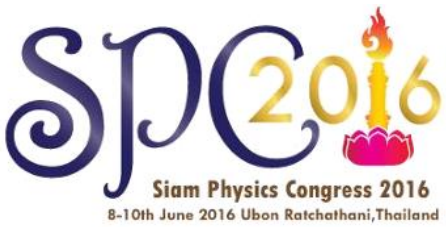


Geometry description of ALICE inner tracking system upgrade

Parinya Namwongsa and Chinorat Kobdaj

(On behalf of the ALICE Collaboration)

Suranaree University of Technology, Nakhon Ratchasima, Thailand

08 Jun 2016

Siam Physics Congress 2016, 8-10th June 2016, Baansuan-Khunta and Golf Resort Hotel, Ubon Ratchathani, Thailand

LHC (Large Hadron Collider)

- The Large Hadron Collider (LHC) with its four detector experiments (ATLAS, CMS, LHCb and ALICE) sits in a 27-km-long circular tunnel, 100m below the ground at the European Organization for Nuclear Research (CERN) on the French-Swiss border, north of Geneva.

ALICE is located at Saint-Genis-Pouilly, France

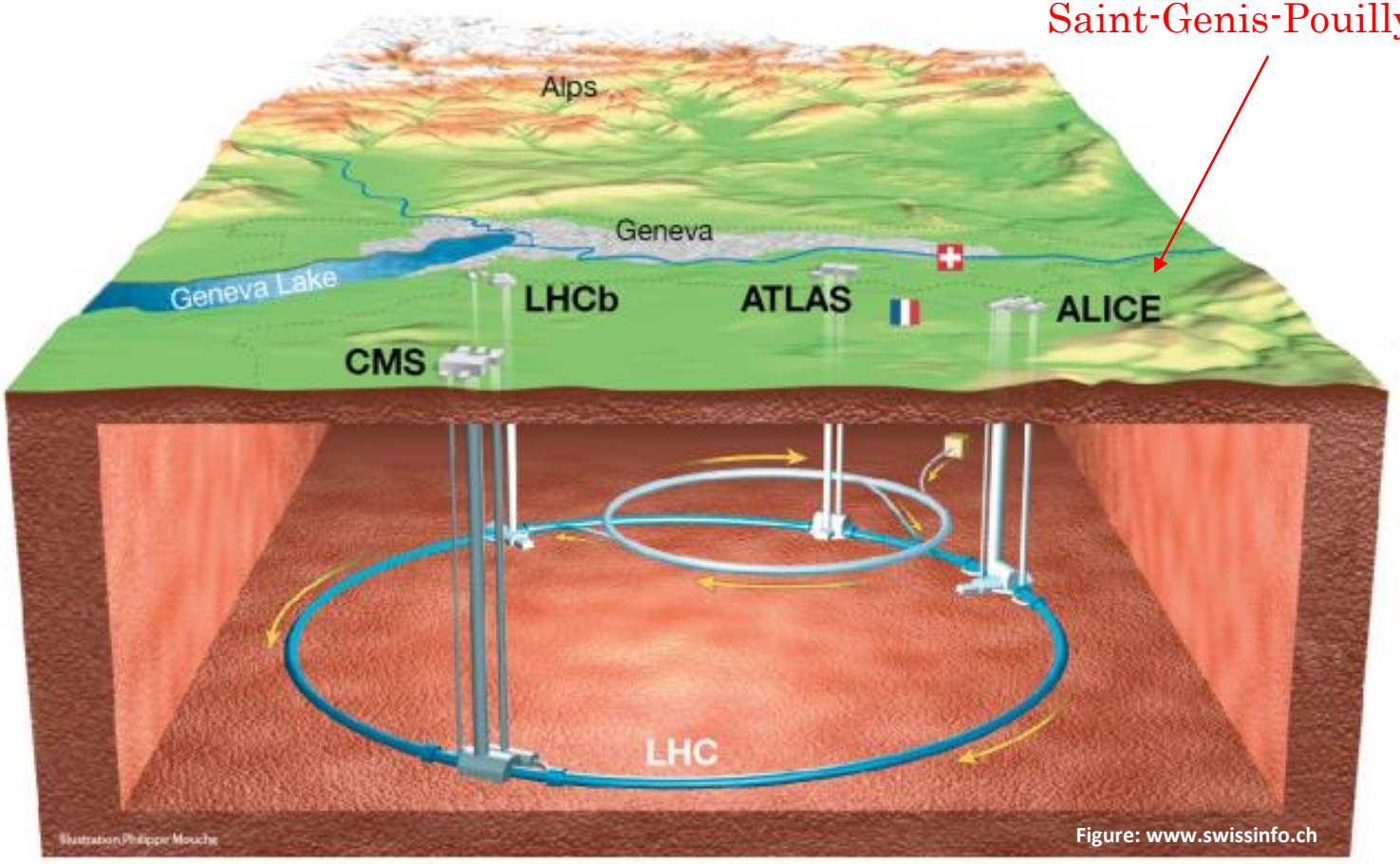
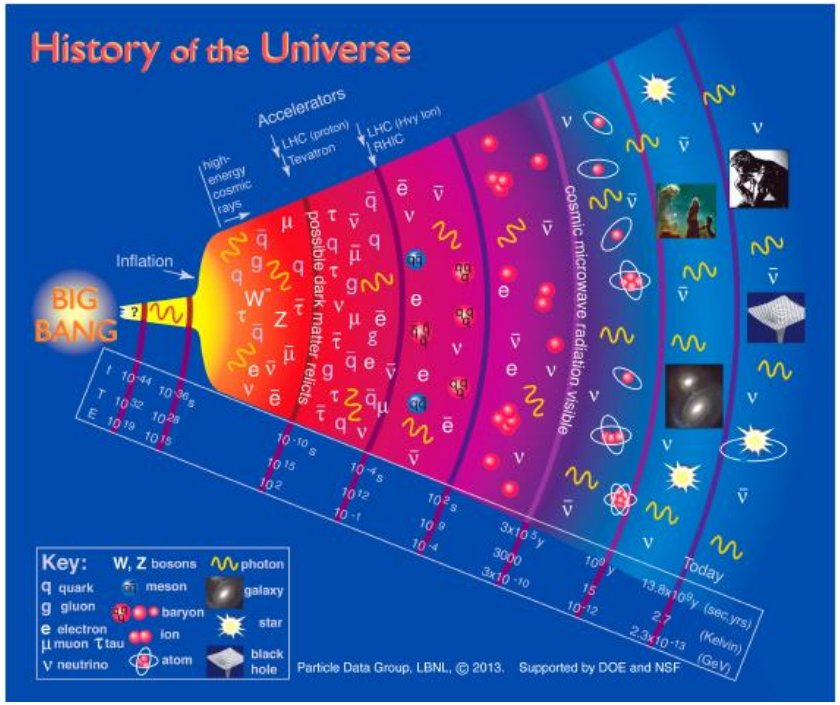
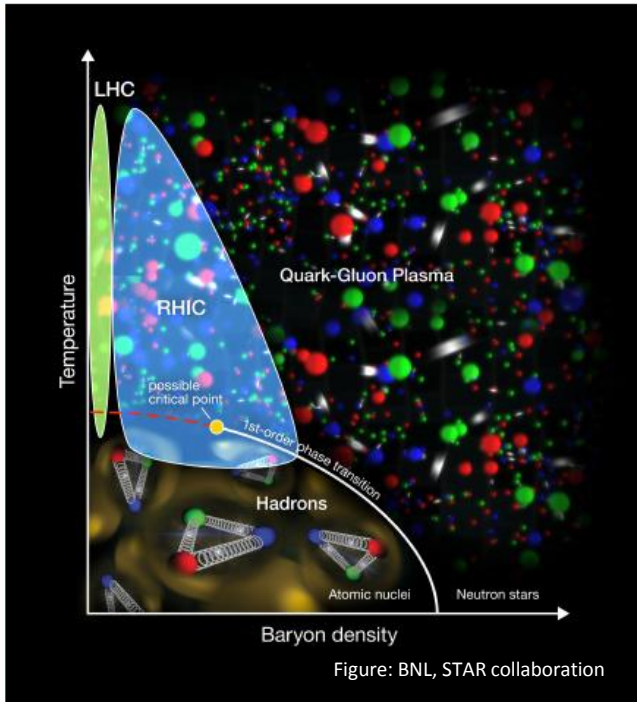


