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КОМПЬЮТЕРНЫЕ ТЕХНОЛОГИИ В ФИЗИКЕ

SIMULATION LOOP BETWEEN CAD SYSTEMS, GEANT4, AND GEOMODEL: IMPLEMENTATION AND RESULTS

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Comparitive analysis of simulation and as-built geometry descriptions of detector is an important field of study for data vs. Monte Carlo discrepancies. Shape consistency and detalization are not important, while adequateness of volumes and weights of detector components are essential for tracking. There are two 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 the 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. The paper represents the results of case studies of ATLAS Coils and End-Cap toroid structures.

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INTRODUCTION

ATLAS simulation is implemented for deep and wide-range investigation of physics processes from the event generator in the 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 analysis for some region of detector shows discrepancies of simulated and real data. Several reasons can cause the above-mentioned discrepancies. In several cases they are caused by inaccuracies of detector geometry descriptions used in the simulation. Plot in Fig. 1 shows example how adequate description of detector geometry will fit closer results of MC simulation and data [3]. Black dots correspond to data from Run 2 and show that the discrepancy for modified geometry of Pixel detector is less than for default one. Most visible it is for IBL structure where default geometry missing surface mount device at around $r = 32$ mm. Updated geometry which includes missed materials significantly improves the agreement between the data and MC.

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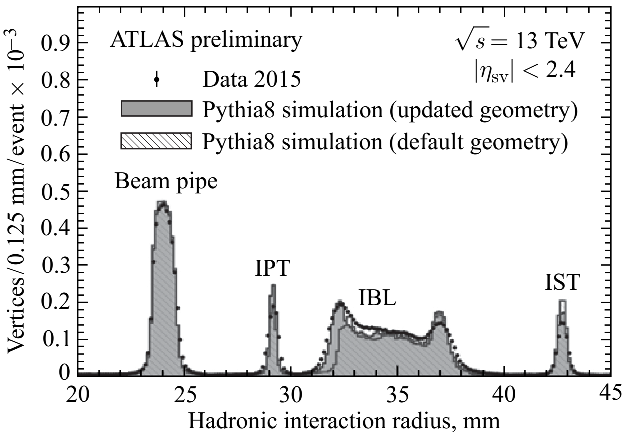

Fig. 1. Data/MC discrepancy

Geometry description analysis includes two kinds of study:

1. Consistency study of simulation geometry descriptions with as-built geometry descriptions of detector.

2. Study of inaccuracy of geometry transactions done by simulation software infrastructure itself.

1. ATLAS DETECTOR GEOMETRY FOR SIMULATION

ATLAS detector is one of the most complex engineering facilities worldwide. Detector geometry consists of simple parts like prisms, cylinders, tubes, etc., having no splines or art profiles but at the same time characterized by enormous complexity [5] of $> 10,000,000$ 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 used because of software infrastructure requirements. In most cases models have no detalization, like holes, pockets, fillets, cut-outs, or even small-size parts. Instead, all volumes are described by standard solid primitives, like prisms, tunes, etc., divided mainly by materials. At the 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 to integration conflicts, like overlaps and contacts. Any overlap of more than 1 pm can lead to stuck tracks during the simulation, while the simulation software may not know to which part it belongs [1]. Also, some approximations are necessary for describing heterogeneous materials, like electronic circuits, cables, cooling pipes, and other services.

2. GEOMETRY SIMULATION LOOP

ATLAS simulation infrastructure uses Geant4 for geometry modelling of detector. However, Geant4 geometry description is generated at run-time during the session. Geometry data containers are built on the basis of XML and ORACLE tables [4]. There is also transient

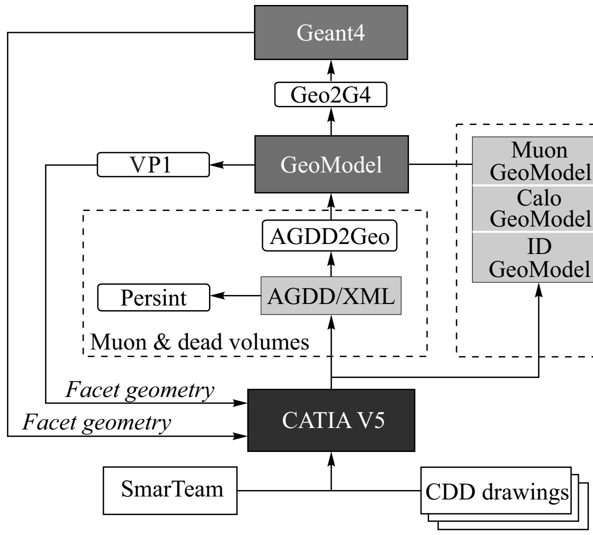

Fig. 2. ATLAS simulation loop with CATIA

C++ like description, the so-called GeoModel which is used as a common platform for simulation, digitization, and reconstruction packages [2]. Thus, before going to the final state the geometry does a number of transformations: XML_to_GeoModel; ORACLE_to_GeoModel, and GeoModel_to_Geant.

New methodology of simulation geometry life cycle foresees 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 Geant4 neutral format .gdml. Then it transforms into facet .wrml and goes to CATIA/DMU as an input. GeoModel_to_CATIA chain grabs 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, the templets are updated according to geometry data coming from the CATIA project tree. At the 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 proceeds different investigations of detector geometry descriptions.

