ATLAS ITk Project

Marianna Testa
on behalf of LNF ATLAS-ITk group

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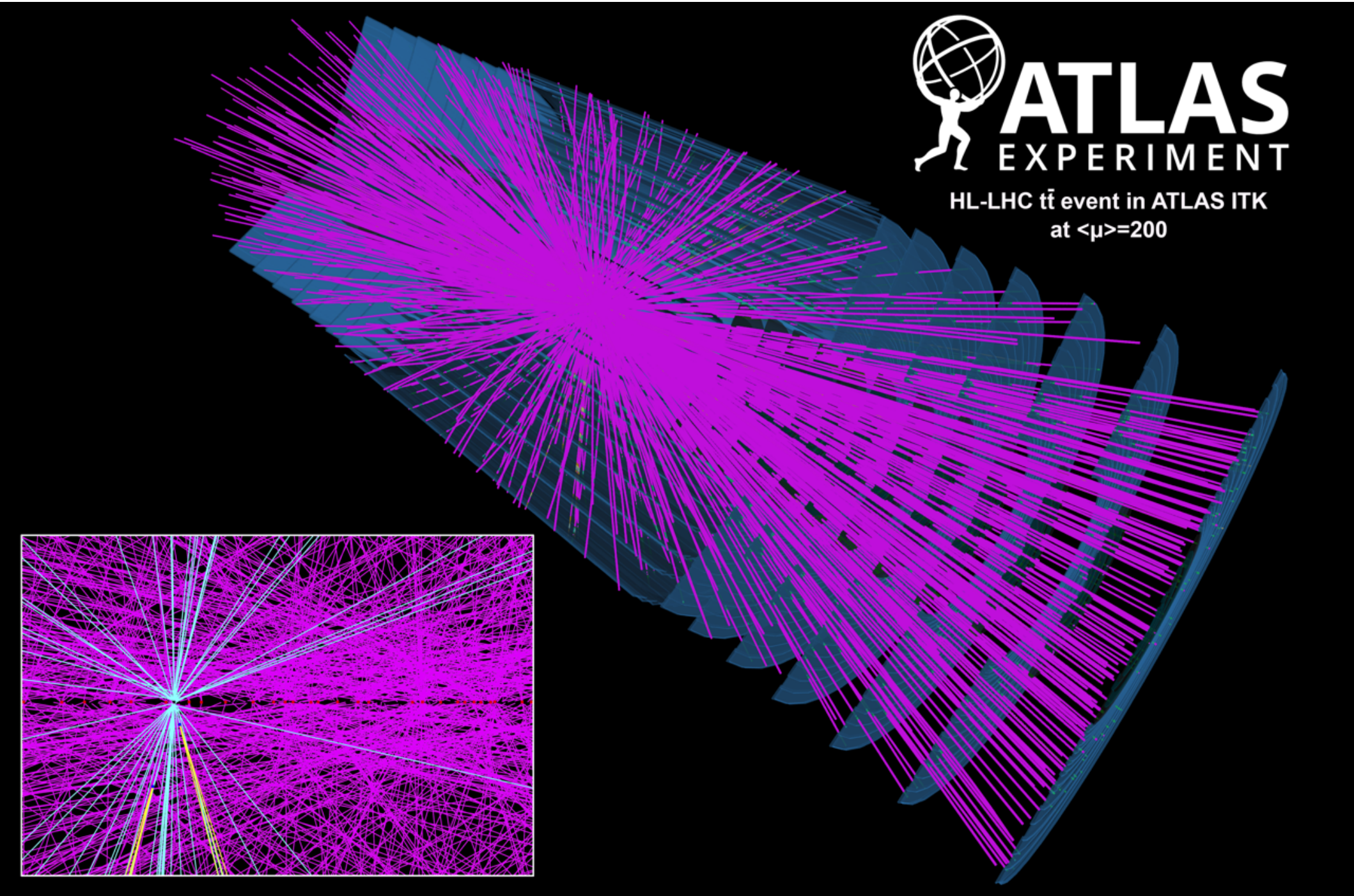
Phase II: High Luminosity LHC

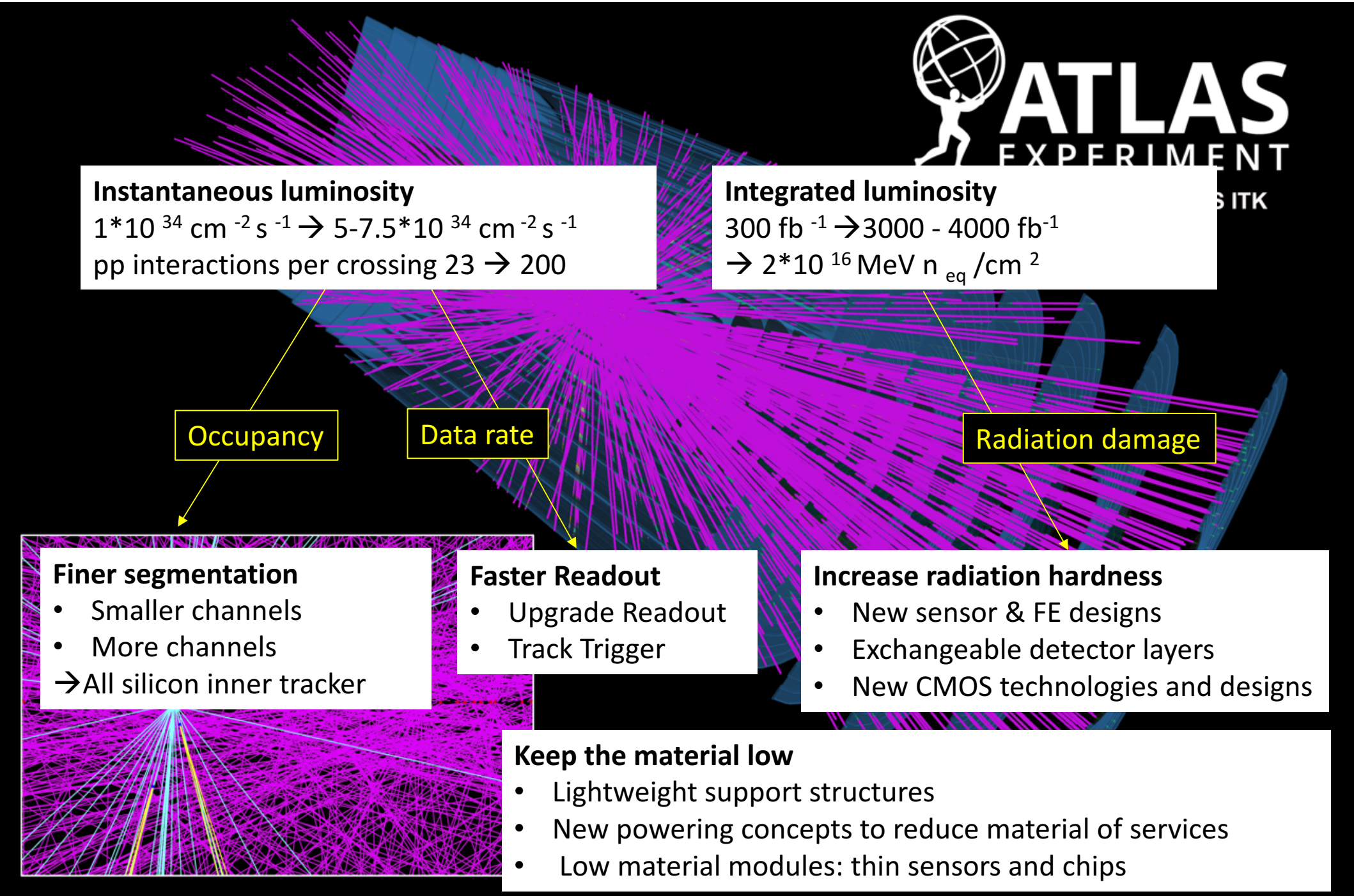
- Operation at up to **$L=7.5\cdot10^{34}Hz/cm^2$** (LHC Run-2: $2\cdot10^{34}$) to collect up to L_{int} = **3000 fb^{-1}**

- Up to **200** (~ 37) **pp collisions** per bunch crossing at HL-LHC (LHC Run2)
  - Very challenging experimental conditions
  - Extensive detector upgrades to operate under HL-LHC conditions

Simulated event with 200 collisions per bunch crossing



ITk requirements



Instantaneous luminosity
$1*10^{34}$ cm $^{-2}$ s $^{-1}$ → 5-7.5*10^{34} cm $^{-2}$ s $^{-1}$
pp interactions per crossing 23 → 200

Integrated luminosity
300 fb $^{-1}$ →3000 - 4000 fb^{-1}
→ 2*10^{16} MeV n_{eq} /cm ^{2}