Figure: www.swissinfo.ch

ALICE (A Large Ion Collider Experiment)

- ALICE is designed to address the physics of strongly interacting matter, and in particular the properties of the Quark-Gluon Plasma (QGP).[1]





- QGP is a state of matter in quantum chromodynamics (QCD) which is hypothesized to exist at extremely high temperature, density, or both temperature and density.
- This state is thought to consist of asymptotically free quarks and gluons, which are several of the basic building blocks of matter.
- It is believed that up to a few milliseconds after the Big Bang, known as the Quark epoch, the Universe was in a quark–gluon plasma state.[2]

(1) ALICE Collaboration, CERN-LHCC-2013-024, ALICE-TDR-017, Nucl. Part. Phys. **41** (2014) 087002
(2) https://en.wikipedia.org/wiki/Quark-gluon_plasma

Study QGP with the ALICE apparatus

- The ALICE apparatus allows for a comprehensive study of hadrons, electrons, muons, photons and jets produced in heavy-ion collisions.(1)

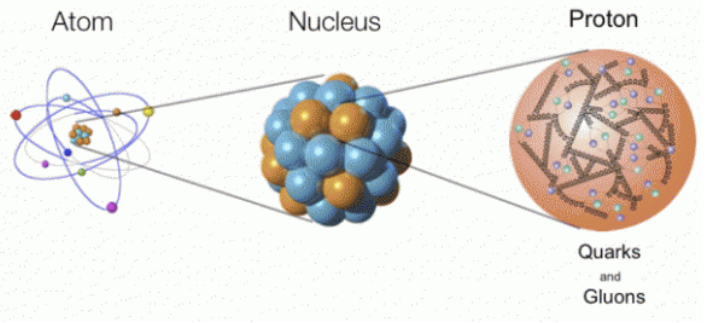


Figure: Hyak / Martin Savage, eScience Institute, University of Washington

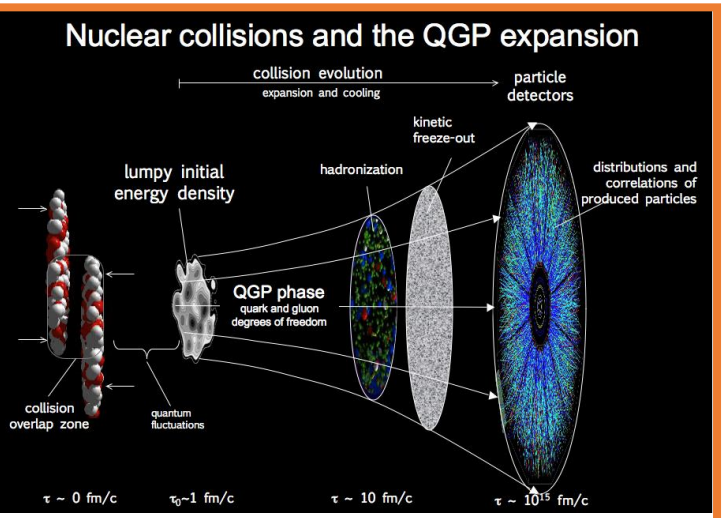


Figure: http://www.phy.uct.ac.za/ctmp/research, by Paul Sorensen

We have focused on the ITS

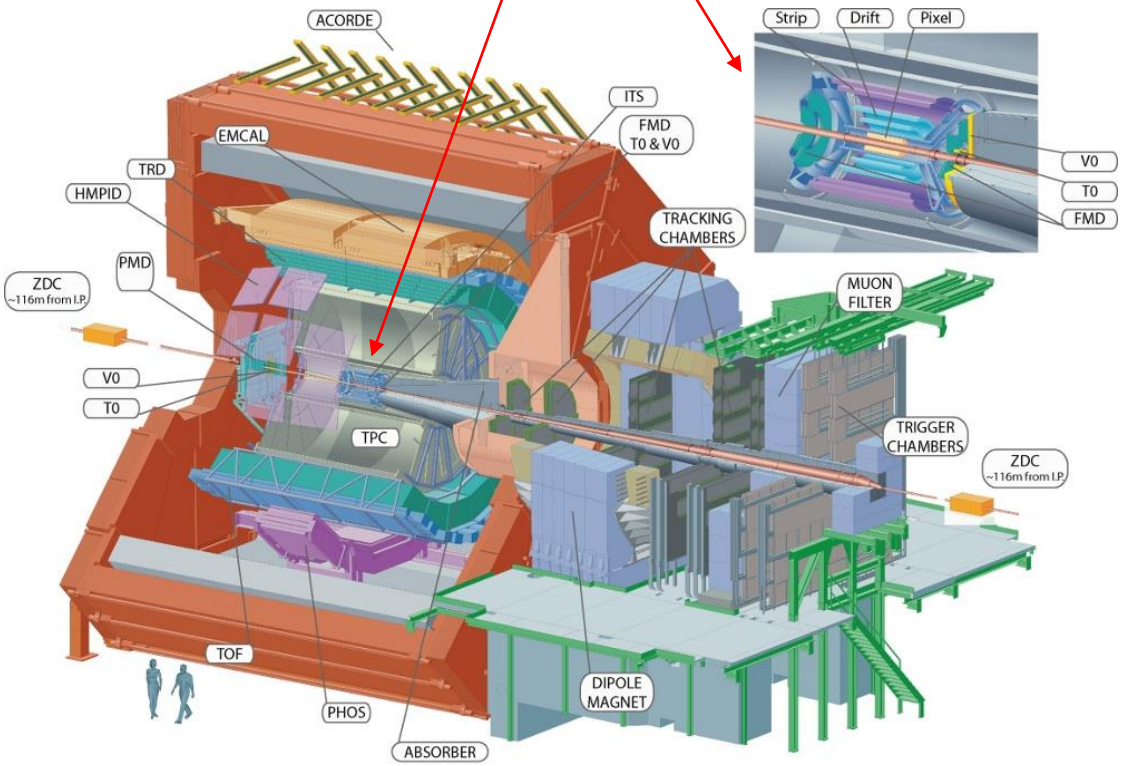
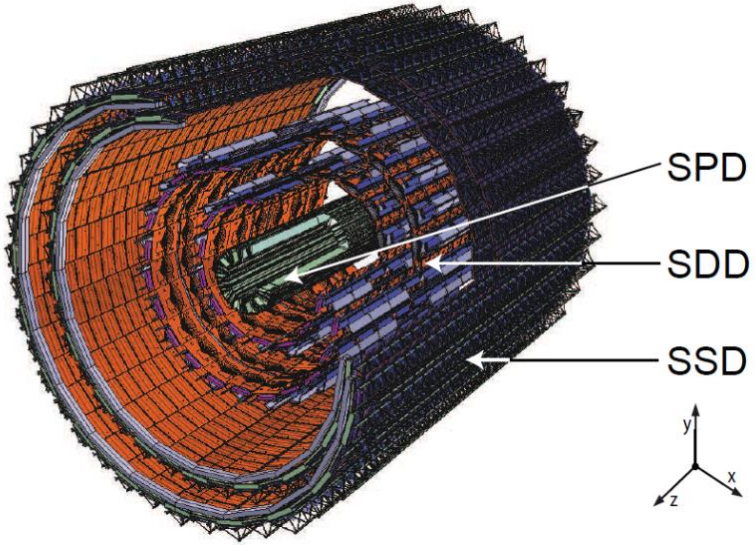


