CATIA-based Tool for Simulation Development

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https://indico.cern.ch/event/1154906/

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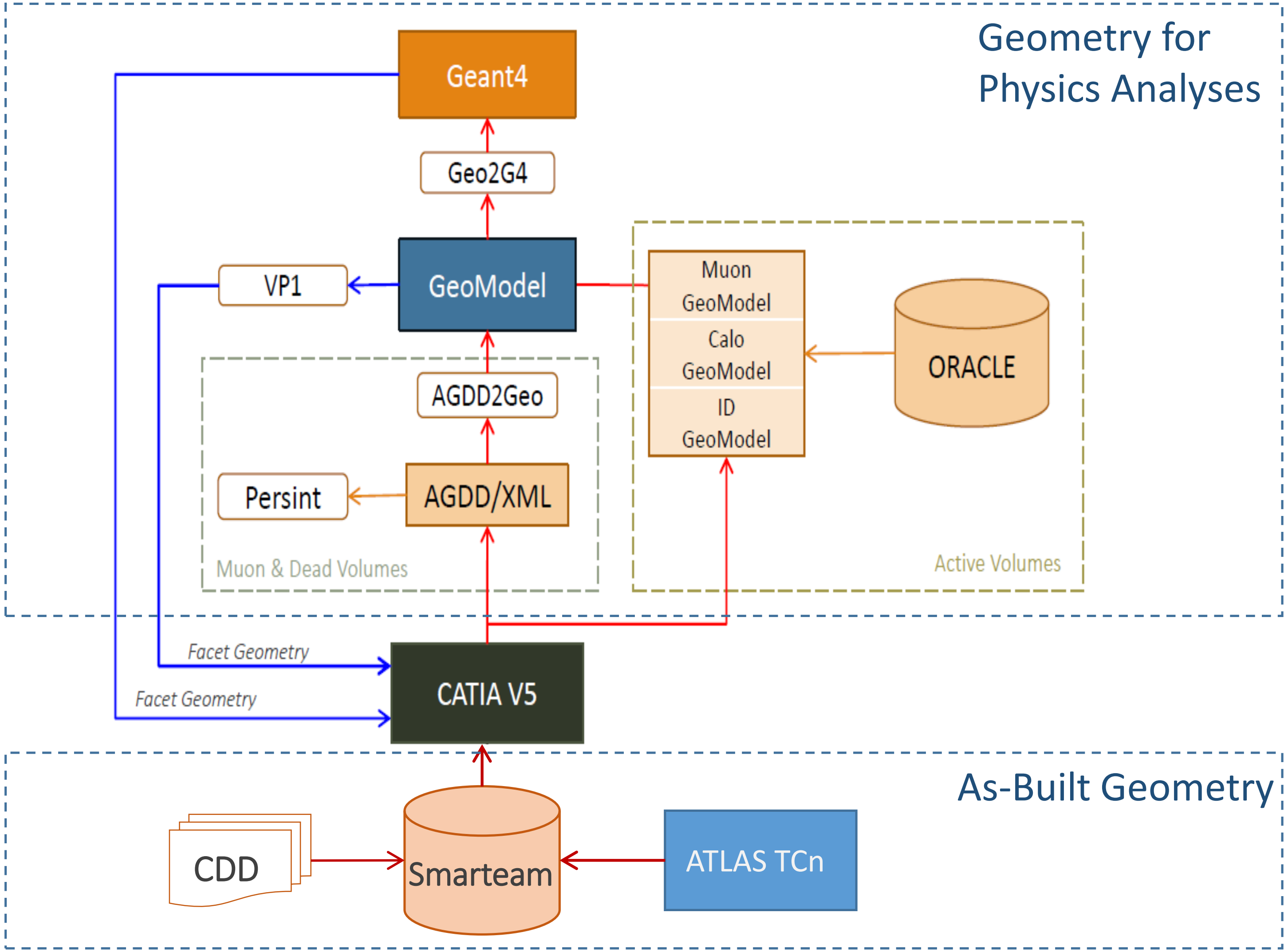
Methodology

What is CATIA?

- The Computer Aided Three-Dimensional Interactive Application (CATIA) is the most powerful tool for engineering geometry modelling, CAE (Computer-Aided Engineering) and CAM (Computer-Aided Manufacture)
- It is the worldwide de-facto standard for 3D geometry modelling, which incorporate all technique for descriptive geometry, parameterized descriptions, and digitalized mock-up analyses
- CATIA is the official platform at CERN for LHC and other projects for preparation and storing as-built geometry descriptions of accelerators and detectors (including ATLAS) for the manufacturing and installation
- CATIA at CERN uses Smateam database for storing 2D and 3D geometry descriptions

Methodology

- The Geometry Descriptions development workflow on the base of CATIA



- We are using CATIA as a hub to collect geometries from the various platforms
- Adding New volumes from the as-built descriptions
- Compare of existing volumes conformity with as-build descriptions

Details about this methodology are here:
https://indico.cern.ch/event/785991/

- New Add X_0 / λ calculations in compare analyses

Methodology

- We are using the open architecture of CATIA and developing third-party software applications inside the CATIA
- Those CATIA customization platforms are based on VBA and C++
- We have developed several built-in applications of CATIA:

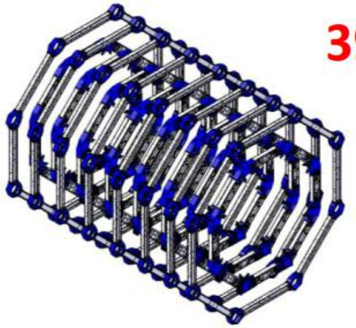
1. CATIA-2-XML – for generation of AGDD/XML descriptions from the CATIA native geometry models
2. CATIA-2-GDML – for generation of Geant-4 descriptions from the CATIA native geometry models
3. CATIA-2-RAD – for radiation parameters calculations of the CATIA native geometry models

- Also, we are strongly using CATIA DMU analyses for the integration conflicts checking

Compare Analyses Projects

- We did 15 Compare Analyses projects since 2010 which were largely discussed in the Simulation meetings and workshops

Warm Structure



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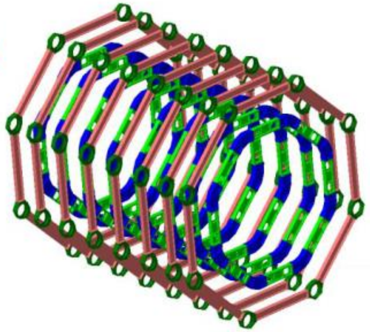

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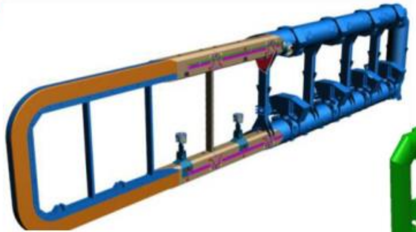
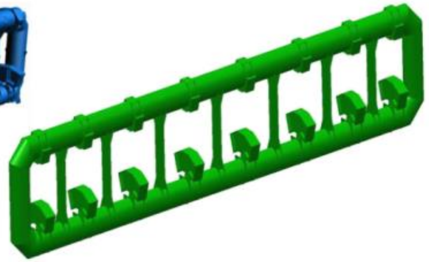
Coils