Occupancy

Data rate

Radiation damage

Finer segmentation
- Smaller channels
- More channels

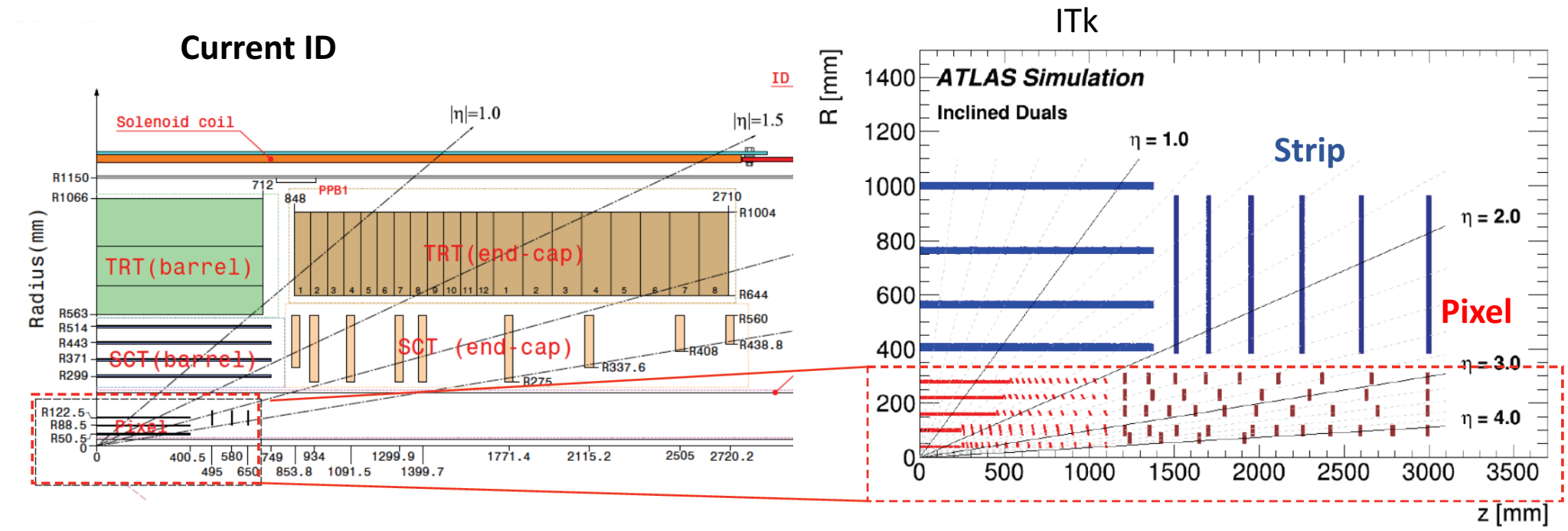
→All silicon inner tracker

Faster Readout
- Upgrade Readout
- Track Trigger

Increase radiation hardness
- New sensor & FE designs
- Exchangeable detector layers
- New CMOS technologies and designs

Keep the material low
- Lightweight support structures
- New powering concepts to reduce material of services
- Low material modules: thin sensors and chips

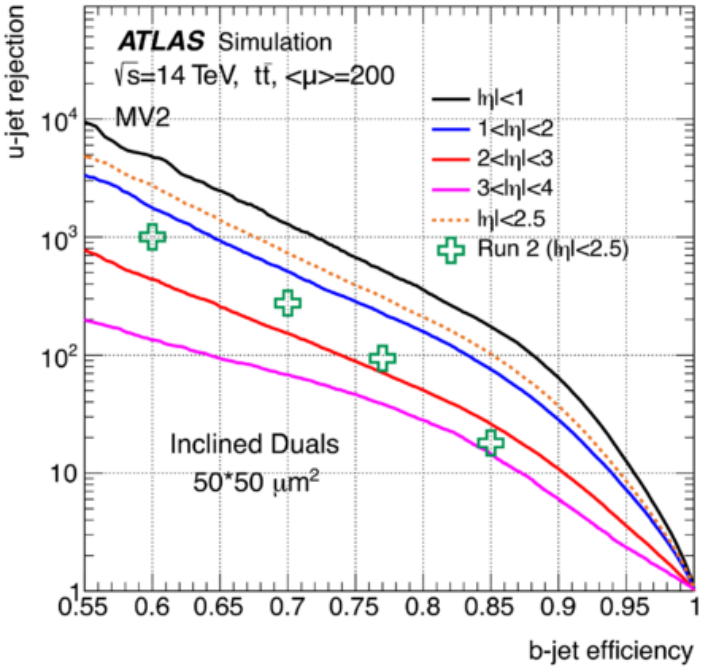
The ITk Layout

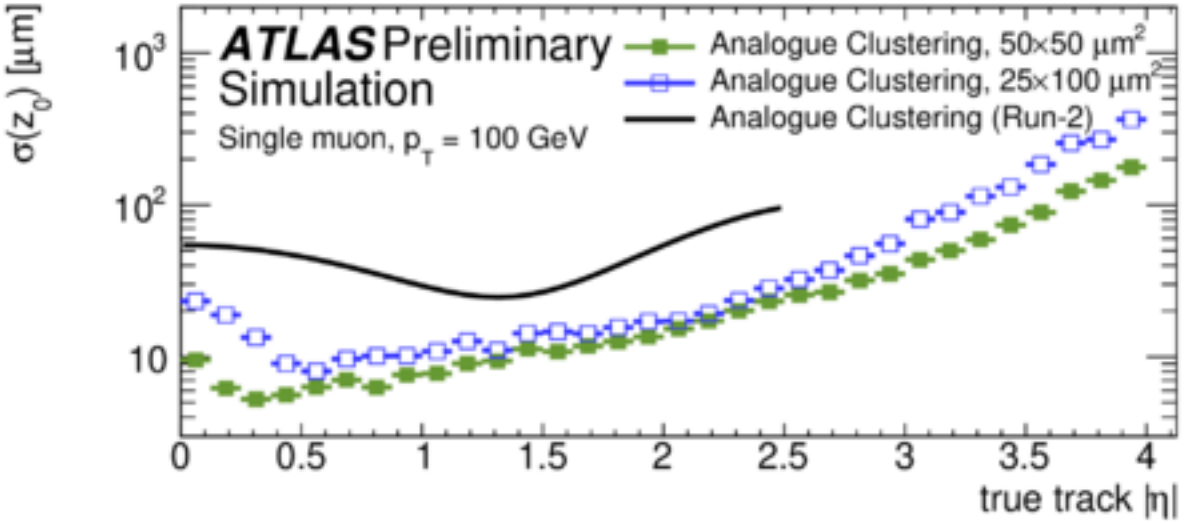


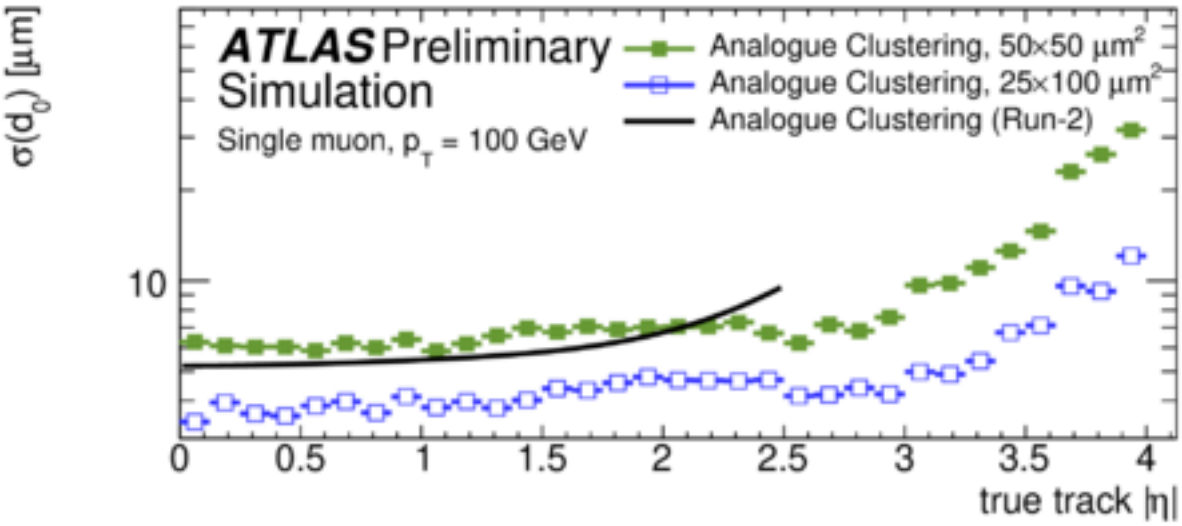
- All silicon detector
- 5-layer pixel detector
- Coverage up to η=4
  - Combined with the strip detector at least 9 points up to η=4
- Inclined layout: minimization of needed modules and more hits per layer for one track
- **10276 modules, 12.7 m^2, 5x10^9 channels**

ITk Performances

- **Tracking resolution** comparable to or better than in Run-2, even with μ~200
- **B-tagging** performance better than in Run2

