SIMULATION LOOP BETWEEN CAD SYSTEMS, GEANT-4 AND GEOMODEL: IMPLEMENTATION AND RESULTS

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Abstract

Compare analysis of simulation and as-built geometry descriptions of detector is important field of study for data_vs_Monte-Carlo discrepancies. Shapes consistency and detalization is not important while adequateness of volumes and weights of detector components are essential for tracking. There are 2 main reasons of faults of geometry descriptions in simulation: 1/ Difference between simulated and as-built geometry descriptions; 2/ Internal inaccuracies of geometry transformations added by simulation software infrastructure itself. Georgian Engineering team developed hub on the base of CATIA platform and several tools enabling to read in CATIA different descriptions used by simulation packages, like XML->CATIA; VP1->CATIA; GeoModel->CATIA; Geant4->CATIA. As a result it becomes possible to compare different descriptions with each other using the full power of CATIA and investigate both classes of reasons of faults of geometry descriptions. Paper represents results of case studies of ATLAS Coils and End-Cap toroid structures.

I. Introduction

ATLAS simulation is implemented for deep and wide range investigation of physics processes from the event generator in a format which is identical to the output of the ATLAS detector data acquisition system. Simulation chain combines as a single job – generated events and decays, detector model and physics interactions, digitized energy deposited into voltages and currents for comparison to the detector outputs [1]. Both the simulated data and detector outputs are running through the same trigger and reconstruction packages. However R1 data analyses for some region of detector shows discrepancies of simulated and real data. Several reasons can cause above mentioned discrepancies. In several cases they caused by inaccuracies of detector geometry descriptions using in simulation. Plot on fig.1 shows example how adequate description of detector geometry will fit closer results of MC simulation and data [3]. Black dots are correspond to data from Run-2 and shows that discrepancy for modified geometry of Pixel detector (in green) is less than for default geometry (in red). Most visible it is for IBL structure where default geometry missing surface mount device at around r=32mm. Updated geometry which includes missed materials significantly improves the agreement between data and MC.

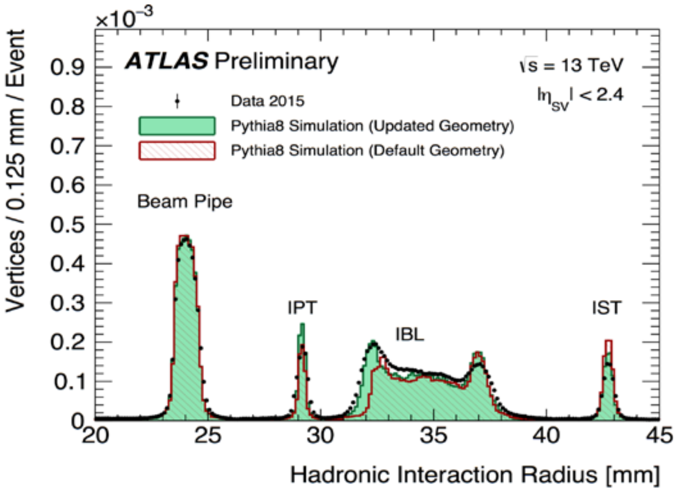

Figure 1. Data/MC discrepancy

Geometry description analyse includes 2 studies:

1. Consistency study of simulation geometry descriptions with as-built geometry descriptions of detector
2. Study of inaccurateness of geometry transactions doing by simulation software infrastructure itself.

II. ATLAS Detector Geometry for Simulation

ATLAS detector is one of the most complex engineering facility worldwide. Detector geometry consists of simple parts like prisms, cylinders, tubes, etc. having no splines or art profiles but in same time characterized with enormous complexity [5] >10'000'000 mechanical features. "As-built" geometry model of ATLAS detector in SmarTeam CERN engineering database contains >3'000 assemblies and occupies 62 Gb disk space.

For simulation and reconstruction simplified geometry descriptions are using because of software infrastructure requirements. In most of the cases models have not any detalization like holes, pockets, fillets, cutouts or even small size parts. Instead all volumes described by standard solid primitives like prisms, tunes, etc. divided mainly by materials. In same time full correspondence of simplified geometry with detailed geometry of detector in terms of volume, weight and position is extremely important. Special attention is paid for integration conflicts like overlaps and contacts. Any overlap of more than 1 picometer can lead to stuck tracks during the simulation while simulation software may not know in which part it belongs [1]. Also, some approximations are necessary for describing heterogeneous materials like electronic circuits, cables, cooling pipes and other services.