25%





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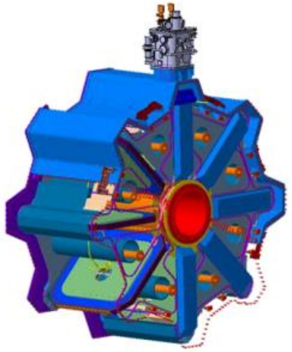
EndCAP Toroid



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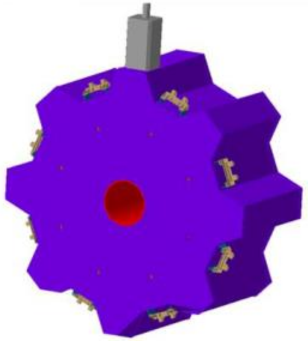

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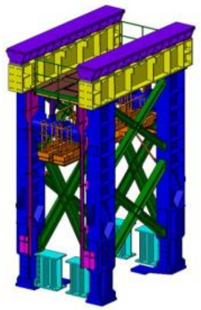
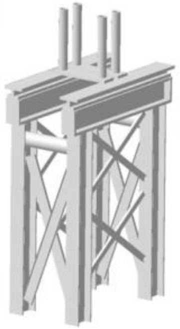
HF Trucks

67%





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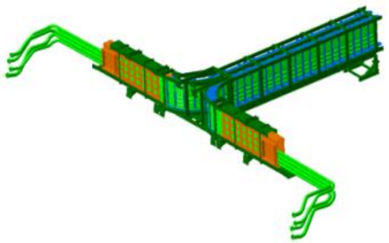
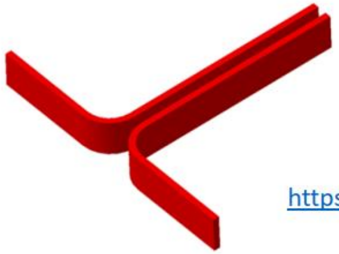
Flexible Chain s.9

97%





https://indico.cern.ch/event/747648/

Radiation Analyses (New)

- In 2020 we had a Work Package with the Tile Calorimeter group for the investigation of geometries in the GAP region
- We have developed together with them Compare analyses method of geometries based on the radiation parameters
- New method foresee calculation of the $\boldsymbol{X_0}$ - radiation length and the $\boldsymbol{\lambda}$ – interaction length alongside the geometry
- $\boldsymbol{X_0}$ is the average length (cm), which is necessary to change electrons' energy by the factor 1/e

$$X_0 = \frac{716.4}{Z \times (Z+1) ln \frac{287}{\sqrt{Z}}} \; g.cm^{-3}$$

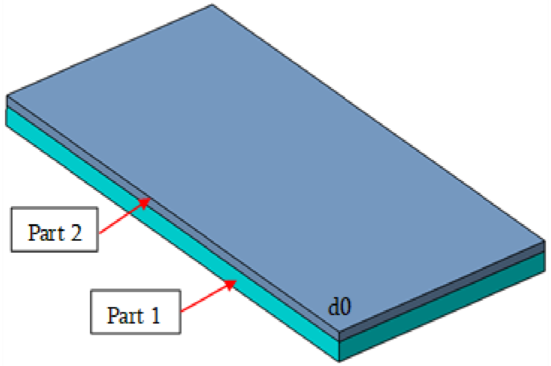
Radiation Analyses

- New method foresee calculation of the $\boldsymbol{X_0}$ - radiation length and the $\boldsymbol{\lambda}$ – interaction length alongside the geometry

$$\frac{d_0\rho_0}{x_0} = \frac{d_1\rho_1}{x_1} + \frac{d_2\rho_2}{x_2}$$

$$d_0 = d_1 + d_2$$

$$d_0\rho_0 = d_1\rho_1 + d_2\rho_2$$



Atomic and nuclear properties of aluminum (Al)

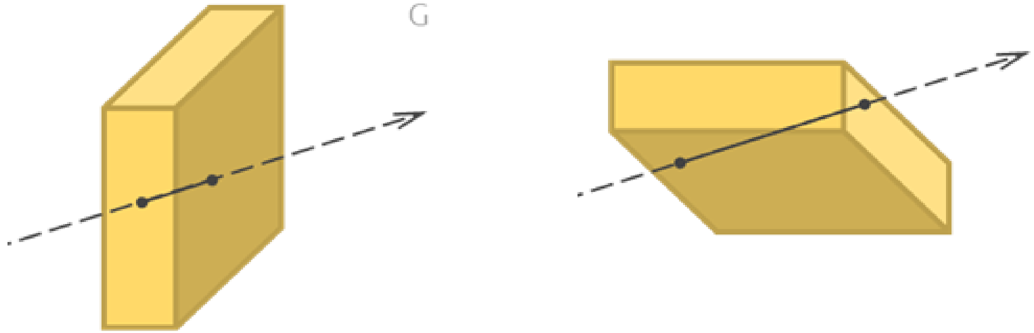
Quantity	Value	Units	Value	Units
Atomic number	13			
Atomic mass	26.9815385(7)	g mole^{-1}		
Specific gravity	2.699	g cm^{-3}		
Mean excitation energy	166.0	eV		
Minimum ionization	1.615	MeV g^{-1}cm^{2}	4.358	MeV cm^{-1}
Nuclear collision length	69.7	g cm^{-2}	25.82	cm
Nuclear interaction length	107.2	g cm^{-2}	39.70	cm
Pion collision length	95.6	g cm^{-2}	35.41	cm
Pion interaction length	136.7	g cm^{-2}	50.64	cm
Radiation length	24.01	g cm^{-2}	8.897	cm
Critical energy	42.70	MeV (for e^-)	41.48	MeV (for e^+)
Molière radius	11.93	g cm^{-2}	4.419	cm
Plasma energy $\hbar\omega_p$	32.86	eV		
Muon critical energy	612.	GeV		
Melting point	933.5	K	660.3	C
Boiling point @ 1 atm	2792.	K	2519.	C