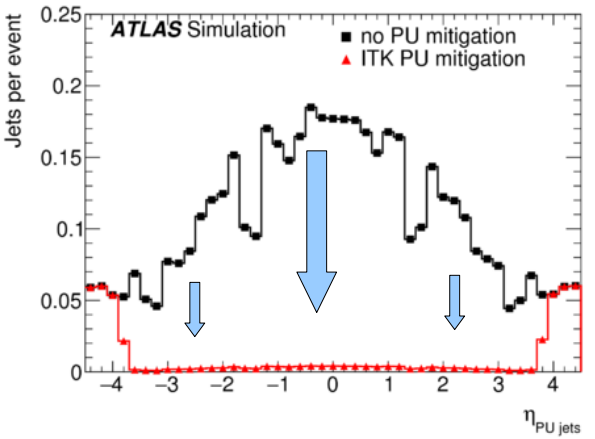


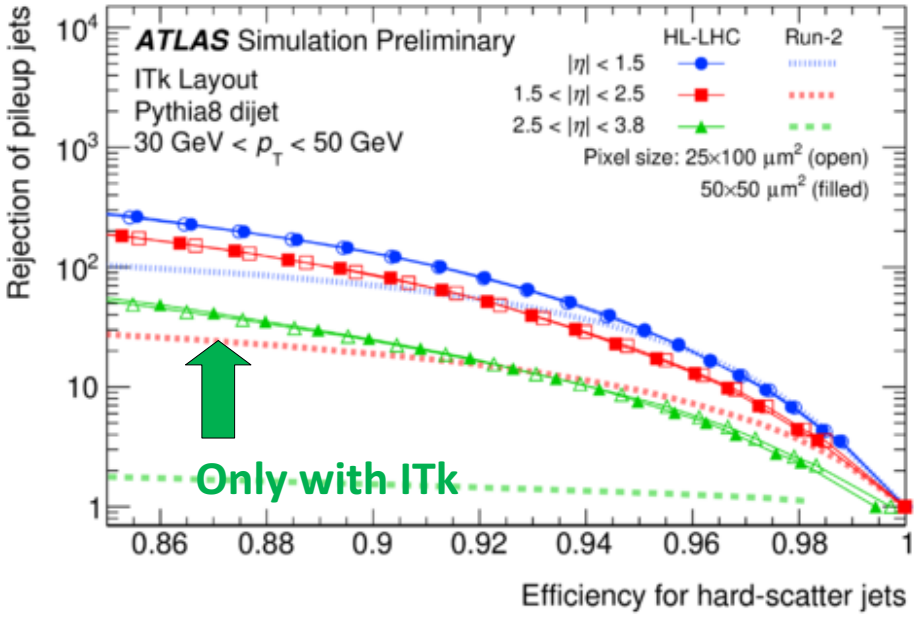


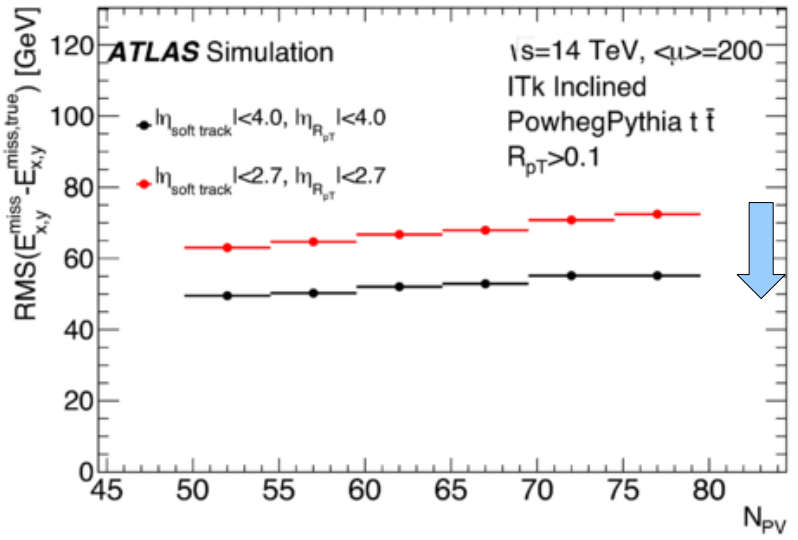


ITk Performances: jets and E_T^{miss} reconstruction

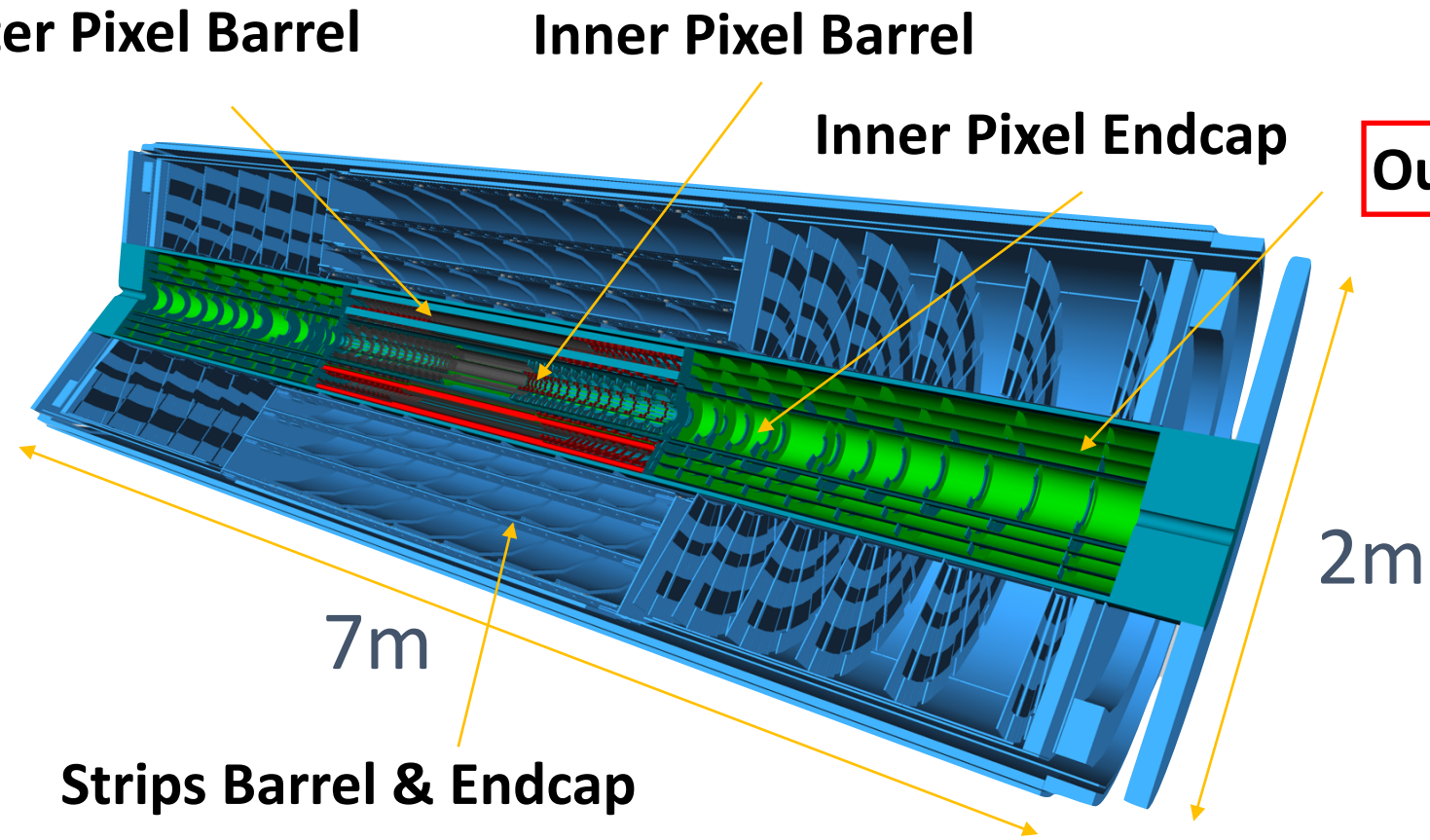
- **Main contribution from LNF**
- Main motivation for increased acceptance up to $|\eta| < 4.0$ (currently $|\eta| < 2.5$)
  - Could suppress pile-up jets in the forward region using tracking information
  - Improve E_T^{miss} resolution
- Critical for layout decision