III. Geometry Simulation Loop

ATLAS simulation infrastructure use Geant-4 for geometry modelling of detector. However Geant-4 geometry description generating at run-time during the session. Geometry data containers are built on the base of XML and ORACLE tables [4]. There is also transient C++ like description, so called GeoModel which is using as a common platform for simulation, digitization and reconstruction packages [2]. Thus, before goes to final state geometry doing number of transformations: XML_to_GeoModel; ORACLE_to_GeoModel and GeoModel_to_Geant.

New methodology of simulation geometry life cycle foresee integration of CATIA platform in existing infrastructure by developing special chains – Geant_to_CATIA, GeoModel_to_CATIA, CATIA_to_XML, CATIA_to_GeoModel (fig.2). Geant_to_CATIA chain permits to dump geometry from memory into Geant-4 neutral format *.gdml*. After it transforms into facet *.wrml* and goes to CATIA/DMU as an input. GeoModel_to_CATIA chain grab GeoModel geometry into inventor neutral format *.iv*. Then again it is transforming into facet *.wrml* and going as an input to CATIA/DMU. CATIA_to_XML and CATIA_to_GeoModel chains are using XML/GeoModel templets. For each particular volume templets are updating according to geometry data coming from the CATIA project tree. In same time CATIA has internal links to the Enovia/Smarteam engineering databases where manufacturing drawings and as-built 3D models are stored. As a result CATIA platform can be considered as a hub for collection of geometry descriptions from various platforms and proceed different studies of detector geometry descriptions.

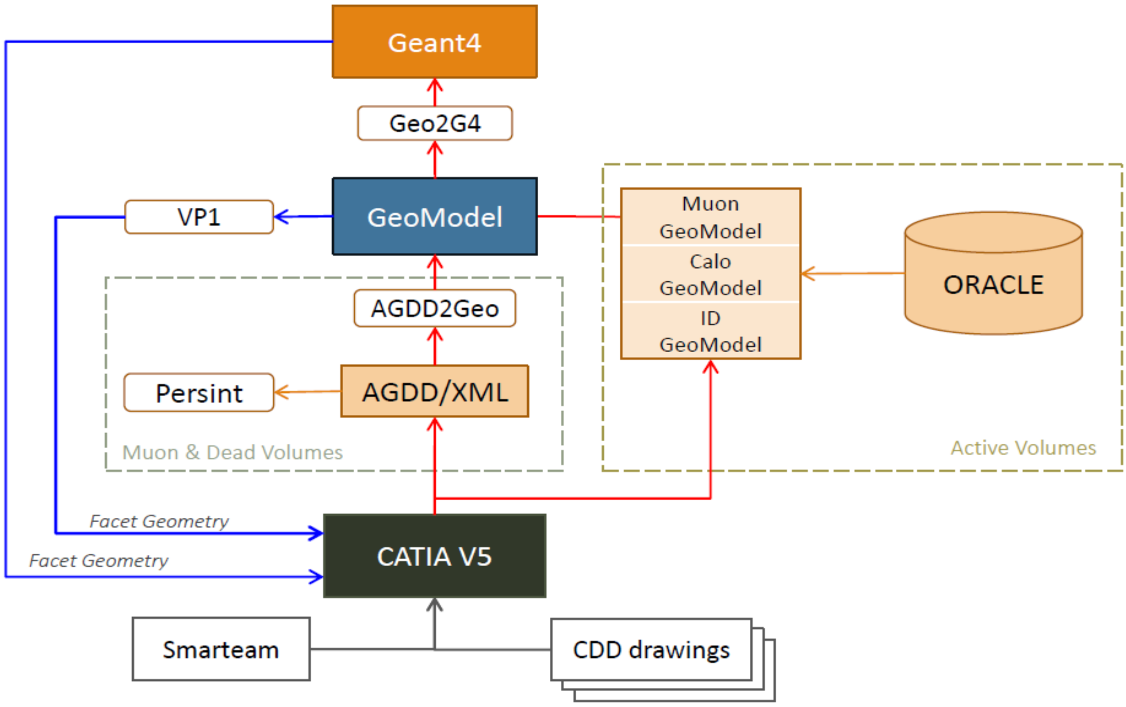

Figure 2. ATLAS simulation loop with CATIA

IV. ATLS End-CAP Toroid Study

End-Cap Toroid (ECT) is one of the biggest and heaviest (250 tonnes) part of ATLAS detector. According to muon team estimations of simulation performance of muon system, current sagitta resolution of all the End-Cap sectors (fig.3) expected to become better after improvement of ECT geometry description [7]. Thus ECT geometry has been investigated. On the 1st stage engineering descriptions on Smarteam have been analysed. Several 3D models compared and most detailed one was chosen. After comparison with several assembly drawings and photos it was concluded necessity in 3D model