- For the composite material

$$\frac{1}{x_0} = \frac{m_1}{x_1} + \frac{m_2}{x_2} + \cdots + \frac{m_n}{x_n}$$

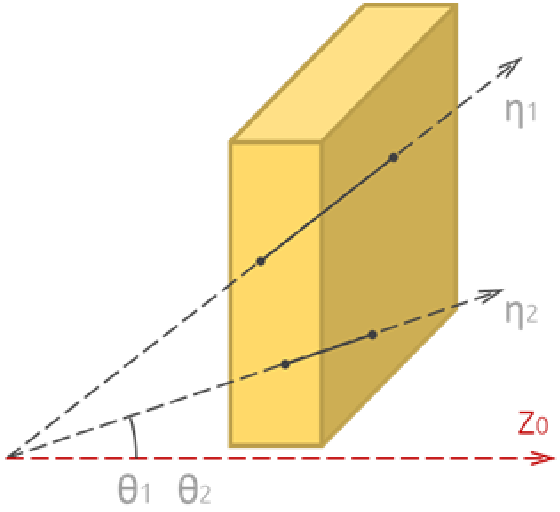
Radiation Analyses

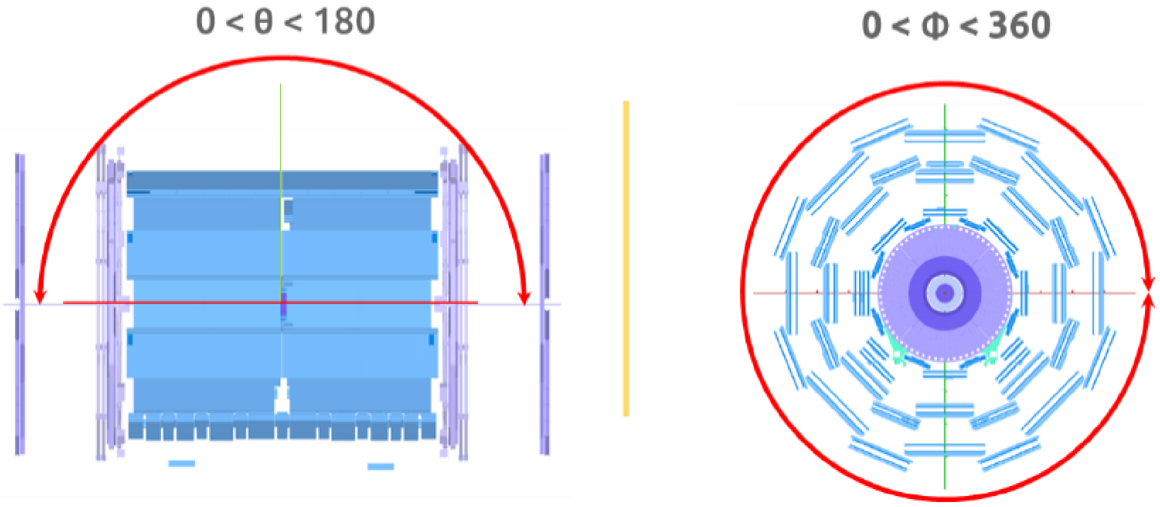
- Influence of positioning on the $\boldsymbol{X_0}$ / $\boldsymbol{\lambda}$



- Scanning directions

θ	η	θ	η
0°	∞	180°	−∞
0.1°	7.04	179.9°	−7.04
0.5°	5.43	179.5°	−5.43
1°	4.74	179°	−4.74
2°	4.05	178°	−4.05
5°	3.13	175°	−3.13
10°	2.44	170°	−2.44
20°	1.74	160°	−1.74
30°	1.32	150°	−1.32
45°	0.88	135°	−0.88
60°	0.55	120°	−0.55
80°	0.175	100°	−0.175
90°	0		





Radiation Analyses

- Condition for the creation of a control points for the $\boldsymbol{X_0}$ / $\boldsymbol{\lambda}$ calculations

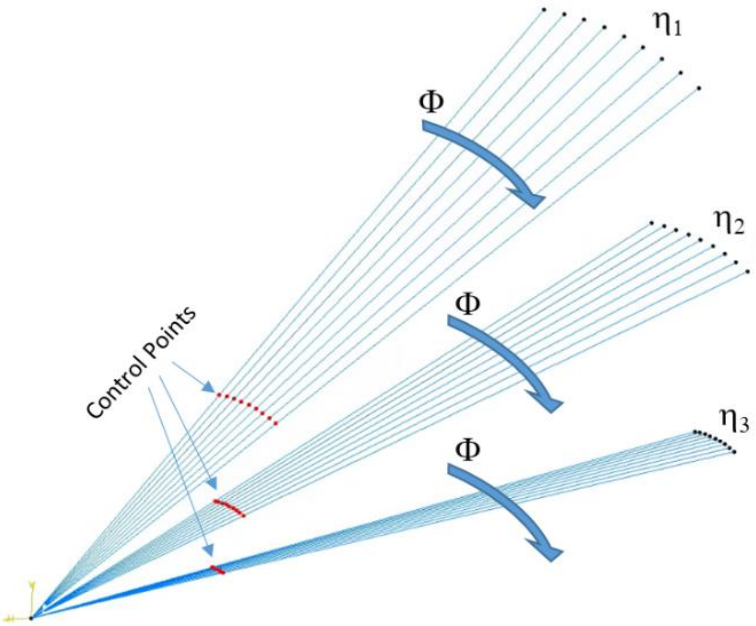
$$C = \forall_i (t_i \neq t_{i+1} \lor m_i \neq m_{i+1})$$

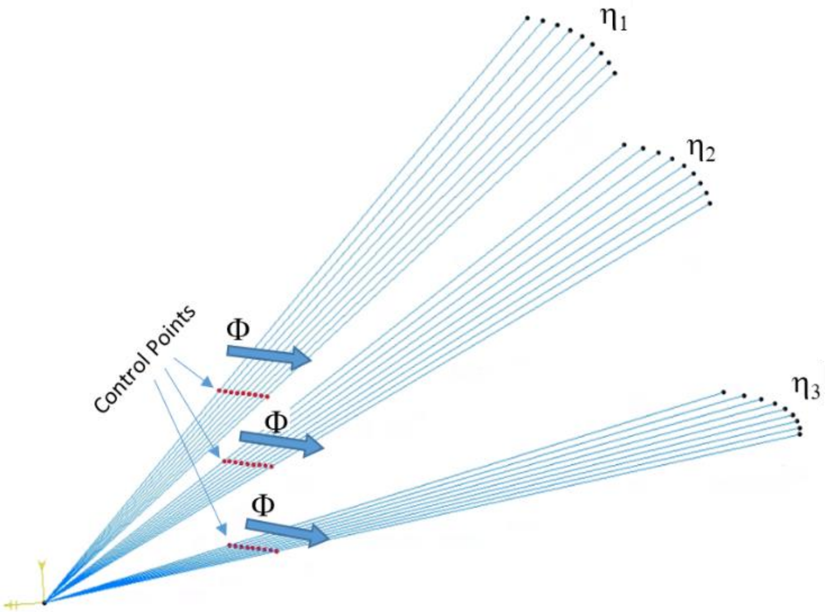
- If the thickness is constantly changing by the $\varphi_{(t)}$ function than the new control point will not be added. Therefore

$$C = \forall_i \left(t_i \neq t_{i+1} \bigwedge \varphi_{(t_i)} = const \bigvee m_i \neq m_{i+1}\right)$$

Radiation Analyses

- The first set of control points have to be created along $\eta\ - P_{1(\eta_1)} \ldots P_{n(\eta_n)}$
- In the second step, for each of the η_n plane, control points $P_{1(\Phi_1)} \ldots P_{n(\Phi_n)}$ have to be created along Φ, takes into account the geometry borders