Figure: ALICE Collaboration, 2008 JINST 3 S08002

(1) ALICE Collaboration, CERN-LHCC-2013-024, ALICE-TDR-017, Nucl. Part. Phys. **41** (2014) 087002

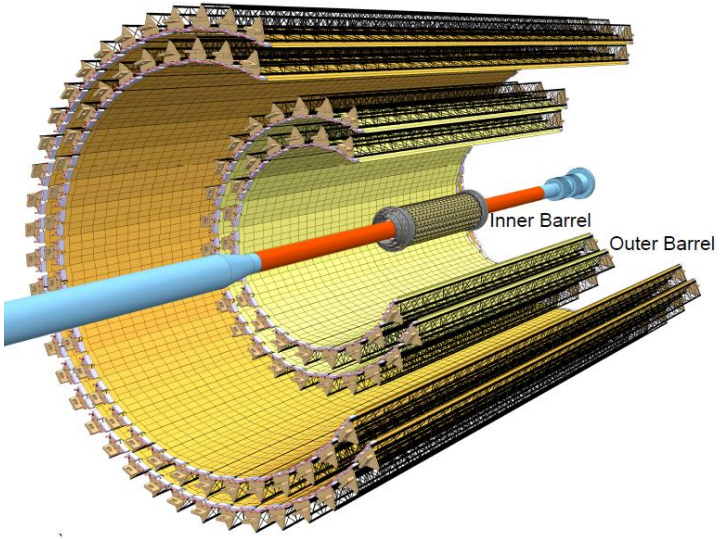
ITS (Inner Tracking System)

Current ITS



- 6 layers
  2xSPD, 2xSDD and 2xSSD
- 1^{st} r = 3.9 cm
- $|\eta| < 0.9$
- X/X_0 = 1.14 for SPD, 1.13/1.26 for SDD and 0.83 for SSD

Upgraded ITS



- 7 layers, all are SPD
  3xInner and 4xOuter
- 1^{st} r = 2.2 cm
- $|\eta| < 1.22$
- X/X_0 = 0.3% for inner barrel and 0.8% for outer barrel.(1)

ALICE Collaboration, 2008 JINST 3 S08002
Figure: ALICE Collaboration, 2010 JINST 5 P03003

ALICE Collaboration, CERN-LHCC-2013-024, ALICE-TDR-017
(1) Expected value: Mario Sitta, PoS (Vertex 2013) 018

ITS upgrade concept: key features

- **1st detection layer closer to beamline:**
  - radius: 3.9 cm -> 2.2 cm.

- **Reduction of material budget:**
  - 0.83%-1.28% -> 0.3% for IB and 0.8% for OB
  - sensor thickness is reduced by the use of MAPS.(1)

- **Geometry and segmentation:**
  - number of layers: 6 layer -> 7 layers
  - pixel size: down to 28µm x 28µm.(2)

- **Readout time:**
  - 1 kHz -> 100 kHz for Pb-Pb collisions and 400kHz for pp collisions.

For the upgraded ITS: ALICE Collaboration, CERN-LHCC-2013-024, ALICE-TDR-017, Nucl. Part. Phys. **41** (2014) 087002
(1) Monolitic Active Pixel Sensors
(2) Mario Sitta, PoS (Vertex 2013) 018

Passage of particles through matter: radiation length X_0

- High-energy electron predominantly lose energy in matter by bremsstrahlung, and high-energy photons by e^+e^- pair production.
- The characteristic amount of matter traversed for these related interactions is called the radiation length X_0, usually measured in $g.cm^{-2}$.

(an element)

$$X_0 = \frac{716.4 \cdot A}{Z(Z+1)\ln\frac{287}{\sqrt{Z}}}$$

(compound or mixture)

$$\frac{1}{X_0} = \sum_i w_i \left(\frac{1}{X_0}\right)_i$$

- Comparison of values of radiation length X_0 for elements and molecules obtained experimentally and analytically.(1)

Medium	Z	A	X_0 (exp)	X_0 (ana)	%error
C	6	12.0108	42.70	43.10	0.72
Si	14	28.0855	21.82	22.08	1.18
H_2O	density = 1 $g.cm^{-3}$		36.08	36.04	0.10
CF_2Cl_2 (Freon-12)	density = 1.12 $g.cm^{-3}$		23.65	23.65	0.00

Paticle Data Group, "Review of Particle Physics", Chin.Phys.C.38.090001
(1) Mukund Gupta, "Calculation of radiation length in materials", PH-EP-Tech-Note-2010-013

Passage of particles through matter: material budget X/X_0

- The radiation length X_0(cm) can be:

$$X_0(cm) = \frac{X_0(g \cdot cm^{-2})}{density\ (g \cdot cm^{-3})}$$

- The material budget X/X_0 can be calculated by using the X_0(cm).[1]

(material)

$$\frac{X}{X_0}(\%) = \frac{thickness}{X_0} \times surface(\%)\,,$$

(combined material)[2]