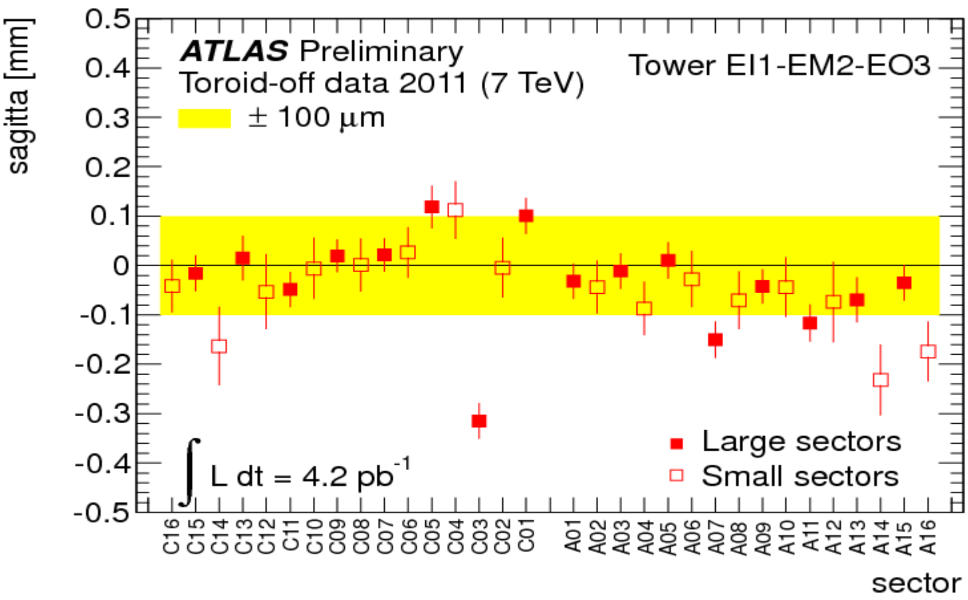

Figure 3. Sagitta resolution for all sectors of ECT

		CATIA	XML	Difference	%
1	Cold Mass	116740 kgs	123012 kgs	+6’272 kgs	5.4 %
2	Thermal Shielding	15988 kgs	15957 kgs	-31 kgs	0.2 %
3	Cover	57966 kgs	57185 kgs	-781 kgs	1.3 %
4	Bore Tube	13433 kgs	10208 kgs	-3’225 kgs	24.0 %
5	Yoke	1820 kgs	1338 kgs	-483 kgs	26.5 %
6	Stay Tube	2028 kgs	2214 kgs	+186 kgs	9.2 %
7	JTV Shielding	4161 kgs	4510 kgs	+349 kgs	8.4 %
8	Turret	2476 kgs	1512 kgs	-964 kgs	38.9 %
9	Tie Rod	3077 kgs	1268 kgs	-1’809 kgs	58.8 %
10	Bolts/	2965 kgs		-2’965 kgs	100.0 %
11	Services	869 kgs		-869 kgs	100.0 %

Figure 4. Weight differences between CATIA and XML description

reproduction in CATIA, because of lot of missing descriptions. Manufacturing drawings for reproduction were downloaded from CDD (CERN Drawing Database). As a result detailed ECT geometry was reproduced in CATIA from 902 manufacturing drawings. On the 2nd stage full ECT description was split into 11th volumes by mechanical structure and materials and for each volume weights were calculated. On the 3rd stage 11th identical volumes have been extracted from XML geometry and calculated their weights. Compare analyse of CATIA vs XML (fig.4) shows >20% difference in volume and weight for majority of components. The grouping of volumes in the two geometry systems may differ somewhat, but the distribution of mass in the detector still shows significant differences.