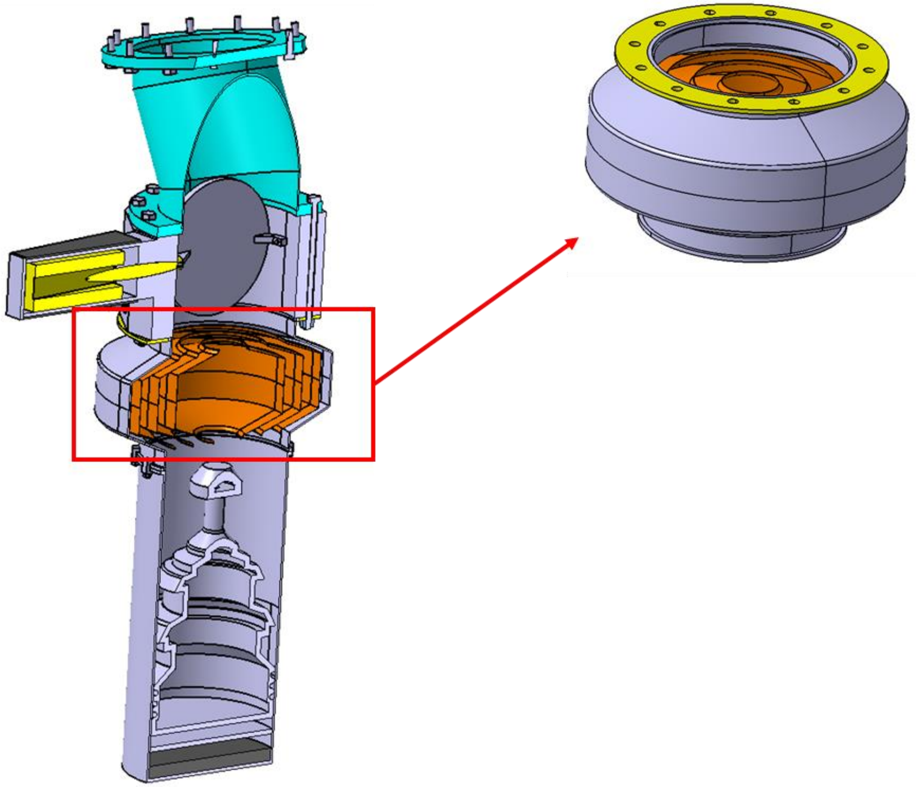




$$P_\Sigma = \sum_{i=1}^{n} \sum_{k=1}^{ij} P_{ik}(\Phi)$$

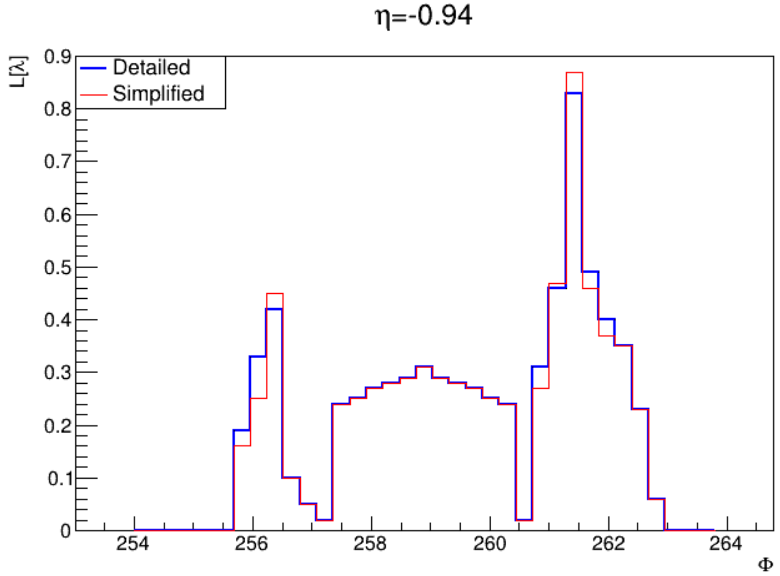
CATIA-2-RAD application consists of **two** modules:

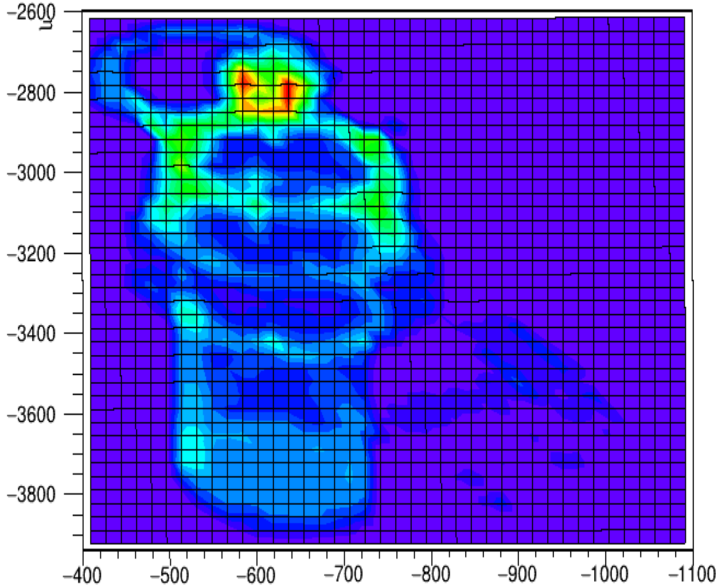
- CATIA-2-Scan – creates control points on the geometry and calculates X_0 / λ in each



Radiation Analyses

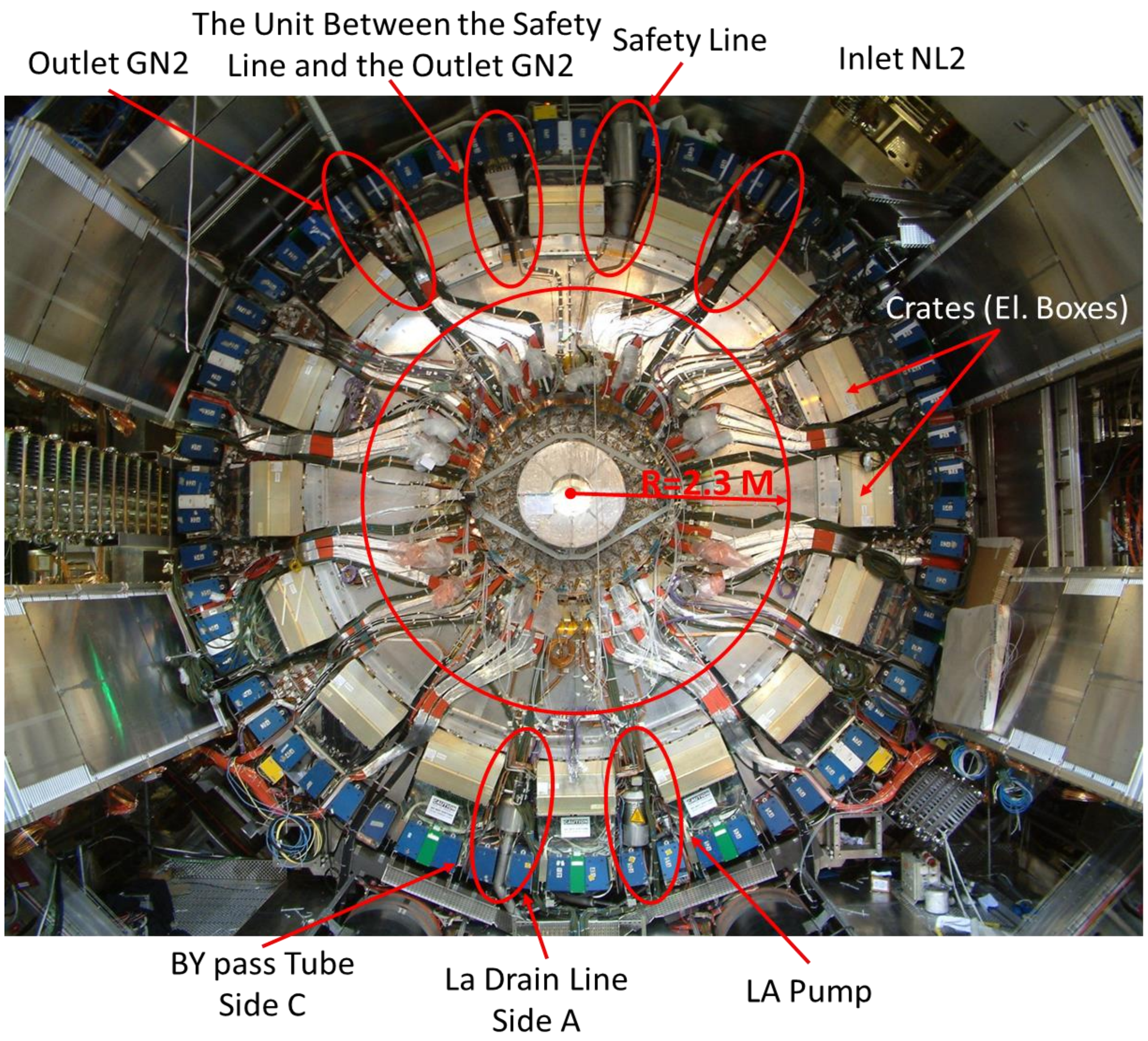
- CATIA-2-Root - exports calculated data to Root and Excel tables for the creation of plots and radiation images