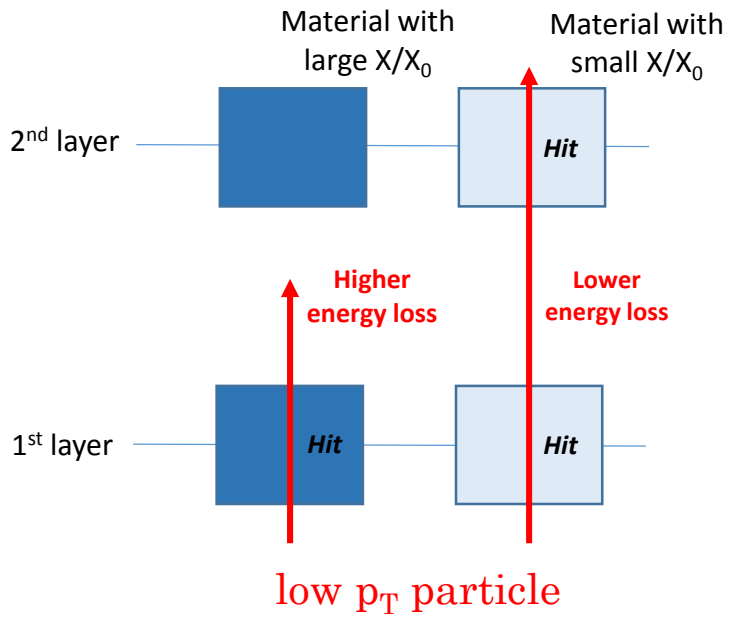
$$\frac{X}{X_0}(\%) = \sum_i w_i \left(\frac{X}{X_0}(\%)\right)_i$$

- List of material budget X/X_0 for example of materials.

Material	Surface (%)	Thickness (μm)	X_0 (cm)	X/X_0 (%)
Si (d = 2.329 g.cm^{-3})	100	50	9.3688	0.05337
H_2O (d = 1.0 g.cm^{-3})	19	1450	36.08	0.07636

(1) Mario Sitta, Chinorat Kobdaj and Wanchaloem Poonsawat
(2) Parinya Namwongsa and Chinorat Kobdaj

Material budget X/X_0: consequences



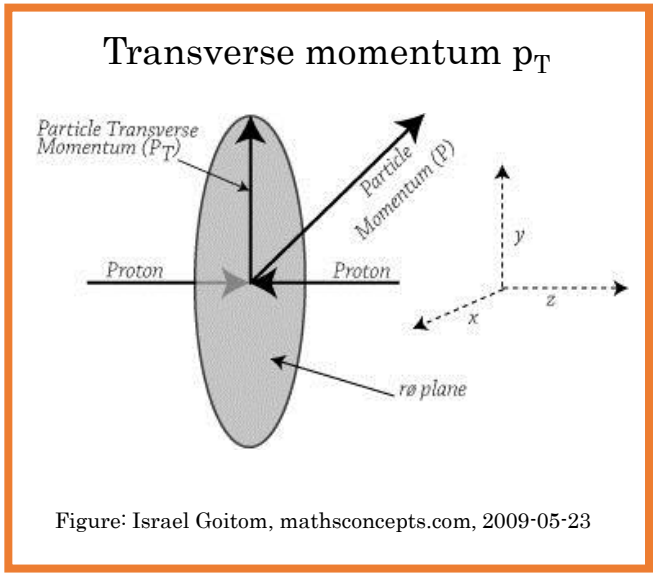


Figure: Israel Goitom, mathsconcepts.com, 2009-05-23

- Reducing the material budget of the first detection layer particularly important for improving the impact parameter resolution.
- In general, reducing the overall material budget will allow the tracking performance and momentum resolution to be significantly improved.

ALICE Collaboration, CERN-LHCC-2013-024, ALICE-TDR-017, Nucl. Part. Phys. **41** (2014) 087002.

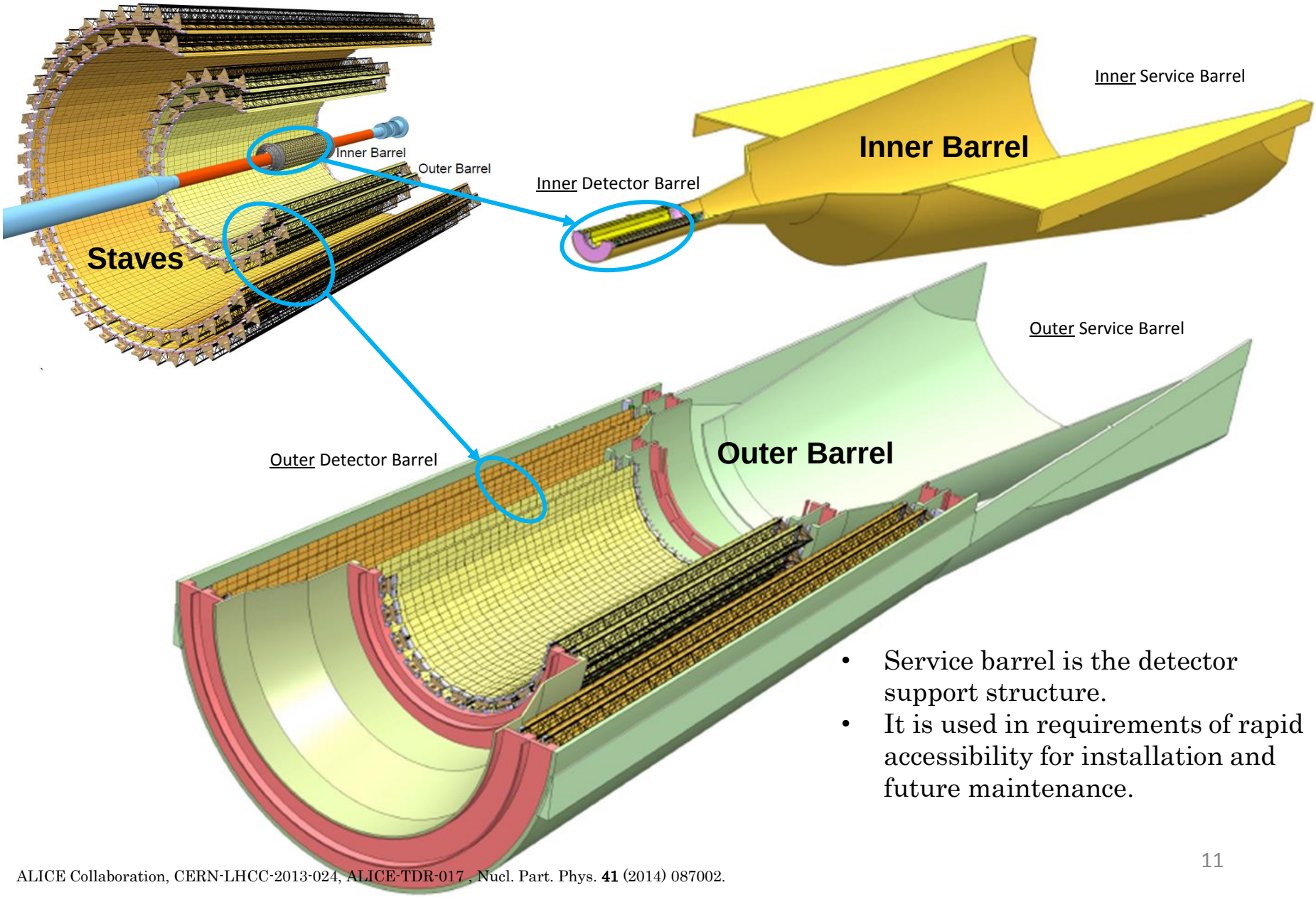
Geometry structure of ITS upgrade

1. Detector Barrel
   - 1.1 Stave
   - 1.2 End-wheel
   - 1.3 DC-DC converter
2. Service Barrel

SUT[1] work concentrates on only the Inner Barrel (IB).
In this work we focus on 1.2 and 1.3

(1) SUT, Suranaree University of Technology, Nakhon Ratchasima, Thailand.