ITk concept

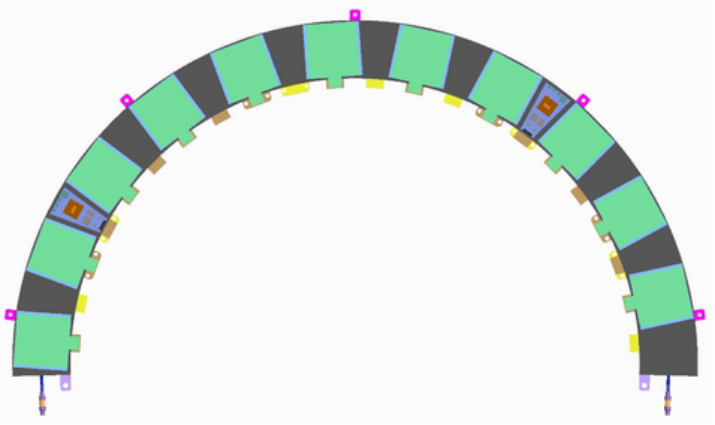


Italy will build one outer pixel endcap of the ITk detector

ITk Pixel Endcap

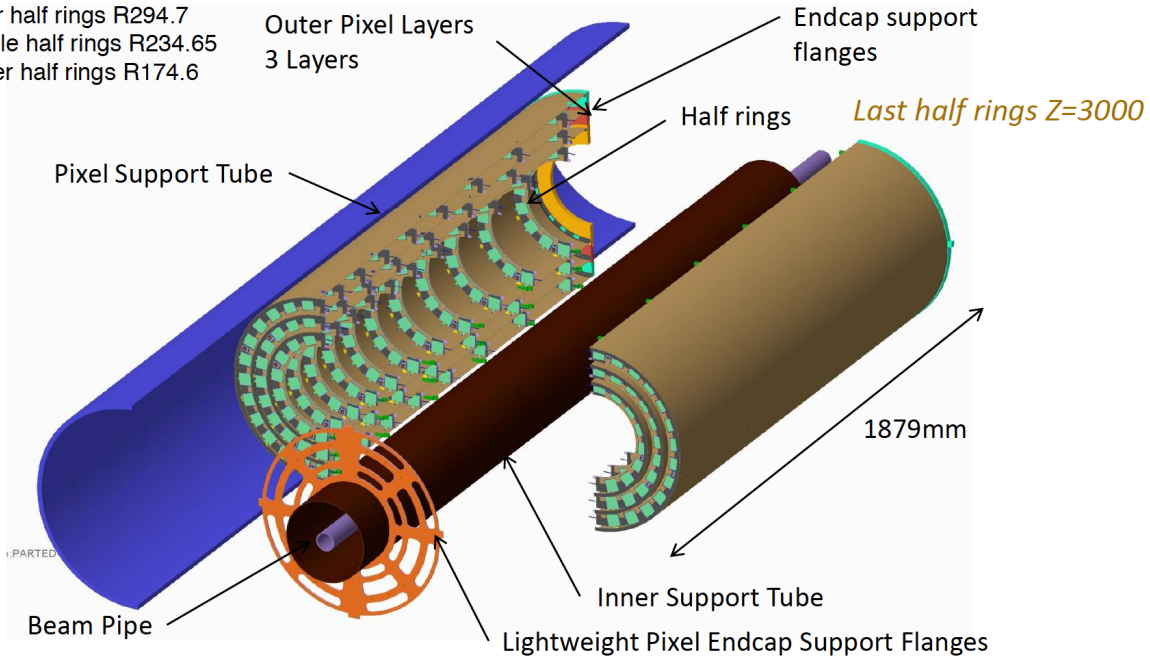
- novel concept of the end-cap ring system
  - position to optimise coverage
- **carbon fiber** half cylinder shell supports

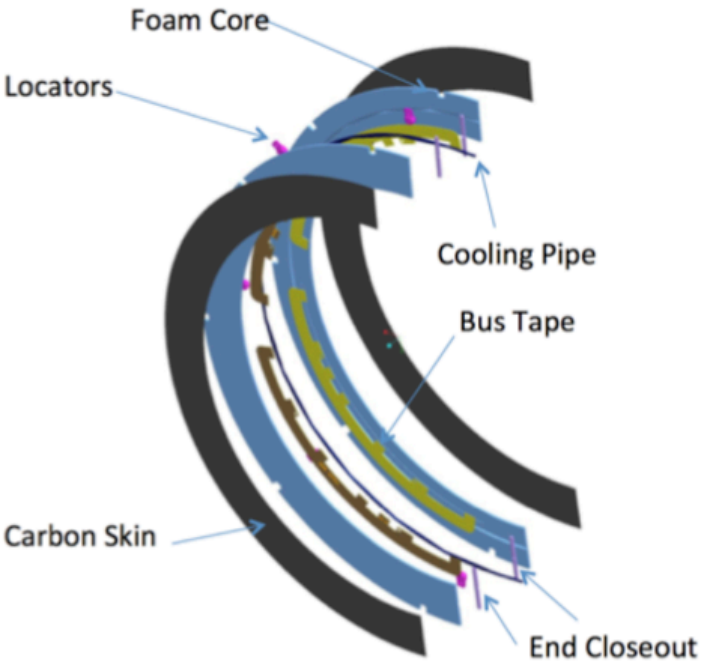
Modules on half rings



Half-rings on half-shell

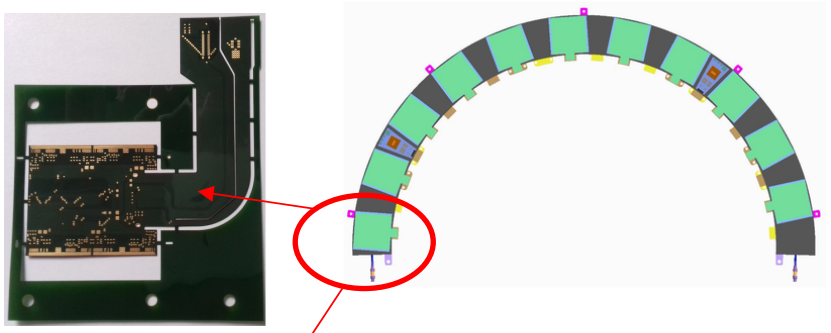
- 9 outer half rings R294.7
- 8 middle half rings R234.65
- 11 inner half rings R174.6





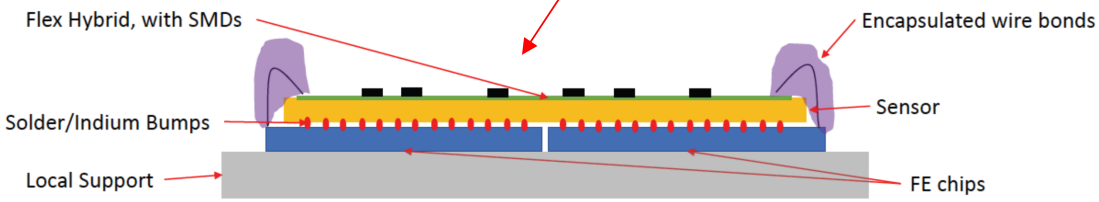
Half-ring structure with cooling pipe

Modules, Sensors and Readout Chip



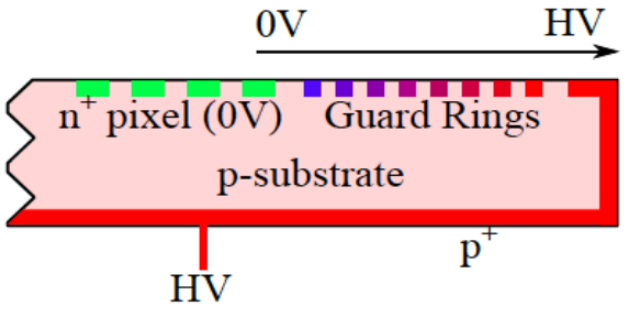
Hybrid Module:

- Sensor bump-bonded to a FE chip
- 4 FE chips for one sensor in the endcap
- **1172 modules** for one endcap



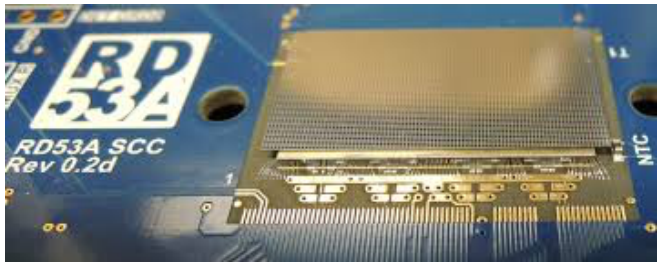
Planar Sensor used for endcaps

- 150 mu active thickness



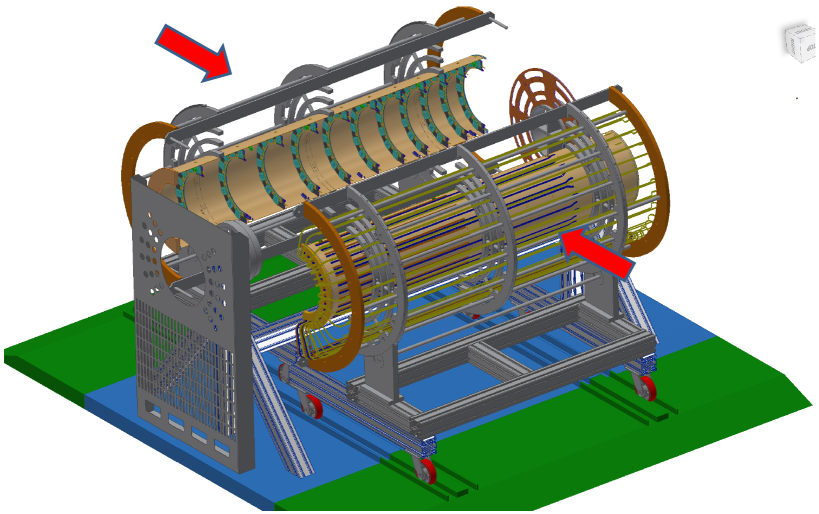
Frontend Chip

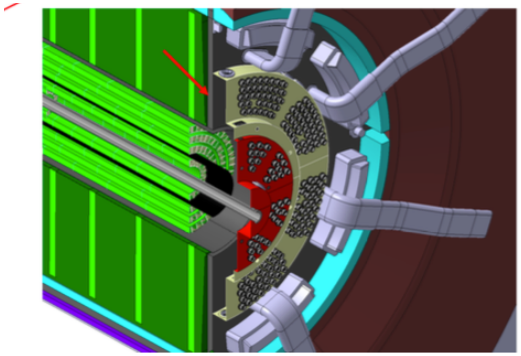
- 65nm technology
- Pixel sizes 50x50 um^2 (25x100 um^2)
- Pixels 384x400
- Readout Data rate 1-4 links @ 1.28Gbits/s = max 5.12 Gbits/s
- **8912 data-links** from modules to off-detector electronics for one endcap



ITk Pixel Endcap at LNF

- Endcap Integration
  - detector assembly and commissioning
    - reception of half-ring
    - insertion into cylinder supports
    - test
  - tooling design
  - services routing design