Implementation

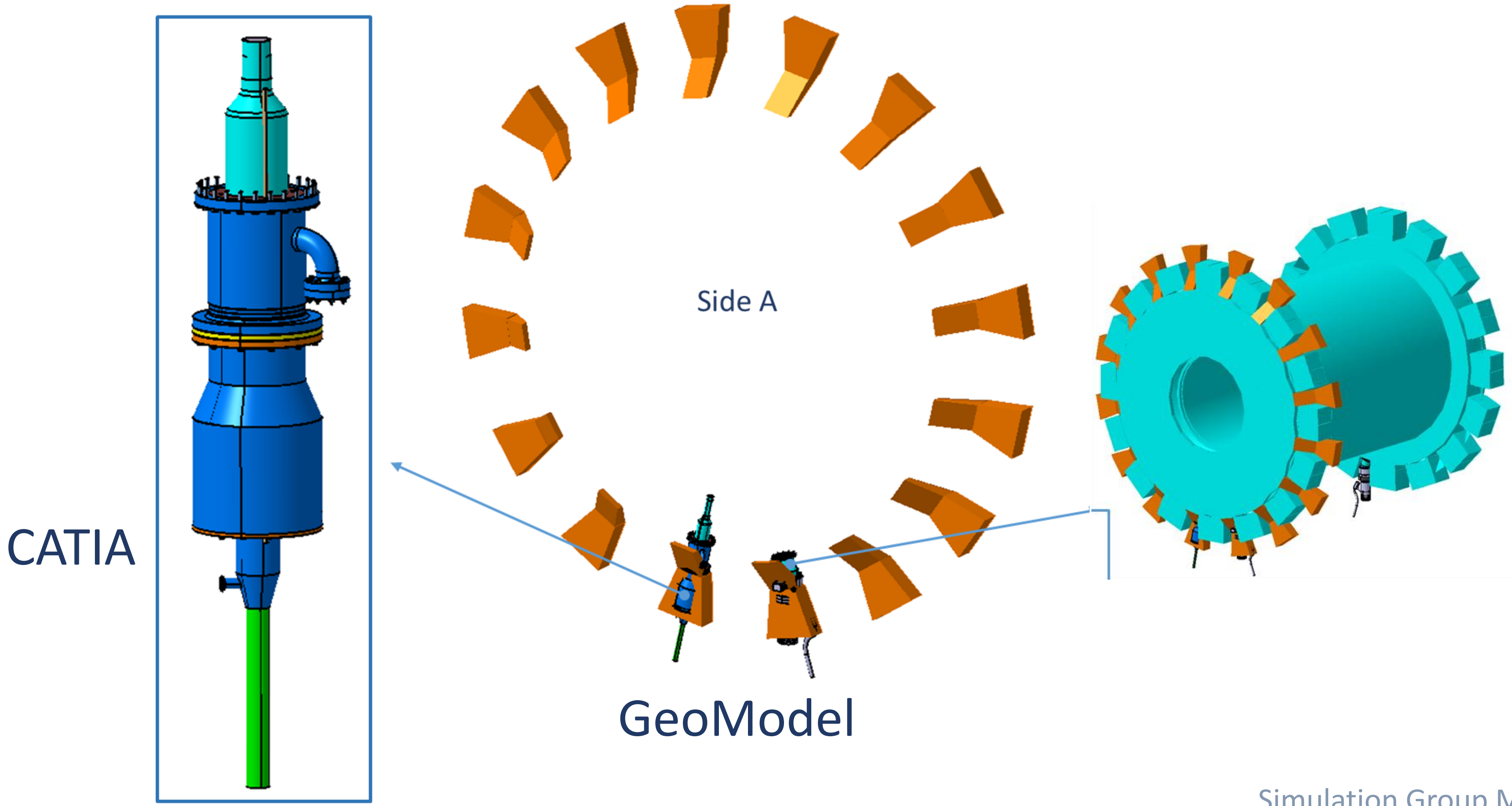
- In 2020 we did the Compare analyses projects based on the radiation parameters calculations for the TileCalorimeter simulation group
- Geometry updates of Services in the GAP region for the simulation was the working package of the Add. 7 of the agreement AA366/10
- We have a working plan for 2021 divided by the quarters and Seven geometries in the GAP region were investigated



Compare Analyses: CATIA-vs-GeoModel Geometries

- Project#02: LA Dump Valve Analyses

CATIA vs GeoModel



Compare Mass Analyses

As-Built

#	Name	material	Volume	Weight
1	Chimney	Stainless Steel	0.001587	12.5
2	Upper Flange	Stainless Steel	0.001257	9.9
3	Insulation Joint	Polycarbonate	0.000595	0.6
4	Valve Adapter	Stainless Steel	0.001417	11.2
5	Loose Upper/Lower Flange	Stainless Steel	0.001537	12.1
6	Lower Flange & Reduction	Stainless Steel	0.001966	15.5
7	Selfa DN70	Stainless Steel	0.00142	11.2
8	Central Tube	Stainless Steel	0.000759	6
9	Flexible DN8 Pipes	Stainless Steel	0.000179	1.4
10	Bolts	Stainless Steel	0.000327	2.6
11	Vacuum and Liquids	~~Vacuum~~ Liquid Argon ~~Argon Gas~~ ~~Helium Gas~~	~~0.04607~~ 0.010675 ~~0.000099~~ ~~0.00015~~	--- 14.9 ~~0.00016~~ ~~0.000025~~
		Total:	**0.022**	**98**