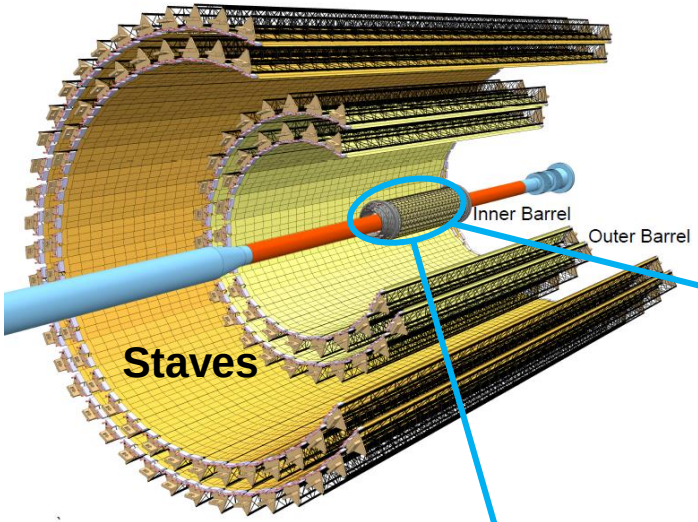
ITS upgrade : service barrel from CAD

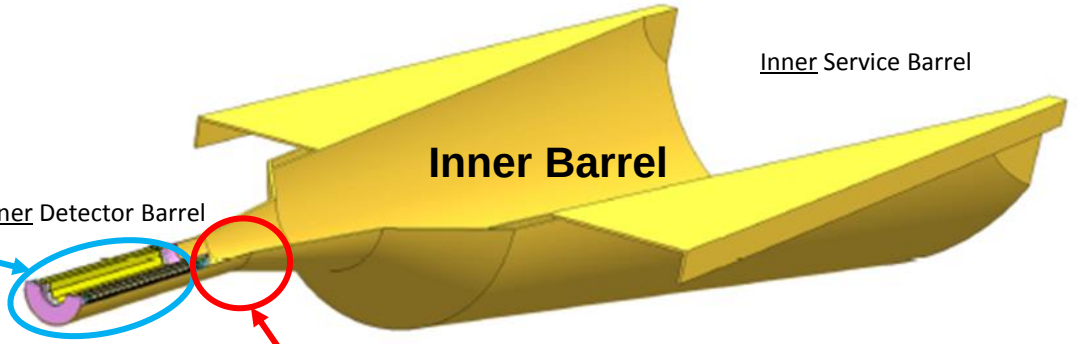


- Service barrel is the detector support structure.
- It is used in requirements of rapid accessibility for installation and future maintenance.

ALICE Collaboration, CERN-LHCC-2013-024, ALICE-TDR-017 , Nucl. Part. Phys. **41** (2014) 087002.

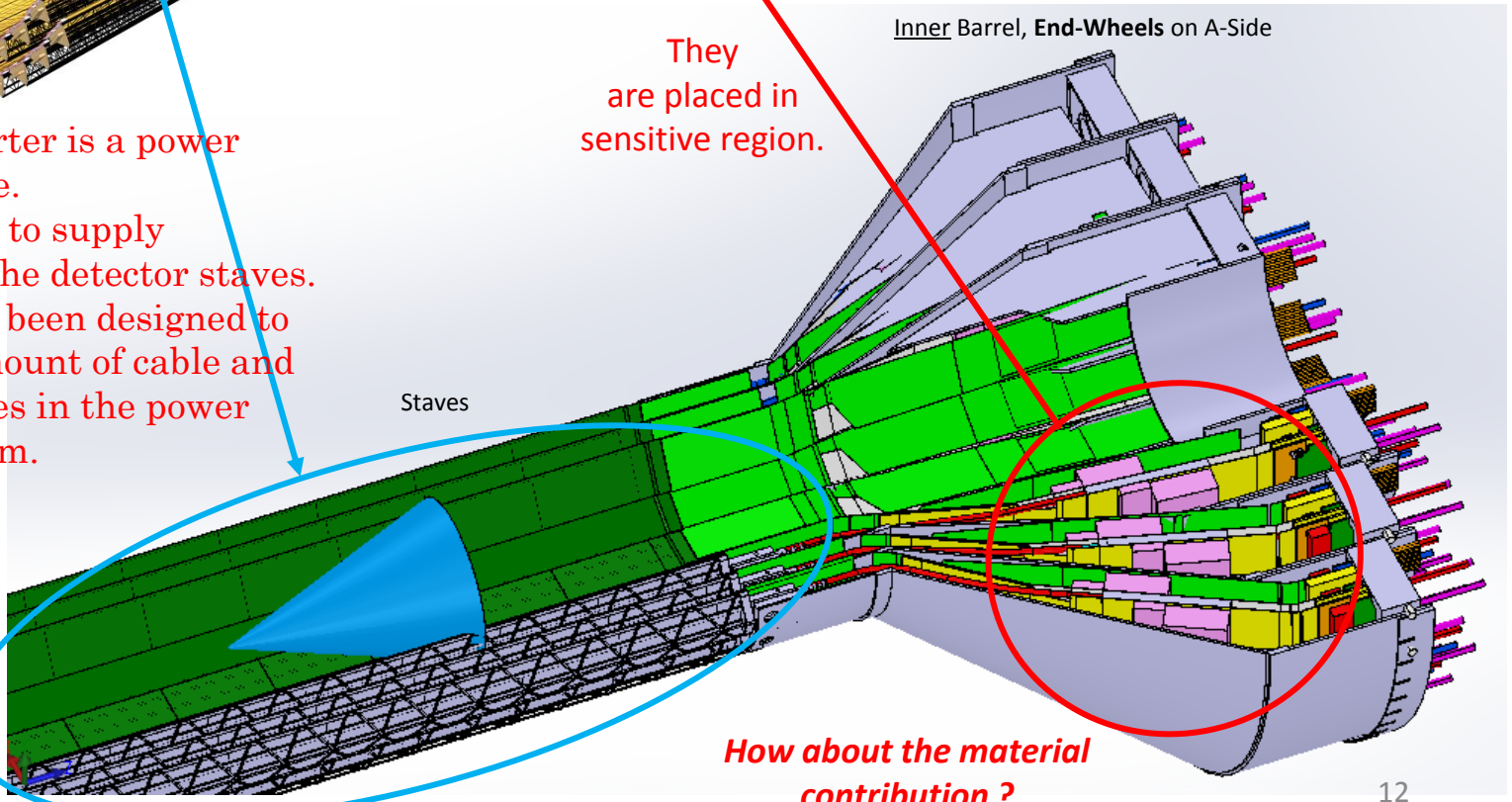
ITS upgrade : DC-DC converters from CAD





- DC-DC converter is a power supply module.
- Its function is to supply electricity to the detector staves.
- Its layout has been designed to reduce the amount of cable and cooling services in the power delivery system.