- Electrical services
  - Patch panel 1 design, mockup, production

Multiple LNF services involved

- Research and Technical Division Mechanical Services
- Research Division Electronic Service
- Accelerators Division Cryogenic Group

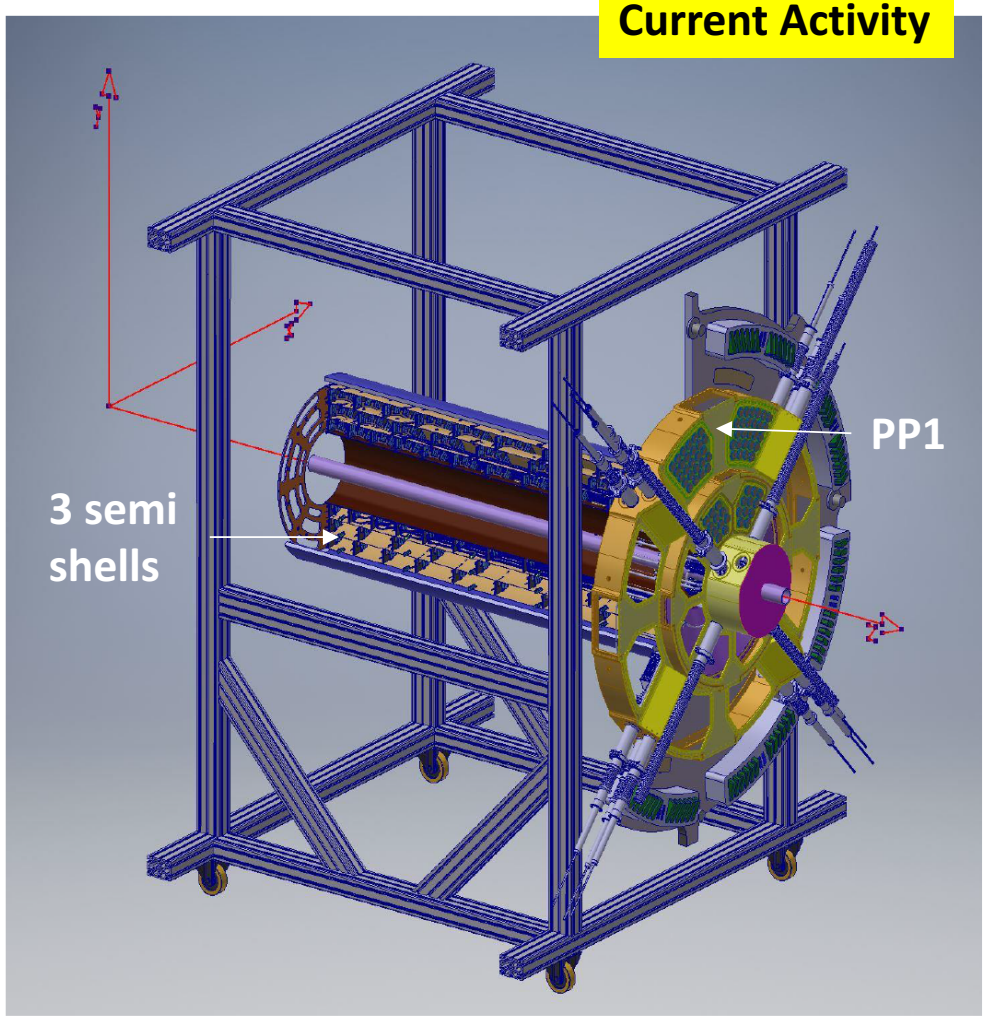
Patch Panel and Endcap mockup at LNF

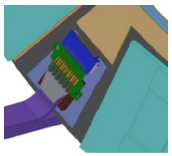
One **full scale** sector prototype

Goals:

- Focus on routing of the cables through cylinder and PP1
- Focus on piping, pipe welding and cooling manifold integration
- Develop and test the assembly toolings/procedures
- Seal test for PP1
- Ready for end 2020