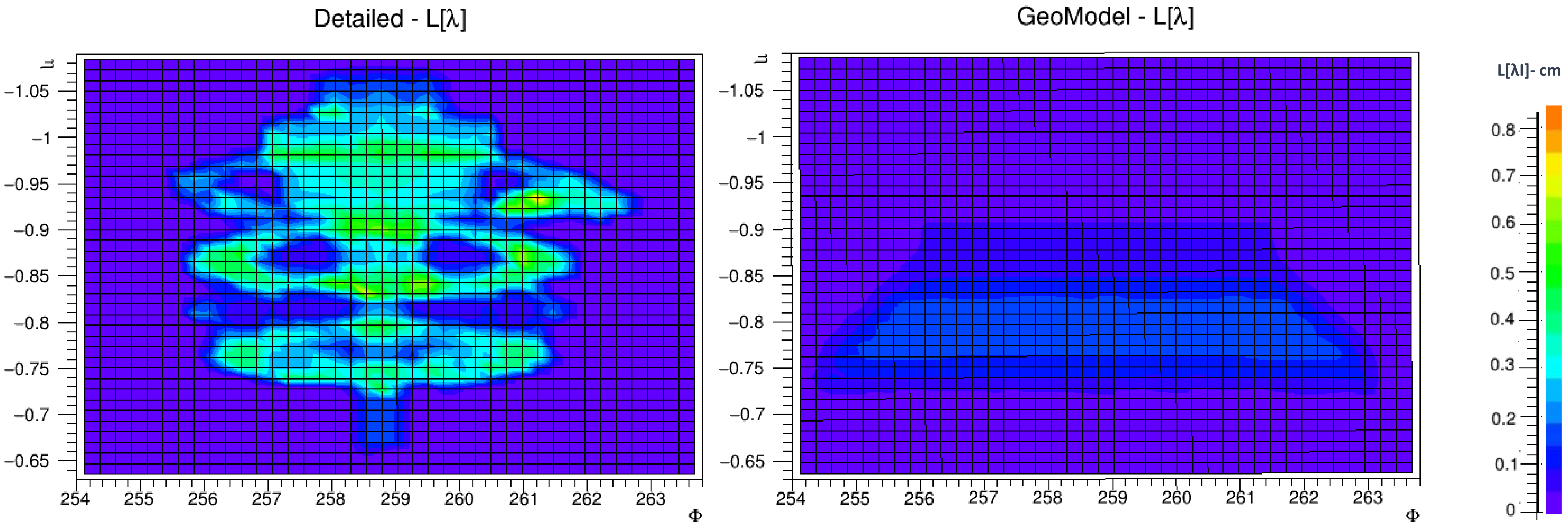
LAr Dump Valve Adapter exists only at Side A

GeoModel

#	name	material	Volume (m3)	Mass (kg)
1	Base Envelope	LArServices8	0.067	23.5
2	Base Plate	Aluminum	0.0027	7.3
3	Bridge Envelope	LArServices8	0.0228	8
			Total:	40