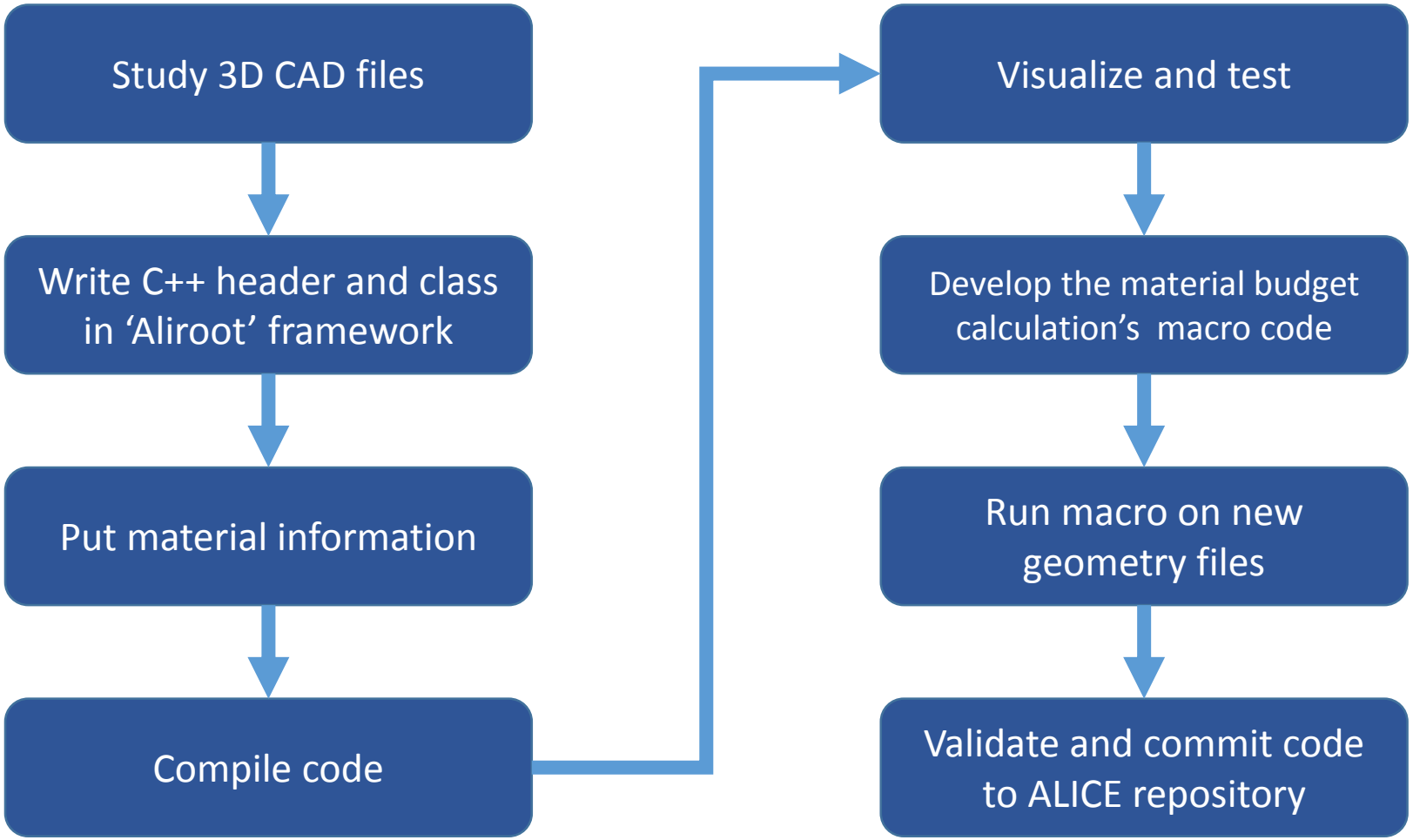
They are placed in sensitive region.



Latest 3D design of upgraded **Inner Service Barrel.** (20151110_IB, Corrado)

How about the material contribution ?

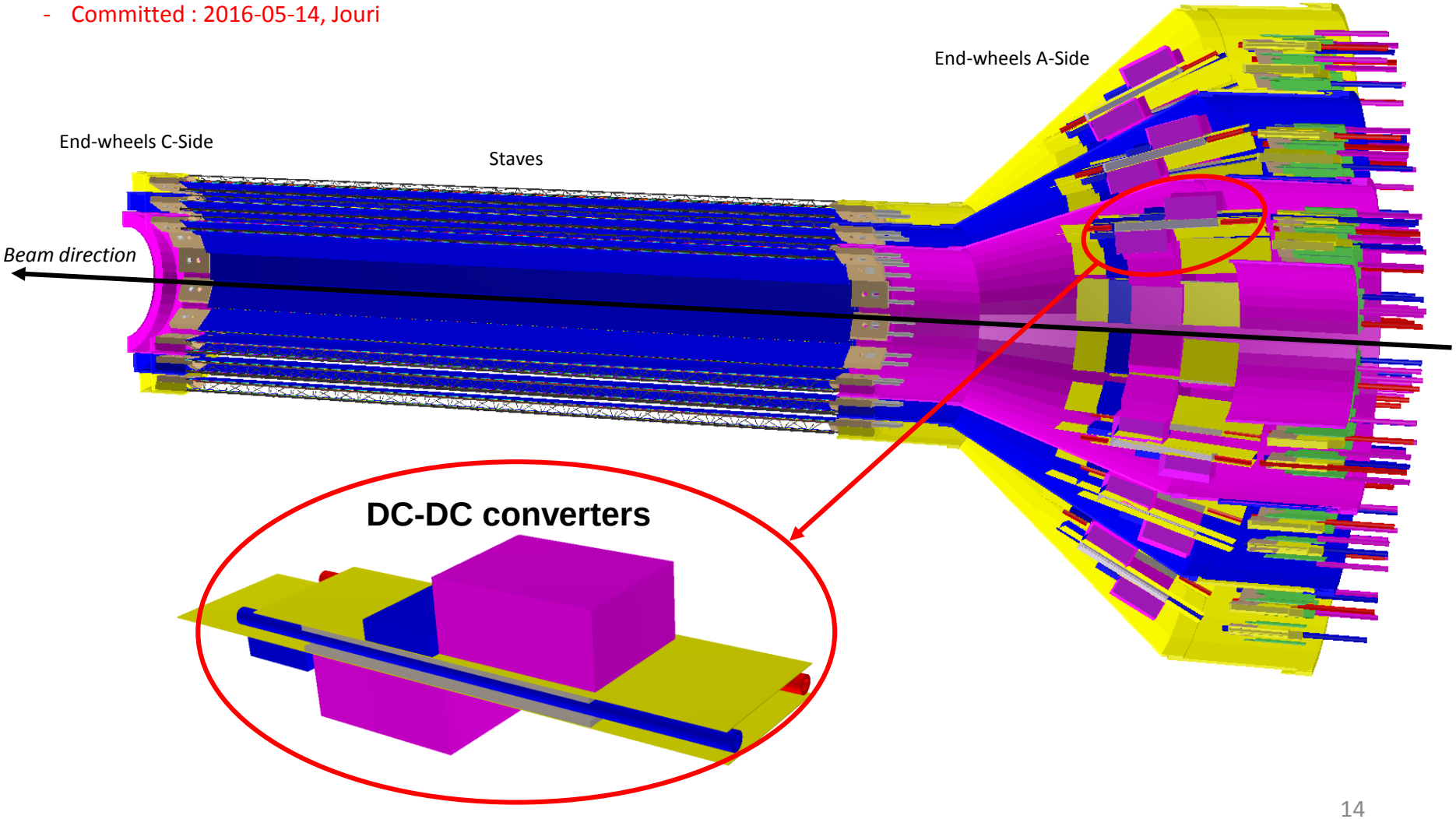
Material budget calculation : steps and methods