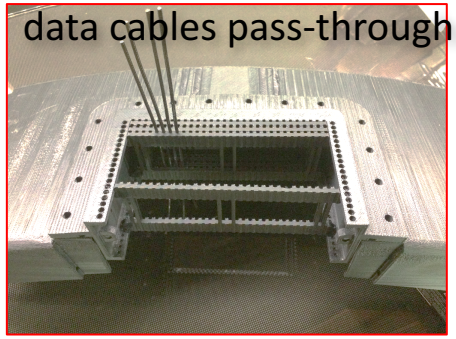
Current Activity





Detail of connection SAMTEC shown here but choice not finalised

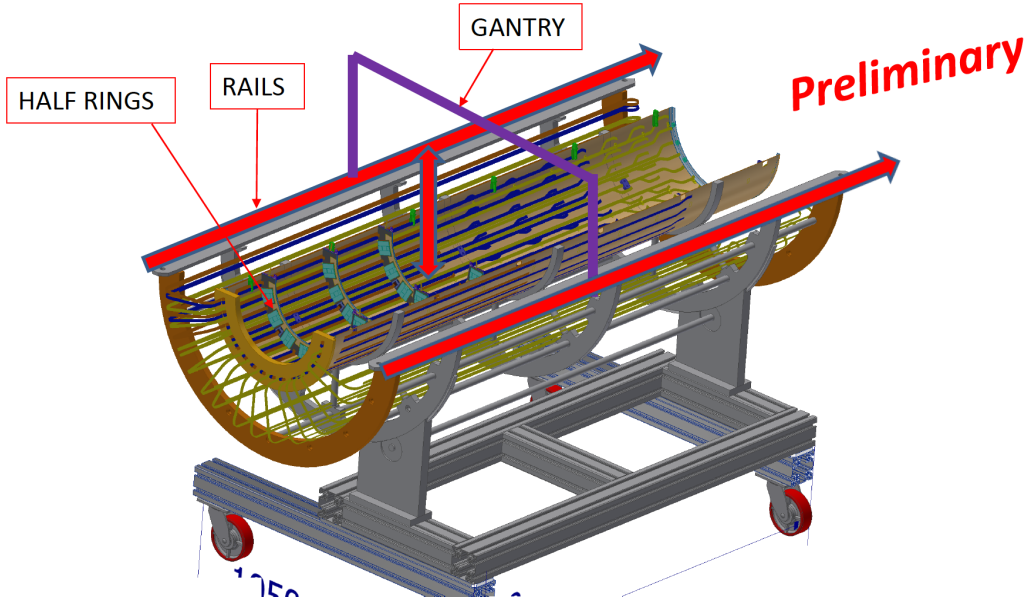
Finally the Rings are installed



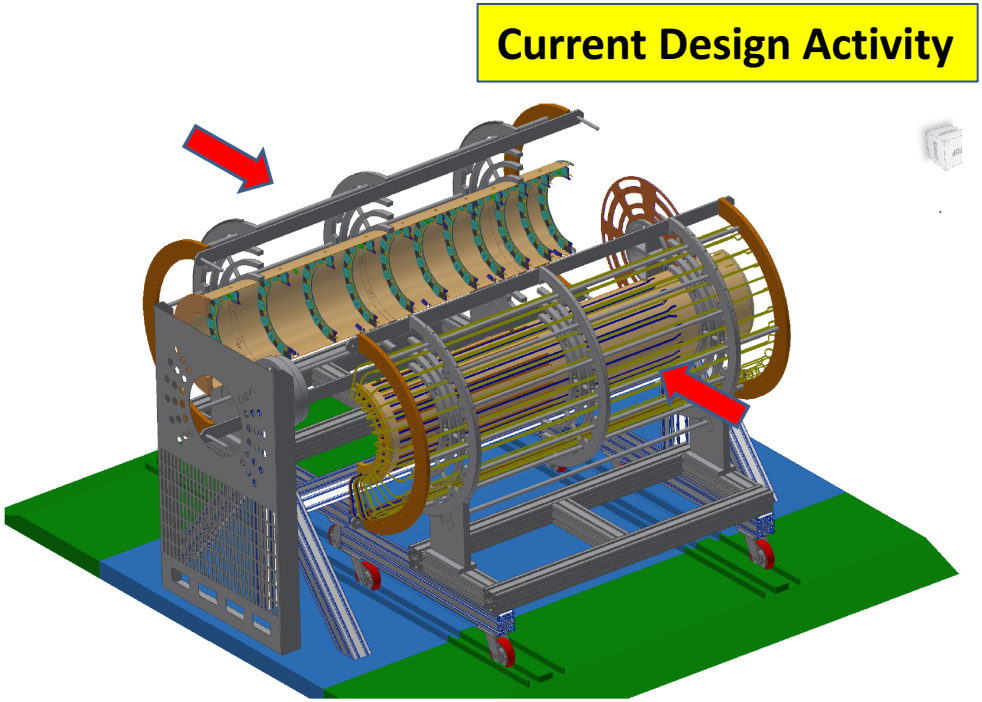
D. Orecchini
S. Tomassini

Assembly Tools at LNF

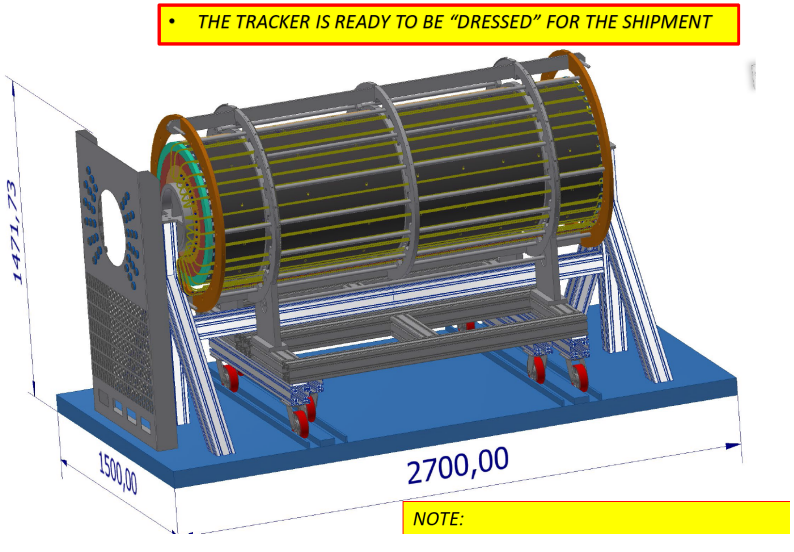
1) Insert half rings into half shells



2) Join half shells, for each layer



3) Endcap ready for shipment

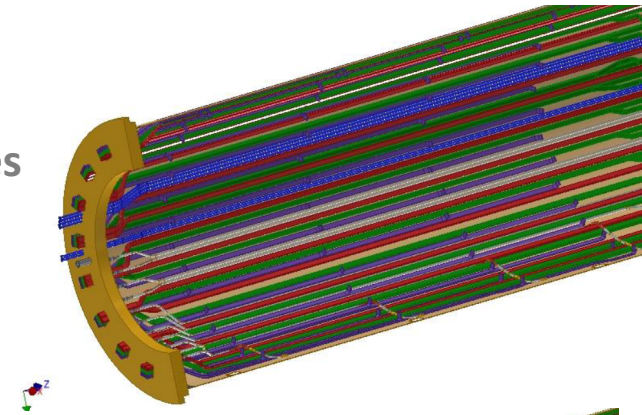


D. Orecchini
S. Tomassini

Tests for Integration

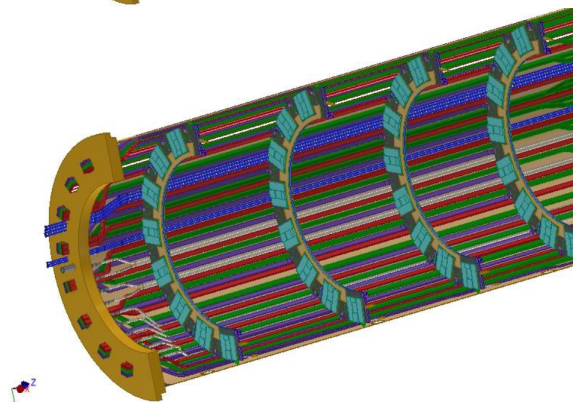
- **All services Installation**
  - Connectivity test

Data cables
HV/LV Cooling pipes

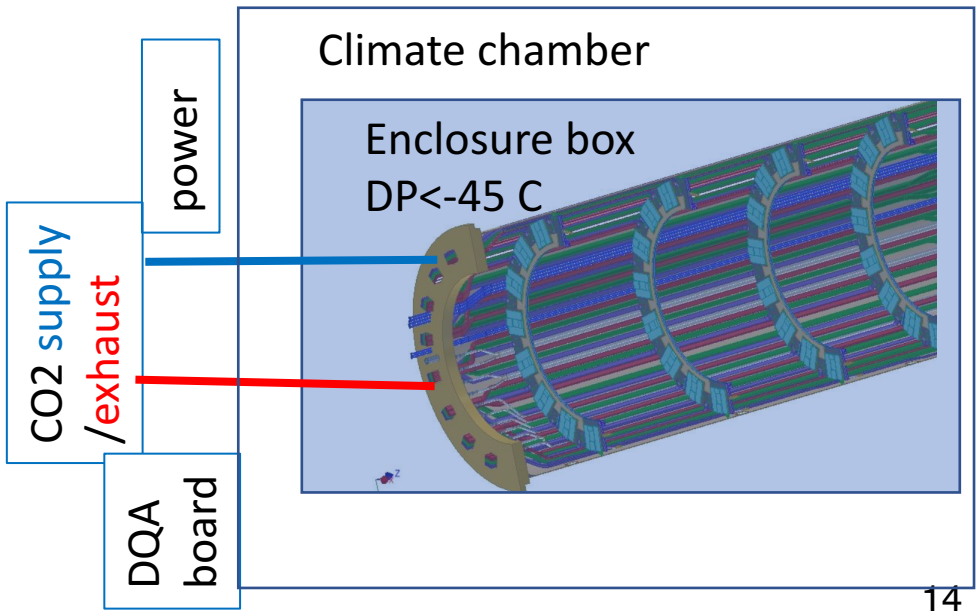


- **Half ring (HR) insertion**
  - Functional test at room temperature
- **TIG (Tungsten Inert Gas) welding of HR to manifold**
  - Pressure tests
  - Functional test at room temperature

Do for all rings



- **Test on a full populated half cylinder**
  - **Thermal cycling** (-55, + 60 C) on detector off
  - Functional test with DAQ with **CO_2 cooling (-35 C)** on powered detector

