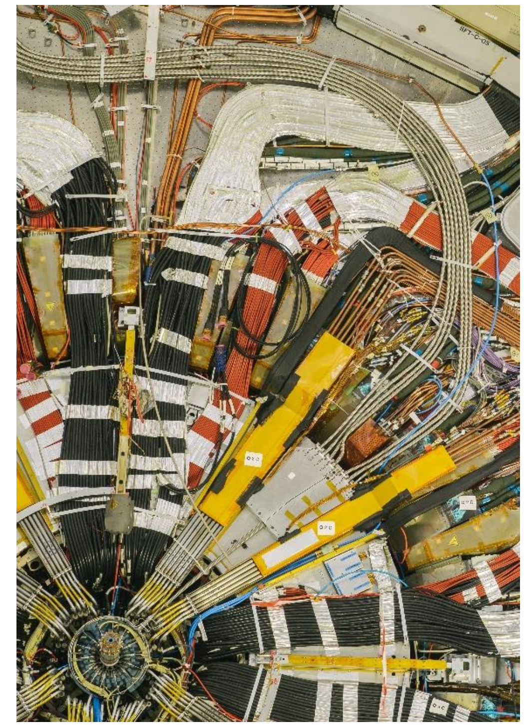
ATLAS IBL cooling results

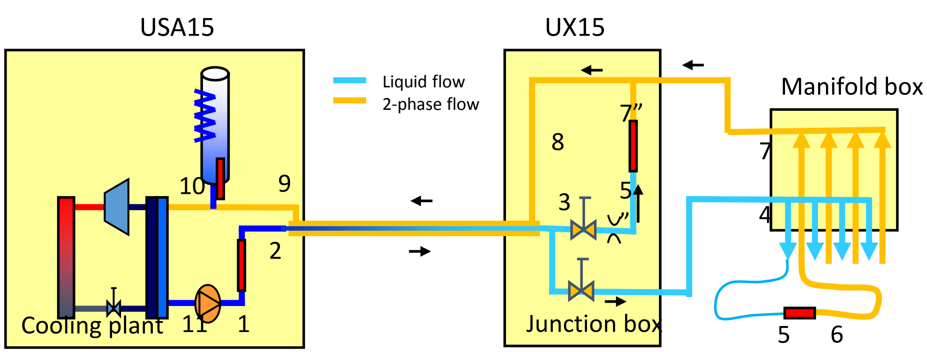
First modules show a larger and more irregular temperature offset

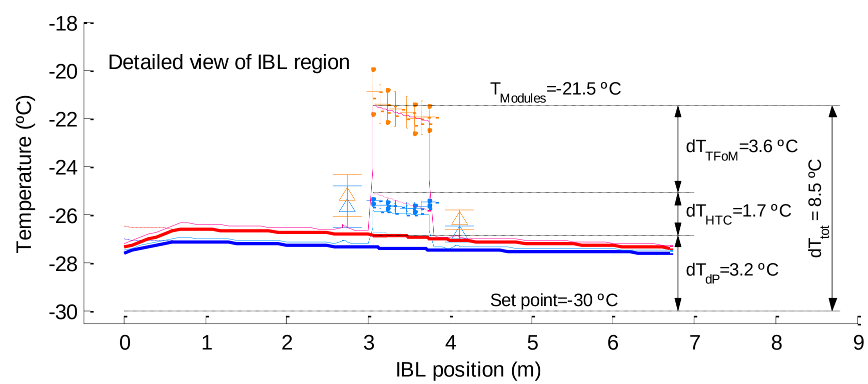
Gradients due to stave conduction relatively constant

Gradients increase as a function of cooling temperature due to pressure drop (Mainly flex lines)