Present work : geometry from Aliroot

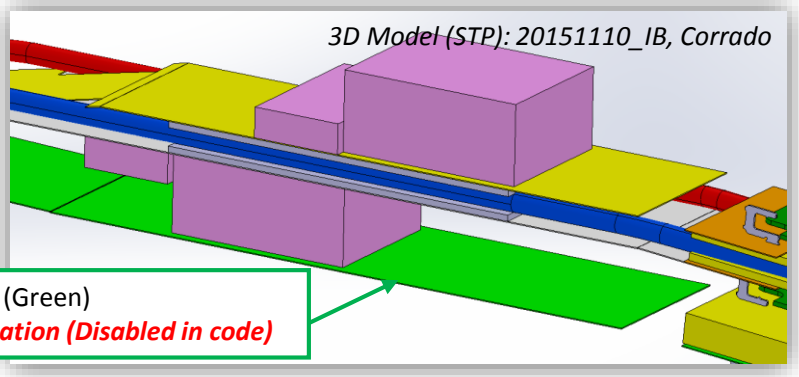
ITSU Inner Barrel

- Parts: Endwheels & DC-DC converters
- Update: 2016-05-11, Parinya & Chinorat
- 3D Model (STP): 20151110_IB, Corrado
- Committed : 2016-05-14, Jouri



Present work: material information of DC-DC converter

DC-DC converter
- Function: AliITSUv2Layer::CreateInnerDCDC3()
- Mediums: AliITSUv2::CreateMaterials()
- Prototype: **FEASTMT_CLP**
- Update: 2016-05-11, Parinya & Chinorat

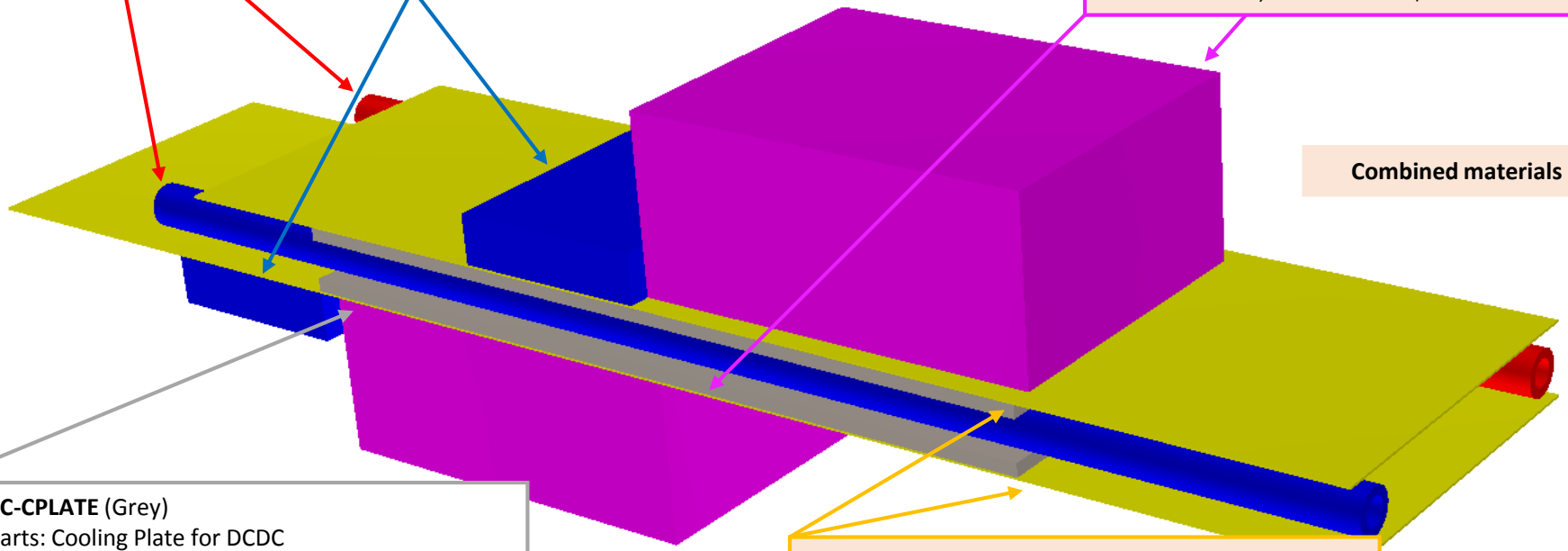


DCDC-CPIPE (Red & Blue)
- Parts: Cooling Pipe (Hot & Cold)
- Medium: 23, "PUR$" (Polyeurethene)

DCCNT-FPGA (Green)
- ***No information (Disabled in code)***

DCDC-PASSCNT (Blue)
- Parts: Passive40% + Connector + Air
- Medium: 26, "DCDCPASSCNT$"

DCDC-SHIELD (Magenta)
- Parts: Maincoil + Shield + Passive60% + Air
- Not include: Gabpad (need information)
- Medium: 25, "DCDCSHIELD$"