3. ATLAS END-CAP TOROID STUDY

End-Cap Toroid (ECT) is one of the biggest and heaviest (250 t) parts 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) is expected to become better after improvement of ECT geometry description [7]. Thus, ECT geometry has been investigated. At the 1st stage, engineering descriptions on SmarTeam have been analyzed. Several 3D

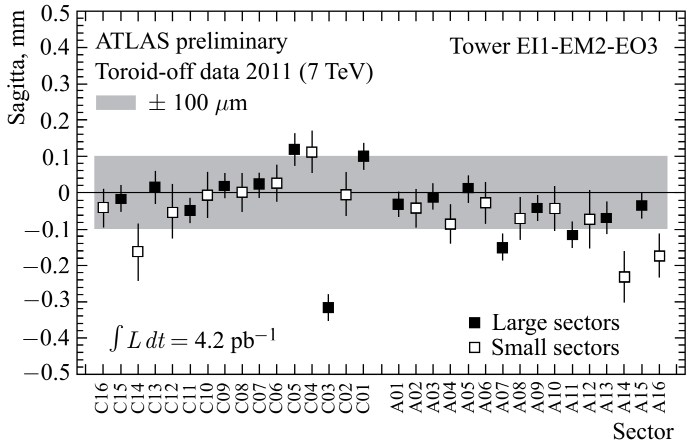

Fig. 3. Sagitta resolution for all sectors of the End-Cap

	CATIA, kg	XML, kg	Difference, kg	%
Cold mass	116740	123012	+6.272	5.4
Thermal shielding	15988	15957	–31	0.2
Cover	57966	57185	–781	1.3
Bore tube	13433	10208	–3.225	24.0
Yoke	1820	1338	–483	26.5
Stay tube	2028	2214	+186	9.2
JTV shielding	4161	4510	+349	8.4
Turret	2476	1512	–964	38.5
Tie rod	3077	1268	–1.809	58.8

Fig. 4. Weight differences between CATIA and XML descriptions

models were compared and the most detailed one was chosen. After comparison with several assembly drawings and photos it was concluded necessity in 3D model reproduction in CATIA, because of lots 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. At the 2nd stage, full ECT description was split into 11 volumes by mechanical structure and materials and for each volume the weights were calculated. At the 3rd stage, 11 identical volumes have been extracted from XML geometry and their weights were calculated. Comparative analysis of CATIA vs. XML (Fig. 4) shows $> 20\%$ difference in volume and weight for majority of components. The grouping of volumes into the two geometry systems may differ somewhat, but the distribution of mass in the detector still shows significant differences.

The biggest discrepancies were detected for BoreTube assembly — 3 t; TieRod assembly — 2 t and Turret assembly — 960 kg. It was decided to update existing XML geometry of ECT. Therefore, at 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 0.01 m^3 and 27 kg, accordingly. At the final stage, baseline geometry was updated by generation of new XML descriptions from the simplified geometry.

4. ATLAS COIL STUDY

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

Therefore, XML baseline geometry was updated by simulation team. Figure 6 illustrates different simulation results by adding thermal shielding to XML description.

		Material	Density, kg/m^3	Volume, m^3	Weight, t	Difference, t
XML	Outside	Steel	7,870	3.887	30.6	5.1
CATIA	assembly	Steel	8,000	4.458	35.7	
XML	Voussoir structures	Aluminium Steel	2,700/7,870	4.56	13.2	–0.9
CATIA		Aluminium Steel	2,650/8,000	4.416	12.3	
XML	Tie road	Aluminium	2,700	0.42	1.1	1.8
CATIA		Steel/Titan Aluminium	8,000/4,480/ 2,705	0.5193	2.9	
XML	Thermal	Aluminium	2,700	13.138	35.5	5.6
	shielding	Aluminium	2,740	0.7517	2.3	
	Coil casing	Aluminium	2,650	12.033	31.9	
CATIA	Coil covers	Aluminium	2,660/2,650	1.898	5	
	Services	Aluminium Steel	28,000/8,000/ 2,650	0.59	1.9	
					Difference:	11.6

Fig. 5. Weight differences between CATIA and XML of Coils

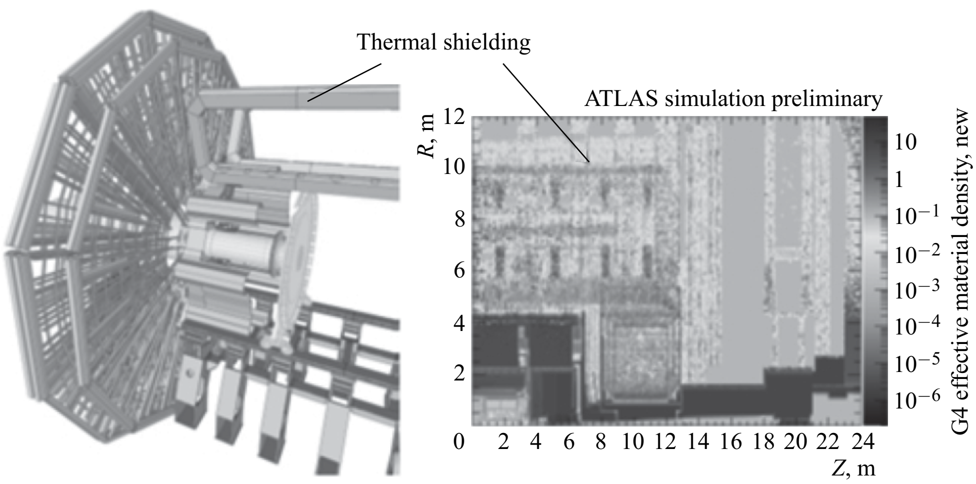

Fig. 6. Simulation results with updated geometry of coils

CONCLUSIONS

1. Creation of geometry hub based on CATIA brings unique possibilities for several geometry cross-checking and investigation of simulation software infrastructure.

2. ATLAS End-Cap Toroid geometry study shows difference (11 t missed/6.7 t added) of weight between XML and as-built geometry volumes.

3. ATLAS Coils geometry study shows 11.6 t of missed materials in XML baseline geometry.

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