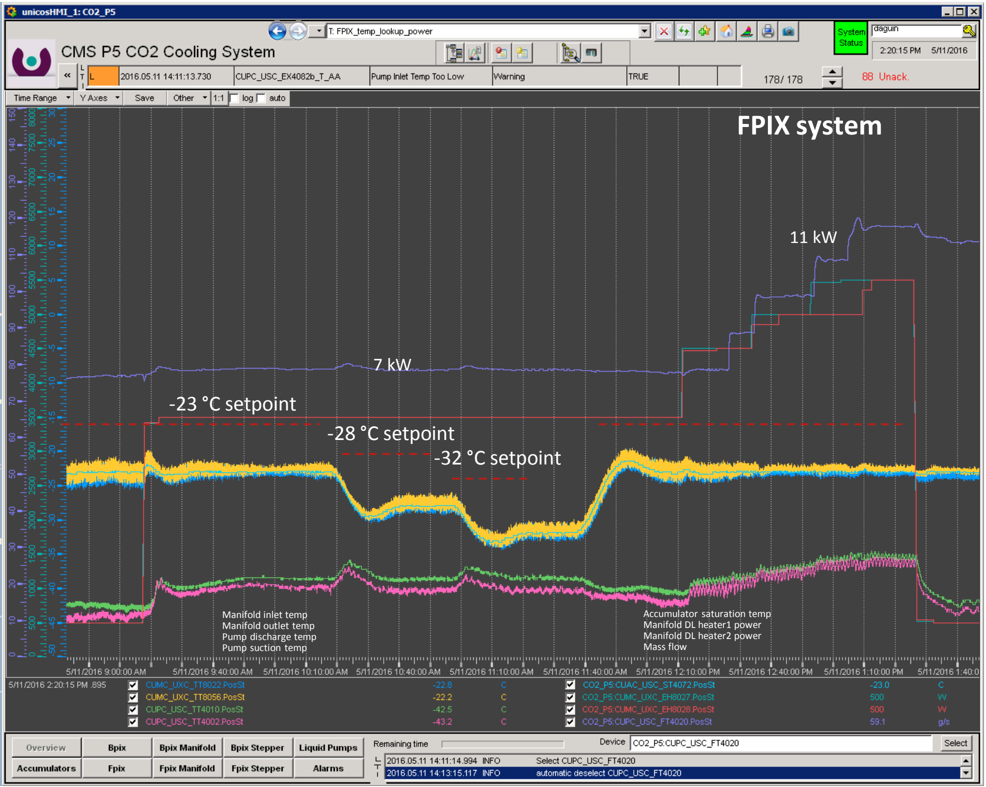




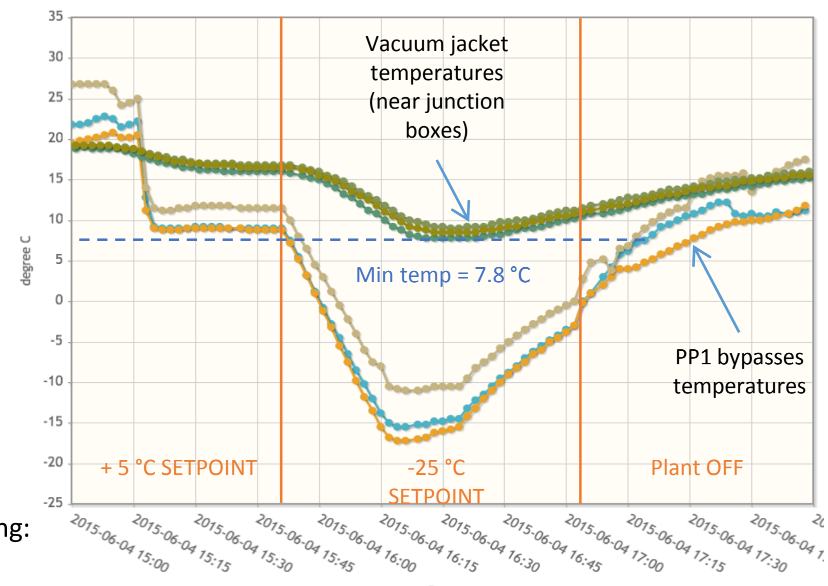


CMS-Pixel Cooling results

The CMS PIXEL Phase 1 CO2 cooling system:
Commissioning and operation of a large scale CO2, *Jerome Daguin*



First large CO2 cooling system (11 kW)



The vacuum insulated transfer lines for CMS CO2 cooling:
performances and lessons learnt, *Paola Tropea*

Mobile CO_2 unit development

Transportable Refrigeration Apparatus for CO_2 Investigation

Commercialization of a mobile CO_2 unit by an Industrial consortium

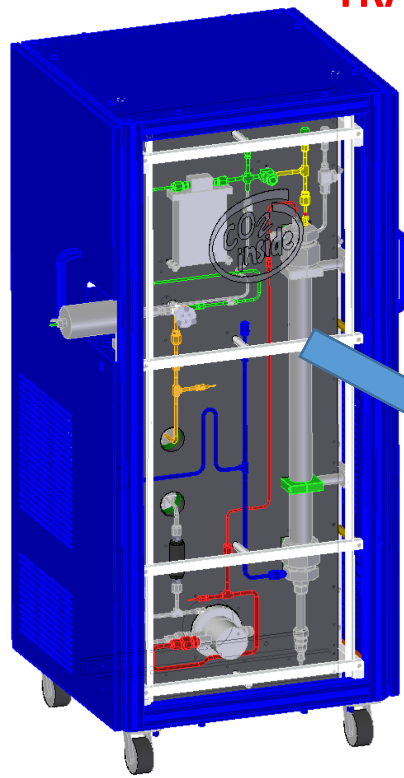
Refrigeration

Hydraulics

Cracow University of Technology

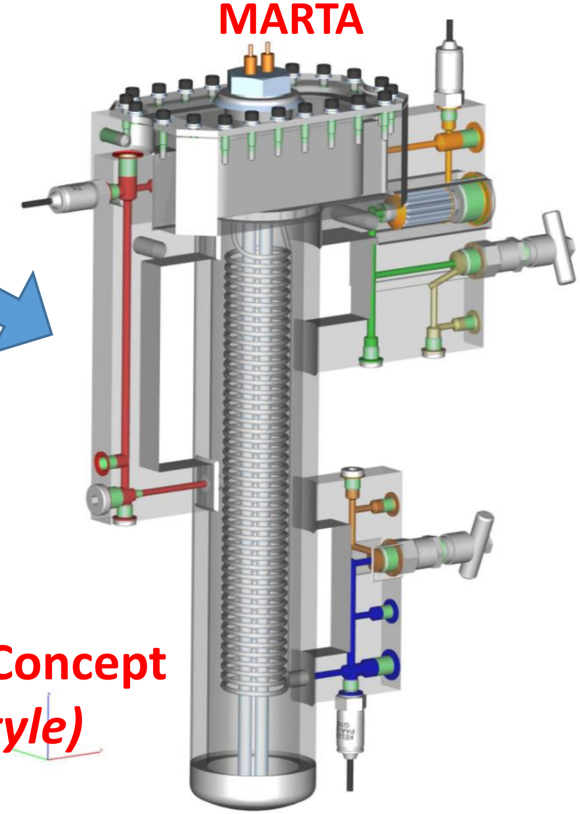
Knowledge

TRACI



Mono-block Approach for Refrigeration Transportable Apparatus

MARTA



Mono-Block Concept
(Hydraulics style)

Summary

- The Forum on Tracking Detector Mechanics 2016 held in Bonn was a success
- Lots of interesting talks related to mechanics and thermal challenges were presented
- We would like to thanks the organizers of the forum for the perfect organization.

Questions?