Combined materials

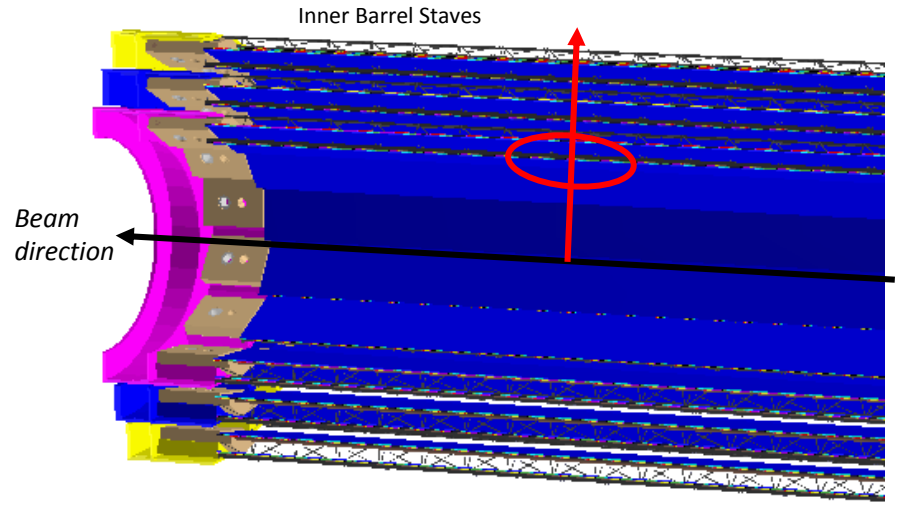
DCDC-CPLATE (Grey)
- Parts: Cooling Plate for DCDC
- Medium: 16, "ALUMINUM$"

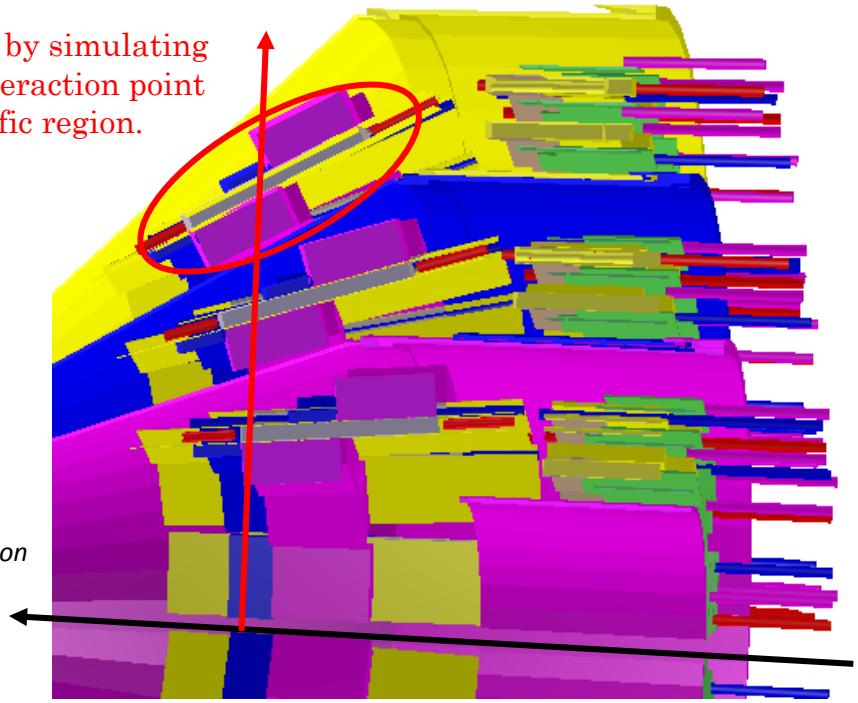
DCDC-PCBCU (Yellow)
- Materials: FR4 + Copper
- Medium: 24, "G10FR4CU$"
- Modified from: AliITSUv11::"G10FR4"

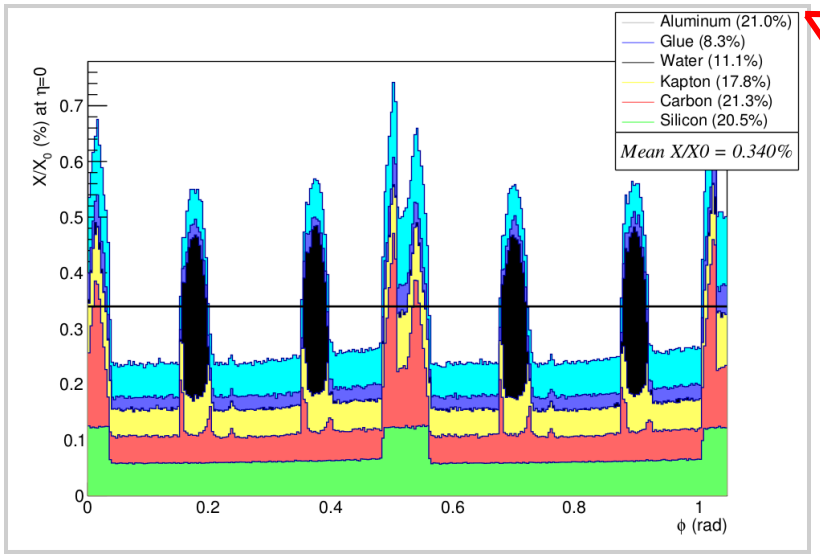
Prospect and outlook

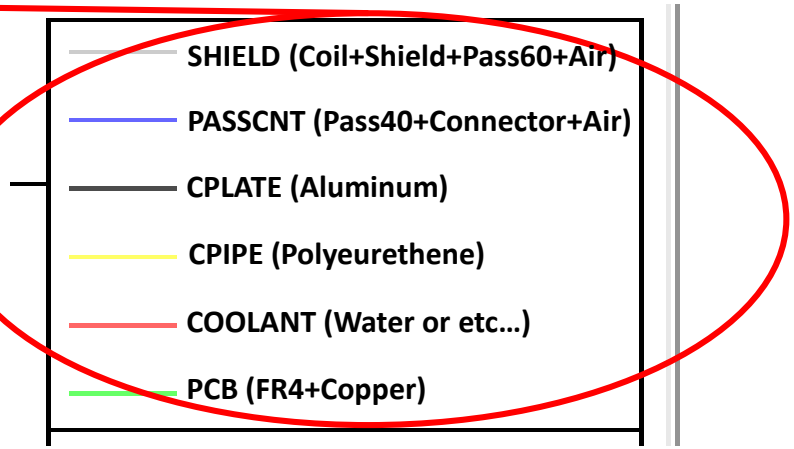
Material budget plot of a Stave in L0.
- Implemented by: Chinorat & Mario

Calculate the material budget by simulating particle collisions from the interaction point passing through the specific region.









Expected material budget contribution for a DC-DC converter module.

Acknowledgement

Suranaree University of Technology (SUT)

- School of Physics, Institute of Science
  Prof. Dr. Yupeng Yan
  Asst. Prof. Dr. Chinorat Kobdaj
  Asst. Prof. Dr. Ayut Limphirat
  Wanchaloem Poonsawat
- SUT OROG scholarship

ALICE Collaboration, CERN

- WP1&2 : ITS Upgrade physics and software
  Dr. Mario Sitta and Dr. Iouri A. Belikov
- WP9 : ITS Upgrade Mechanics and Cooling
  Dr. Corrado Gargiulo, Dr. Elisa Laudi and Gael Ledey