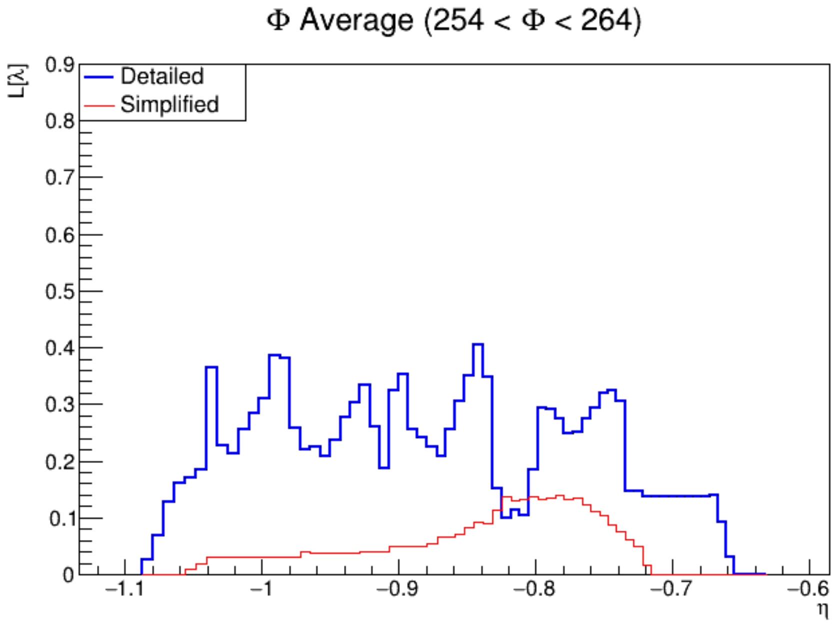
Diff: -59 kg

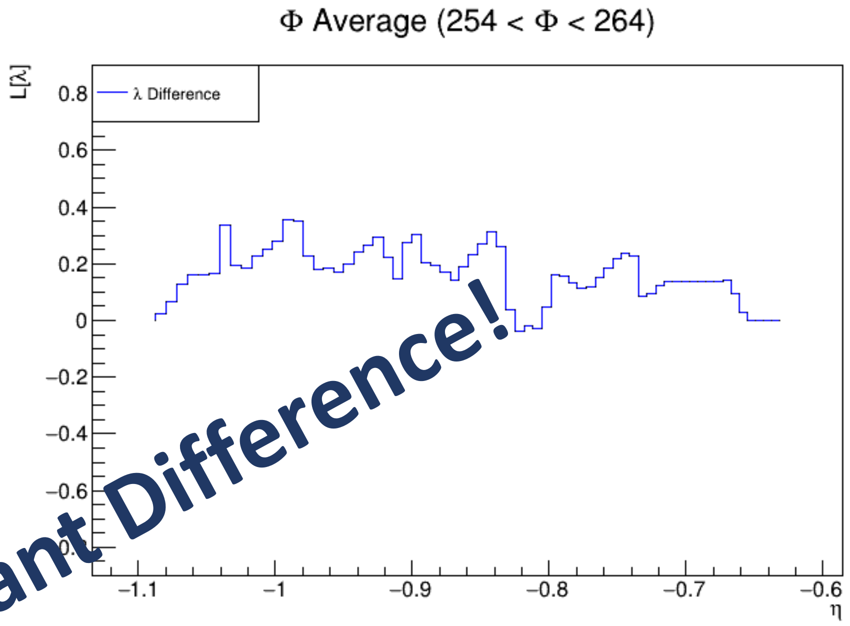
Compare Radiation Analyses

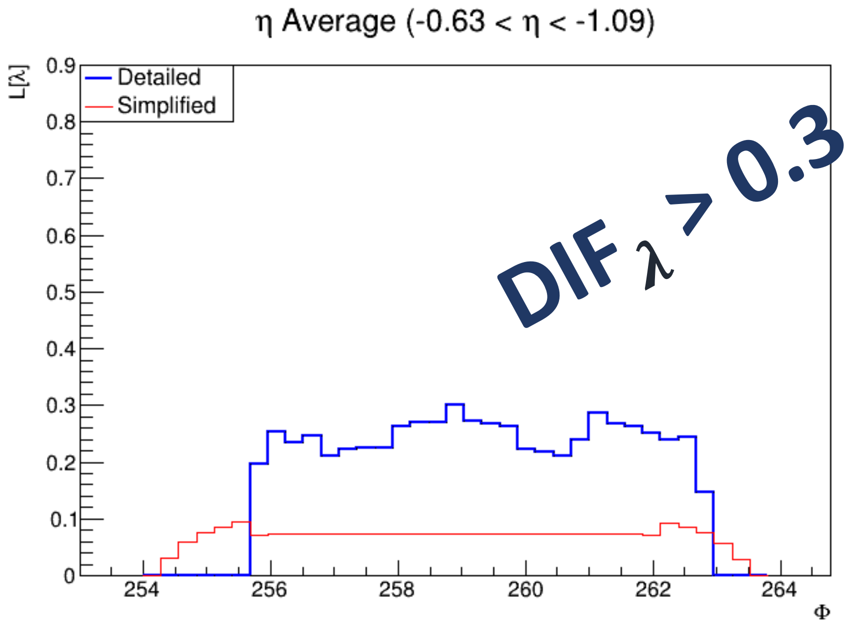


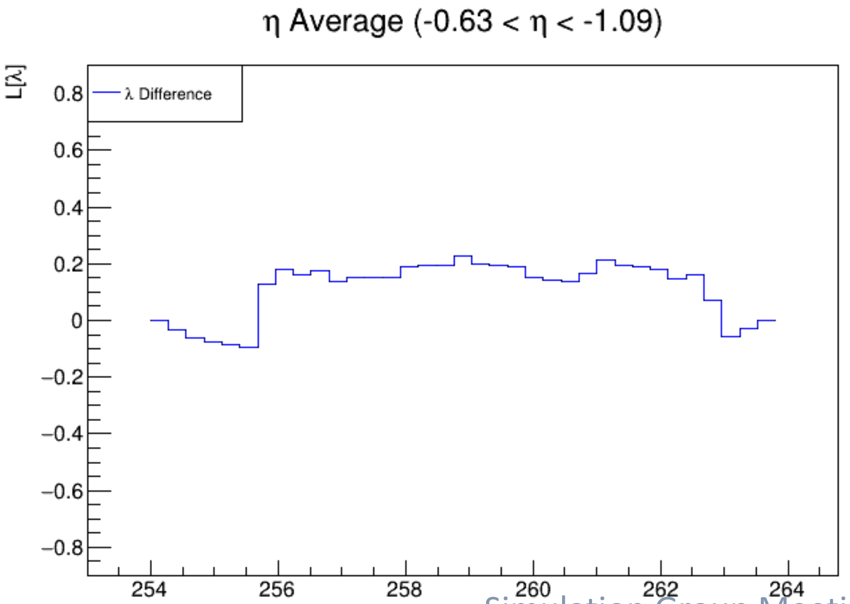
Z = 3.07m

Compare Radiation Analyses





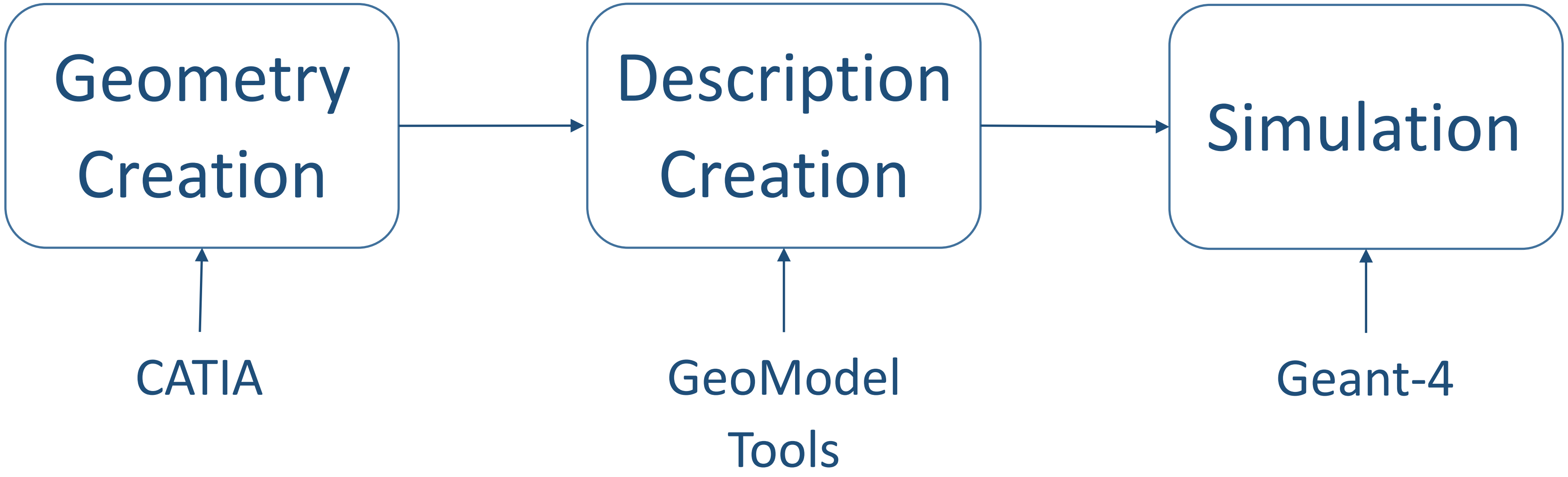




$DIF_{\lambda} > 0.3$ – Important Difference!