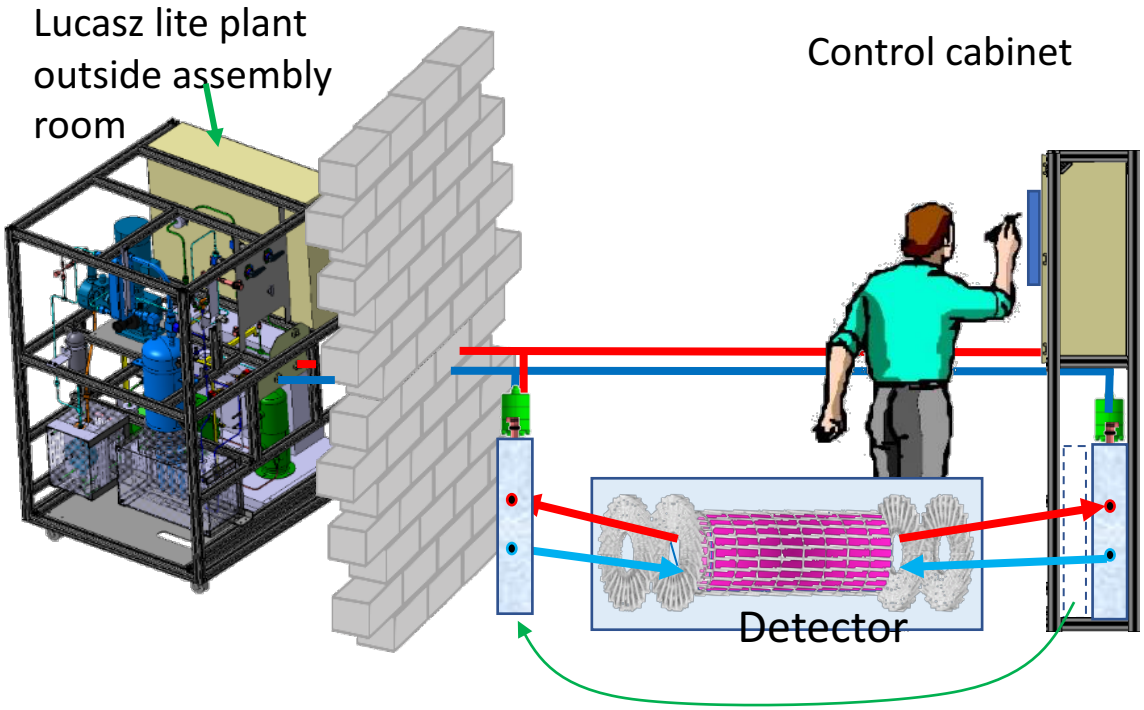


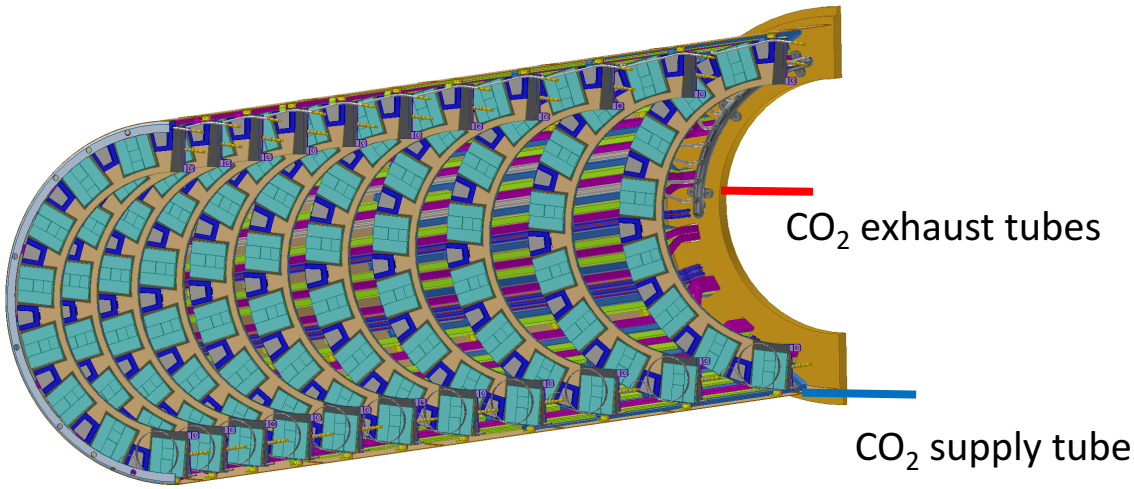
New infrastructures needed

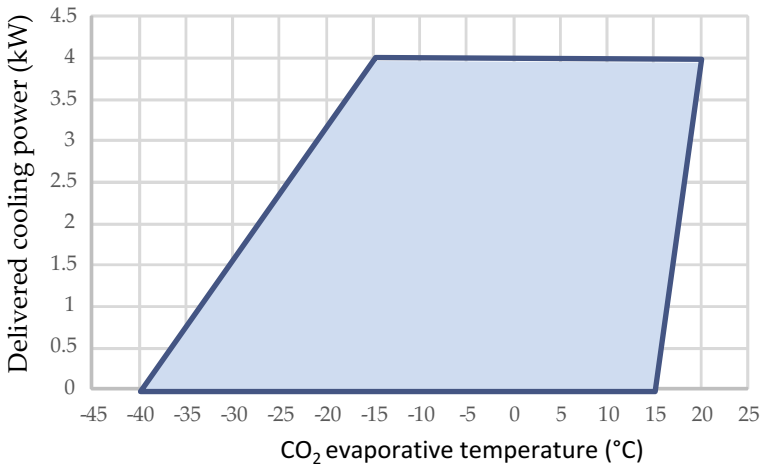
New Infrastructures at LNF: CO_2 cooling plant

CO_2 Cooling system LUCASZ –
Light **U**se **C**ooling **A**ppliance for **S**urface **Z**ones

- Used to cool down detector at -35 C
- In construction at DESY,
  - CERN, DESY, LNF, Nikhef collaboration



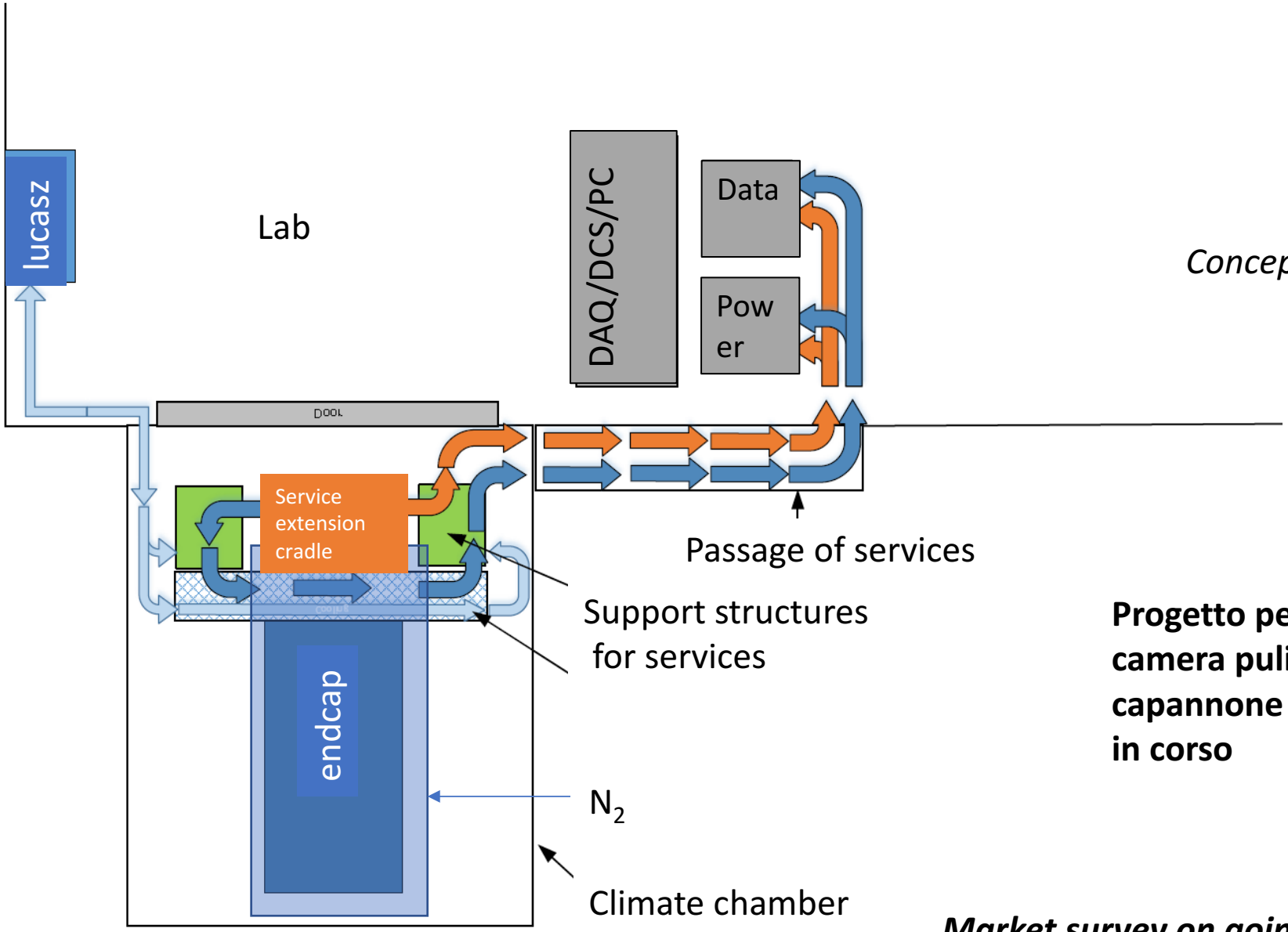




G. Delle Monache group

New Infrastructures at LNF: Large Climate chamber

- Needed for thermal cycling the detector (off) between -55 and +60 C
- Large chamber to contain endcap + services ~ 3 × 2 × 4 m^3



Conceptual design

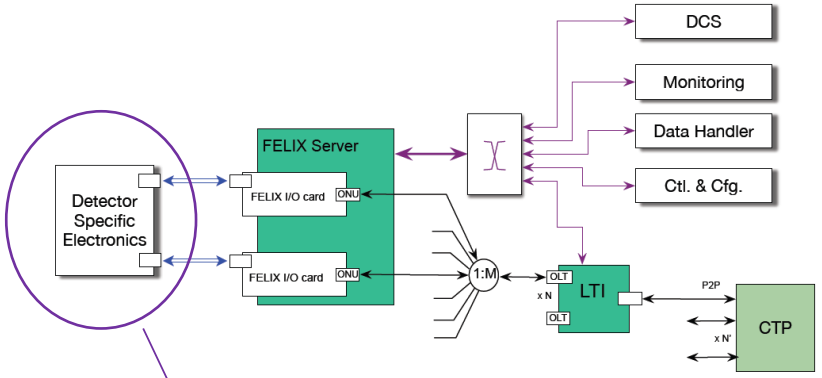
E. Dane', M.Testa

Progetto per rinnovo camera pulita nel capannone gran sasso in corso

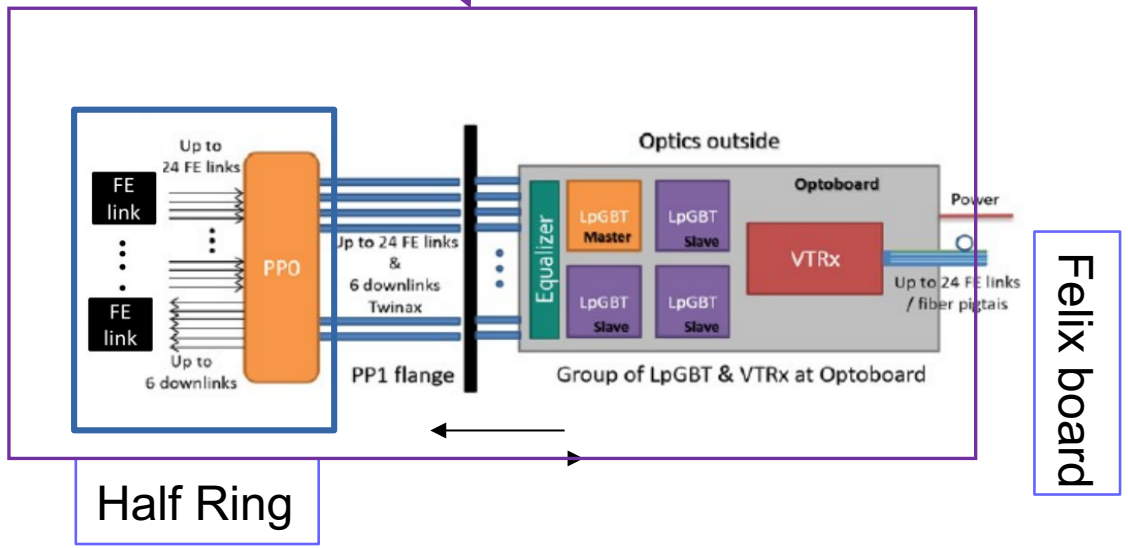
Market survey on going

Felix DAQ Board Phase II

- The DAQ is based on FELIX boards
  - already used for phase I upgrade
  - more stringent for Phase II upgrade
- LNF Electronic services will join the firmware development of Phase II boards
  - study of high bandwidth memory in next generation FPGA's and their benefits in terms of firmware design