Most big discrepancies were detected for BoreTube assembly – 3 tonnes; TieRod assembly – 2 tonnes and Turret assembly – 960 kg. It was decided to update existing XML geometry of ECT. Therefore, on the next stage detailed CATIA geometry was simplified by keeping volume and weight of each component. Maximum scattering of volume and weight after simplification was 0.01m^3 and 27kg accordingly. On the final stage baseline geometry was updated by generation of new XML descriptions from the simplified geometry.

V. ATLAS Coil Study

ATLAS detector have 8 identical coils. Coil is complex engineering facility which consists of lots of various parts inside and outside. Initial analyse of Smarteam model on completeness shows necessity for model reproduction in CATIA. 255 CDD drawings have been considered and added as a 3D parts to Smarteam model of coil. After, coil assembly was split into 7 volumes according to mechanical structure and materials [6]. Then weight for each of volume were calculated. On the next stage identical 7 volumes were extracting from XML geometry and also weights were calculated. Compare analyse shows big differences in volume and weight between CATIA and XML descriptions (fig.5).

Therefore XML baseline geometry were updated by simulation team. Fig.6 illustrates different simulation results by adding thermal shielding to XML description.

		Material	Density kg/m³	Volume m³	Weight tones	Difference tones
XML	Outside Assembly	*Steel*	7’870	3.887	30.6	5.1
CATIA		*Steel*	8’000	4.458	35.7	
XML	Voussoir Structures	*Aluminum Steel*	2’700/7’870	4.56	13.2	-0.9
CATIA		*Aluminum Steel*	2’650/8’000	4.416	12.3	
XML	Tie Road	*Aluminum*	2’700	0.42	1.1	1.8
CATIA		*Steel/Titan Aluminum*	8’000/4’480/ 2’705	0.5193	2.9	
XML	Thermal	*Aluminum*	2’700	13.138	35.5	5.6
CATIA	Shielding	*Aluminum*	2’740	0.7517	2.3	
	Coil Casing	*Aluminum*	2’650	12.033	31.9	
	Coil Covers	*Aluminum*	2’660/2’650	1.898	5	
	Services	*Aluminum Steel*	8’000/8’000/ 2’650	0.59	1.9	
					Difference:	11.6

Figure 5. Weight differences between CATIA and XML of Coils

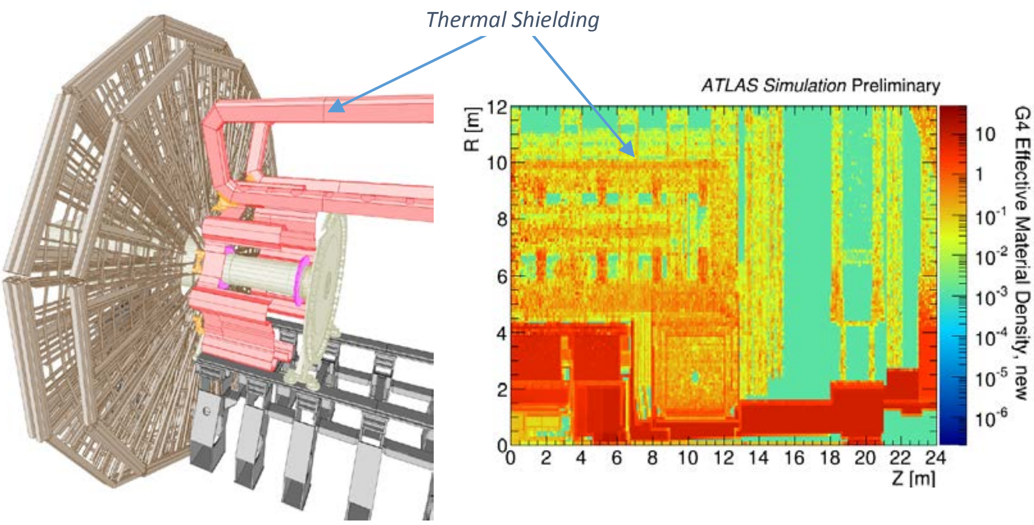

Figure 6. Simulation results with updated geometry of coils

VI. Conclusions

1. Creation geometry hub on the base of CATIA brings unique possibilities for several geometry crosschecking and investigation of simulation software infrastructure
2. ATLAS End-CAP Toroid geometry study shows difference (11t missed / 6.7t added) of weight between XML and as-built geometry volumes
3. ATLAS Coils geometry study shows 11.6 tones missed materials in XML baseline geometry.

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