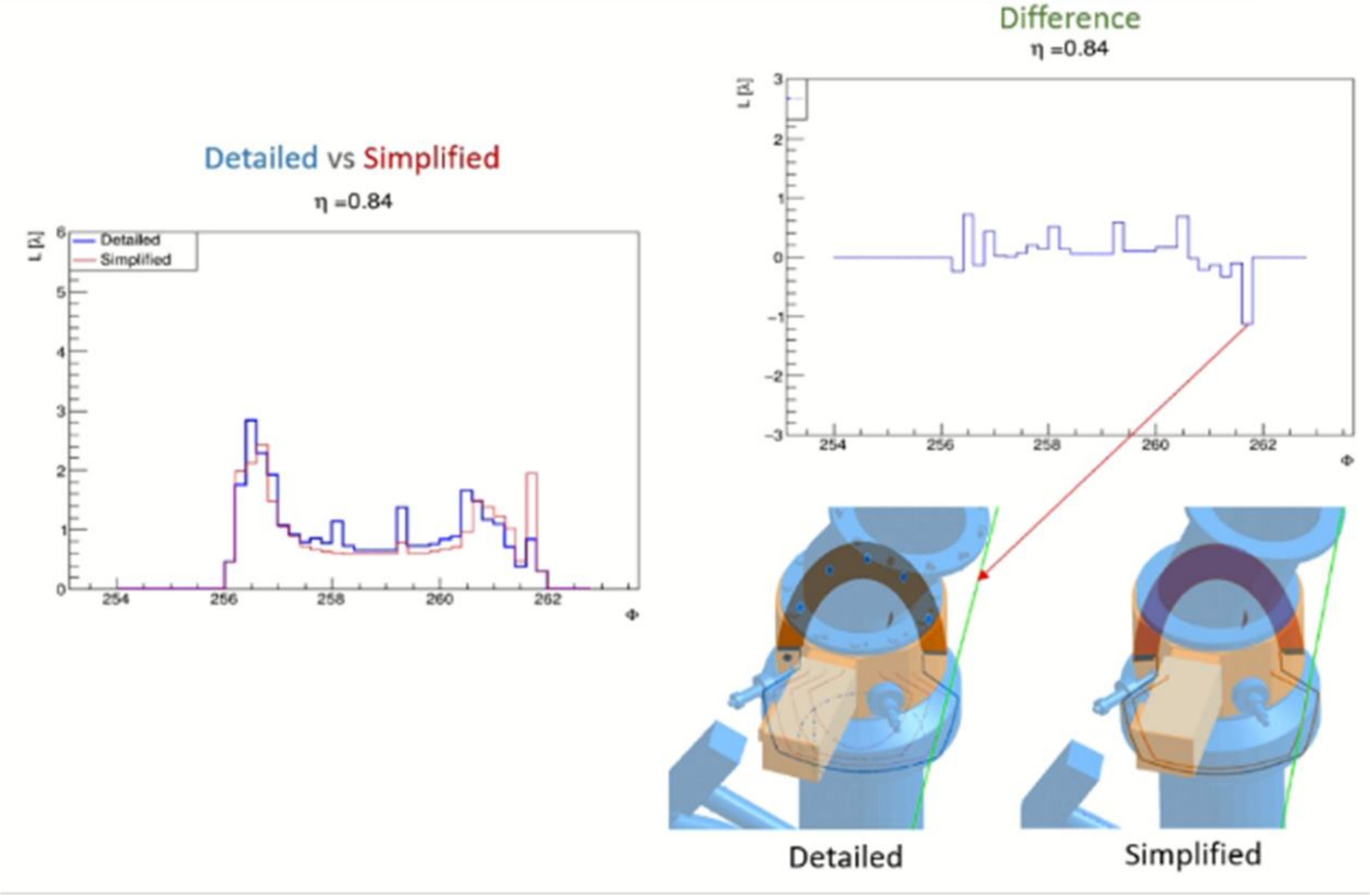
Concept

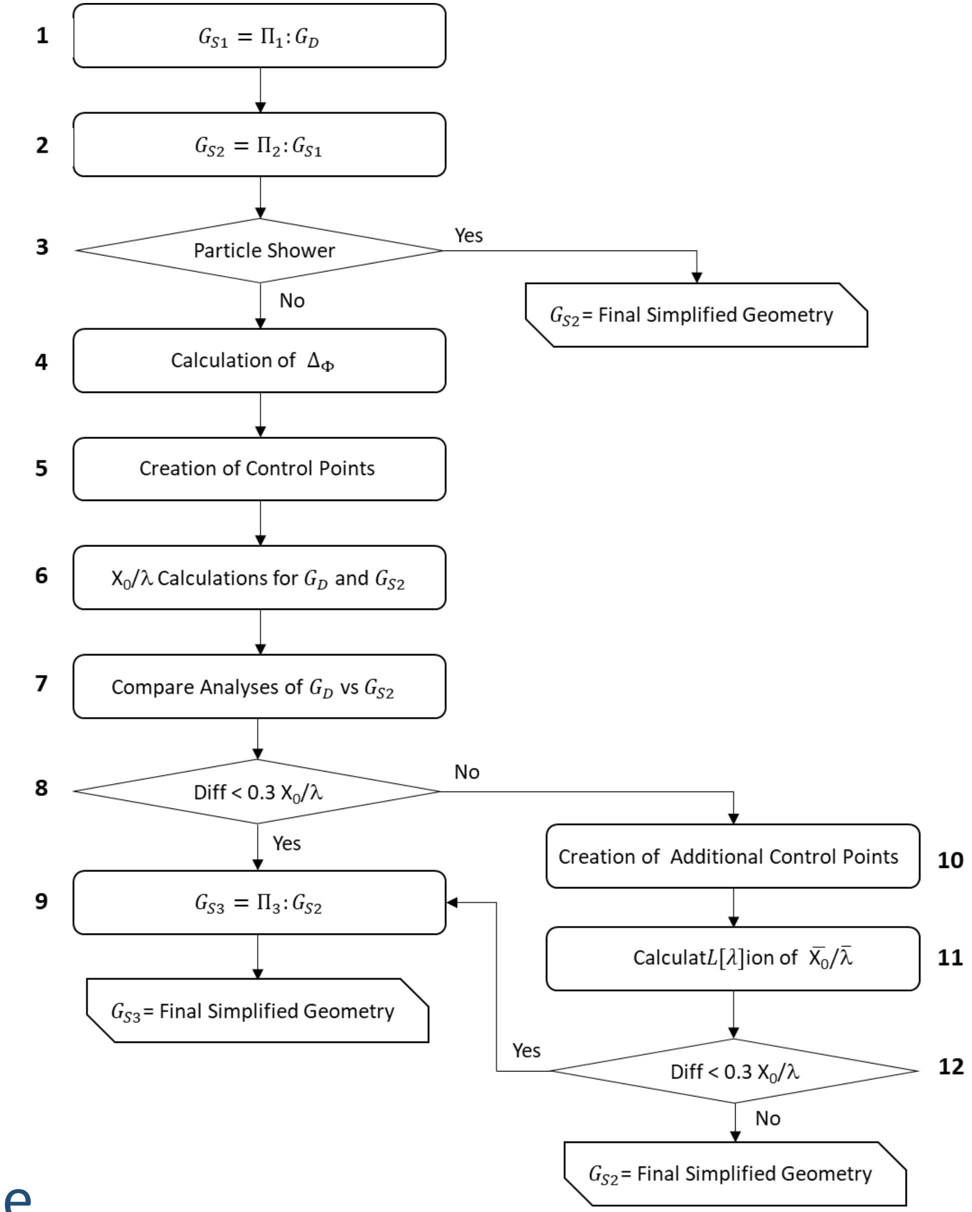
- Now let's watch the big picture



Concept

- Simplification of CATIA geometry





- Paper will be submitted to the ACAT2022 conference

Conclusions and Future Steps

1. New method of radiation analyses on the early stage of Geometry development in CATIA brings opportunity to deliver in simulation accurate, “as-built” descriptions
2. Geometry analyses in the GAP region showed inadequateness of the current GeoModel descriptions and therefore have been modified
3. The proposed CATIA tools fulfils with existing GeoModel tools because they are serving for different purposes - one is for the preparation of the geometry itself and another one is for the preparation of geometry descriptions
4. The next steps for the development of the CATIA tools concern with simplification of the detailed CATIA geometries and the development of the interfaces with GeoModel file standards
5. CATIA tools can be proposed to the other platforms and experiments

Thanks for the attention

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