- Local knowledge of felix boards very important for the endcap commissioning
  - Uplinks from rings → optical conversion →felix boards



CSN1 LNF: Richieste 2018, assegnato e SJ ’19

Sigla	Ric	Tec	FTE	<FTE>	MISS	CON	APP	ALTRO CAP
FASE2_ ATLAS	3	1	1,9	0.4		27 25		

Missioni sotto preventivo ATLAS

Tecnologi sotto ATLAS

Richieste servizi II sem. 2019 gruppo ATLAS-ITk

Richieste II semestre 2019		
SEA	System test, servizi prototipo endcap	6mu
SPCM	carpenteria lavori integrazione, lavorazioni prototipi pp1, stampante 3d per mockup	3 mu
SPAS	Prototipo Patch panel e Endcap	11 mu
Criogenia	Impianto CO2 2 kW	6mu
Impianti a Fluido	Progetto camera pulita	2.5mu

Richieste servizi I sem. 2020 gruppo ATLAS-ITk

Richieste I semestre 2020		
SEA	System test, firmware scheda Felix, servizi prototipo endcap	6mu
SPCM	carpenteria lavori integrazione, lavorazioni prototipi pp1, stampante 3d per mockup	3 mu
SPAS	Prototipo Patch panel e Endcap	11 mu
Criogenia	Impianto CO2 2 kW	6mu
Impianti a Fluido	Progetto camera pulita	2.5mu

Preventivi di spesa preliminari (Keuro) (possibili aggiustamenti al ~10%):

Missioni	Consumo
37	40

Backup

	Task Mode	Task Name	Duration	Start	Finish	Predecessors	WBS	Successors		Start Slack
1570		**Mock-up tests**	**170 days**	**Mon 22/06/20**	**Fri 12/02/21**		**2.1.7**			**85 days**
1571		**Test with EC detector slice**	**40 days**	**Fri 18/12/20**	**Fri 12/02/21**		**1.4.1.1**			**1558 days**
1572		Slice testing in System Test Setup	0 days	Fri 18/12/20	Fri 18/12/20	466	2.1.7	1573		1558 days
1573		Assembly of loaded endcap half-ring in half-cylinder section	20 days	Mon 21/12/20	Fri 15/01/21	1572;470	1.4.1.1.:	1574		1558 days
1574		Check of envelopes and clearances	10 days	Mon 18/01/21	Fri 29/01/21	1573	1.4.1.1.:	1575		1558 days
1575		Check of electrical functionality and G&S	10 days	Mon 01/02/21	Fri 12/02/21	1574	1.4.1.1.4			1558 days
1576		**Test with detector slice (non-electrical)**	**30 days**	**Mon 22/06/20**	**Fri 31/07/20**		**1.4.1.2**			**85 days**
1577		PP1 Prototype with prototype services: assembly test	20 days	Mon 22/06/20	Fri 17/07/20	468	1.4.1.2.:	1061;1578		85 days
1578		Check of envelopes and clearances	10 days	Mon 20/07/20	Fri 31/07/20	1577	1.4.1.2.:	1579		115 days
1579		Document procedure and results	30 days	Mon 03/08/20	Fri 11/09/20	1578	1.4.1.3	788		115 days
1580		**UK EndCap**	**1035 days**	**Mon 15/02/21**	**Fri 31/01/25**		**1.4.2**			**221 days**
1672		**Italy Endcap**	**1035 days**	**Mon 15/02/21**	**Fri 31/01/25**		**1.4.3**			**188 days**
1673		**Reception test and test infrastructure of Italy Endcap half-rings**	**555,75 days**	**Tue 09/11/21**	**Wed 27/12/23**		**1.4.3.1**			**213,25 days**
1674		Reception test infrastructure of Italy Endcap half-rings Ready and Commissioned	0 days	Tue 09/11/21	Tue 09/11/21	734;733;750;744;669;38	1.4.3.1.:	1675		213,25 days
1675		Testing inner half-ring 12.5% IT (L2)	2,75 days	Thu 04/08/22	Mon 08/08/22	623;1674	1.4.3.1.:	1676;1729		22,25 days
1676		Testing inner half-ring 25% IT (L2)	2,75 days	Tue 30/08/22	Thu 01/09/22	625;1675	1.4.3.1.:	1677;1730		84,25 days
1677		Testing inner half-ring 37.5% IT (L2)	2,75 days	Fri 23/09/22	Tue 27/09/22	627;1676	1.4.3.1.4	1678;1731		106,25 days
1678		Testing inner half-ring 50% IT (L2)	2,75 days	Wed 19/10/22	Fri 21/10/22	628;1677	1.4.3.1.:	1679;1732		108,25 days
1679		Testing inner half-ring 62.5% IT (L2)	2,75 days	Mon 14/11/22	Wed 16/11/22	631;1678	1.4.3.1.4	1680;1733		110,25 days
1680		Testing inner half-ring 75% IT (L2)	2,75 days	Thu 08/12/22	Mon 12/12/22	633;1679	1.4.3.1.'	1681;1734		112,25 days
1681		Testing inner half-ring 87.5% IT (L2)	2,75 days	Tue 03/01/23	Thu 05/01/23	635;1680	1.4.3.1.:	1682;1735		114,25 days
1682		Testing inner half-ring 100% IT (L2)	2,75 days	Thu 19/01/23	Mon 23/01/23	636;1681	1.4.3.1.:	1683;1736		122,25 days
1683		Testing Outer half-ring 12.5% IT (L4)	2,75 days	Mon 20/02/23	Wed 22/02/23	1682;655	1.4.3.1.:	1684;1738		180,25 days
1684		Testing Outer half-ring 25% IT (L4)	2,75 days	Mon 13/03/23	Wed 15/03/23	1683;657	1.4.3.1.:	1685;1739		185,25 days
1685		Testing Outer half-ring 37.5% IT (L4)	2,75 days	Wed 12/04/23	Fri 14/04/23	1684;659	1.4.3.1.:	1686;1740		183,25 days
1686		Testing Outer half-ring 50% IT (L4)	2,75 days	Wed 03/05/23	Fri 05/05/23	1685;660	1.4.3.1.:	1687;1741		178,25 days
1687		Testing Outer half-ring 62.5% IT (L4)	2,75 days	Thu 01/06/23	Mon 05/06/23	1686;663	1.4.3.1.:	1688;1742		167,25 days
1688		Testing Outer half-ring 75% IT (L4)	2,75 days	Thu 22/06/23	Mon 26/06/23	1687;665	1.4.3.1.:	1689;1743		162,25 days
1689		Testing Outer half-ring 87.5% IT (L4)	2,75 days	Thu 13/07/23	Mon 17/07/23	1688;667	1.4.3.1.:	1690;1744		157,25 days
1690		Testing Outer half-ring 100% IT (L4)	2,75 days	Thu 03/08/23	Mon 07/08/23	1689;668	1.4.3.1.:	1745;1691		152,25 days
1691		Testing Middle half-ring 12.5% IT (L3)	2,75 days	Tue 29/08/23	Thu 31/08/23	1690;639	1.4.3.1.:	1746;1692		144,25 days
1692		Testing Middle half-ring 25% IT (L3)	2,75 days	Thu 14/09/23	Mon 18/09/23	641;1691	1.4.3.1.:	1747;1693		142,25 days
1693		Testing Middle half-ring 37.5% IT (L3)	2,75 days	Mon 02/10/23	Wed 04/10/23	643;1692	1.4.3.1.:	1694;1748		140,25 days
1694		Testing Middle half-ring 50% IT (L3)	2,75 days	Wed 18/10/23	Fri 20/10/23	1693;644	1.4.3.1.:	1695;1749		138,25 days
1695		Testing Middle half-ring 62.5% IT (L3)	2,75 days	Fri 03/11/23	Tue 07/11/23	1694;647	1.4.3.1.:	1696;1750		136,25 days
1696		Testing Middle half-ring 75% IT (L3)	2,75 days	Tue 21/11/23	Thu 23/11/23	1695;649	1.4.3.1.:	1697;1751		134,25 days
1697		Testing Middle half-ring 87.5% IT (L3)	2,75 days	Thu 07/12/23	Mon 11/12/23	1696;651	1.4.3.1.:	1698;1752		132,25 days
1698		Testing Middle half-ring 100% IT (L3)	2,75 days	Mon 25/12/23	Wed 27/12/23	1697;652	1.4.3.1.:	1753		130,25 days
1699		**Tooling and Test infrastruction for Outer Endcap Half-cylinder integration in Italy**	**160 days**	**Mon 15/02/21**	**Fri 24/09/21**		**1.4.3.2**			**188 days**
1700		Production EC-A half Cyclinder Holding tooling	8 mons	Mon 15/02/21	Fri 24/09/21	808	1.4.3.2.:	1704		9,4 mons
1701		Production EC-A Service Trolley	8 mons	Mon 15/02/21	Fri 24/09/21	808	1.4.3.2.:	1705		9,4 mons
1702		Production EC-A Half Ring Integration Tooling	8 mons	Mon 15/02/21	Fri 24/09/21	808	1.4.3.2.:	1706		9,4 mons

Pixel schedule: Jul 19

baseline foreseen by Aug