STEAM

Revival of SIGMA and Extended STEAM-SDK Coupling

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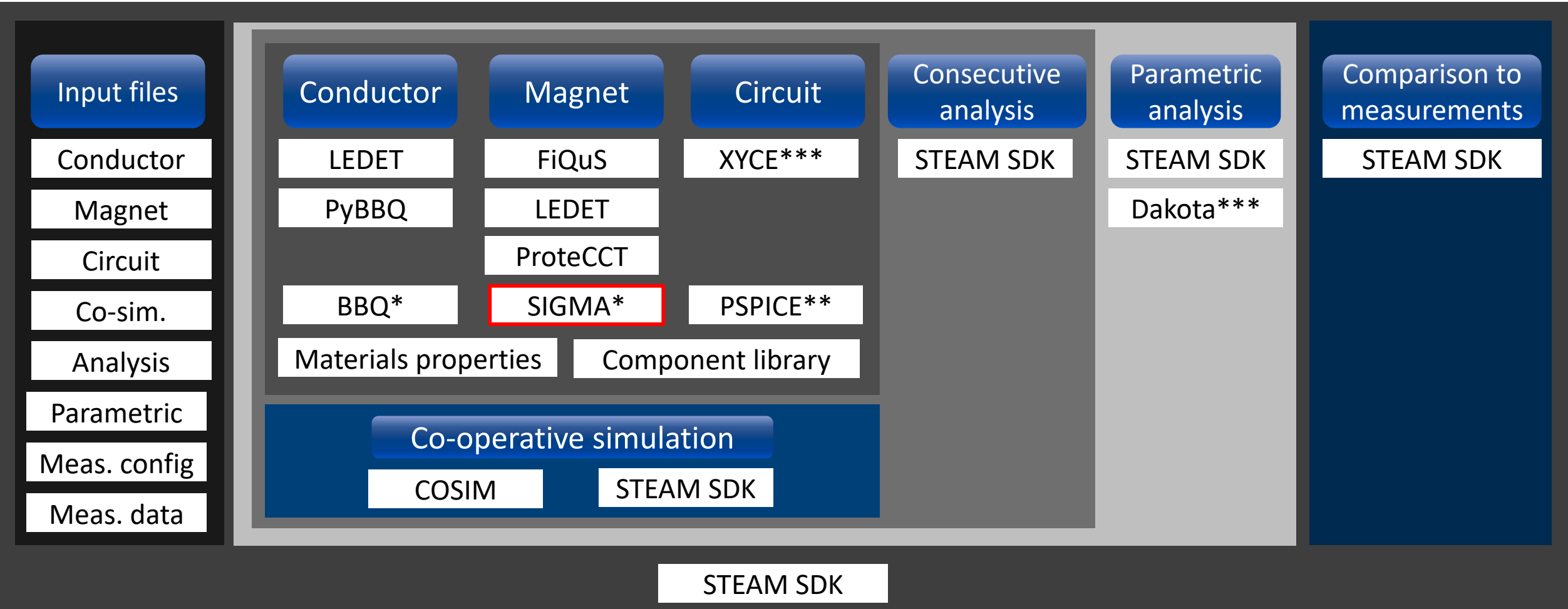https://espace.cern.ch/steam

Outline

- SIGMA in the STEAM-Framework

- Background: What is SIGMA?

- Development of SIGMA

- Lessons learned and future of SIGMA

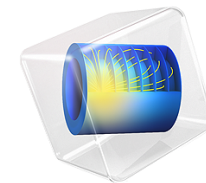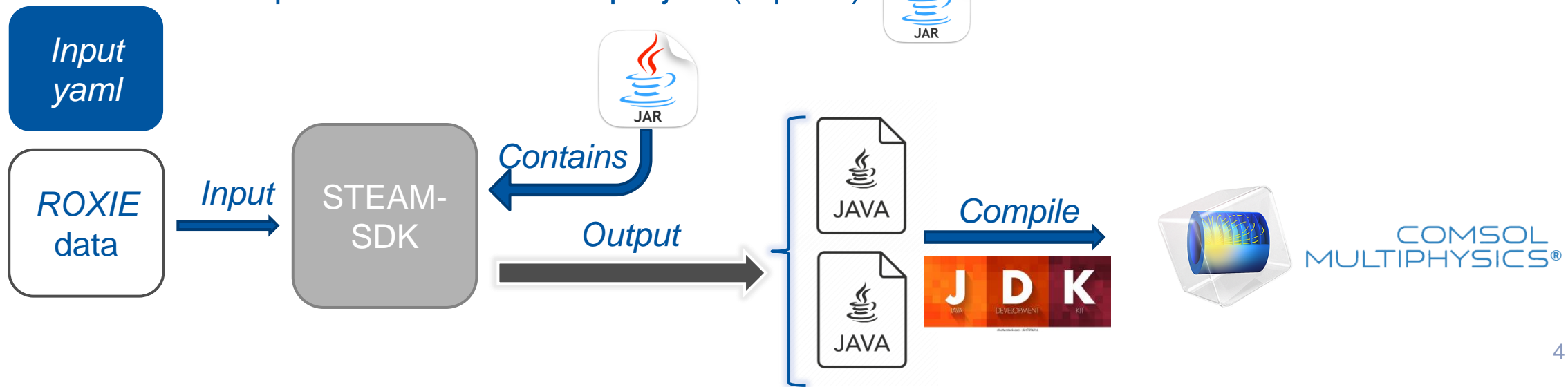- Additional Work in STEAM-SDK & FiQuS

STEAM framework

Input files		Conductor	Magnet	Circuit	Consecutive analysis	Parametric analysis	Comparison to measurements
Conductor		LEDET	FiQuS	XYCE***	STEAM SDK	STEAM SDK	STEAM SDK
Magnet		PyBBQ	LEDET			Dakota***	
Circuit			ProteCCT				
Co-sim.		BBQ*	SIGMA*	PSPICE**			
Analysis		Materials properties	Component library				
Parametric							
Meas. config							
Meas. data							

Co-operative simulation

COSIM   STEAM SDK

STEAM SDK

some functionality is under active development

*COMSOL license needed. **Commercial circuit solver from Cadence Design Systems. ***Free tools from Sandia Labs.

Background: What is SIGMA?

- SIGMA – Simulation of Transient Effects in Accelerator Magnets

- Java application developed 2017-2020 at CERN

- Generate COMSOL-based transient models of accelerator magnets

- Official development stopped in 2020 (before steam-sdk)

- STEAM-SDK integration:

  - Gradle (build tool) build SIGMA project to jar file

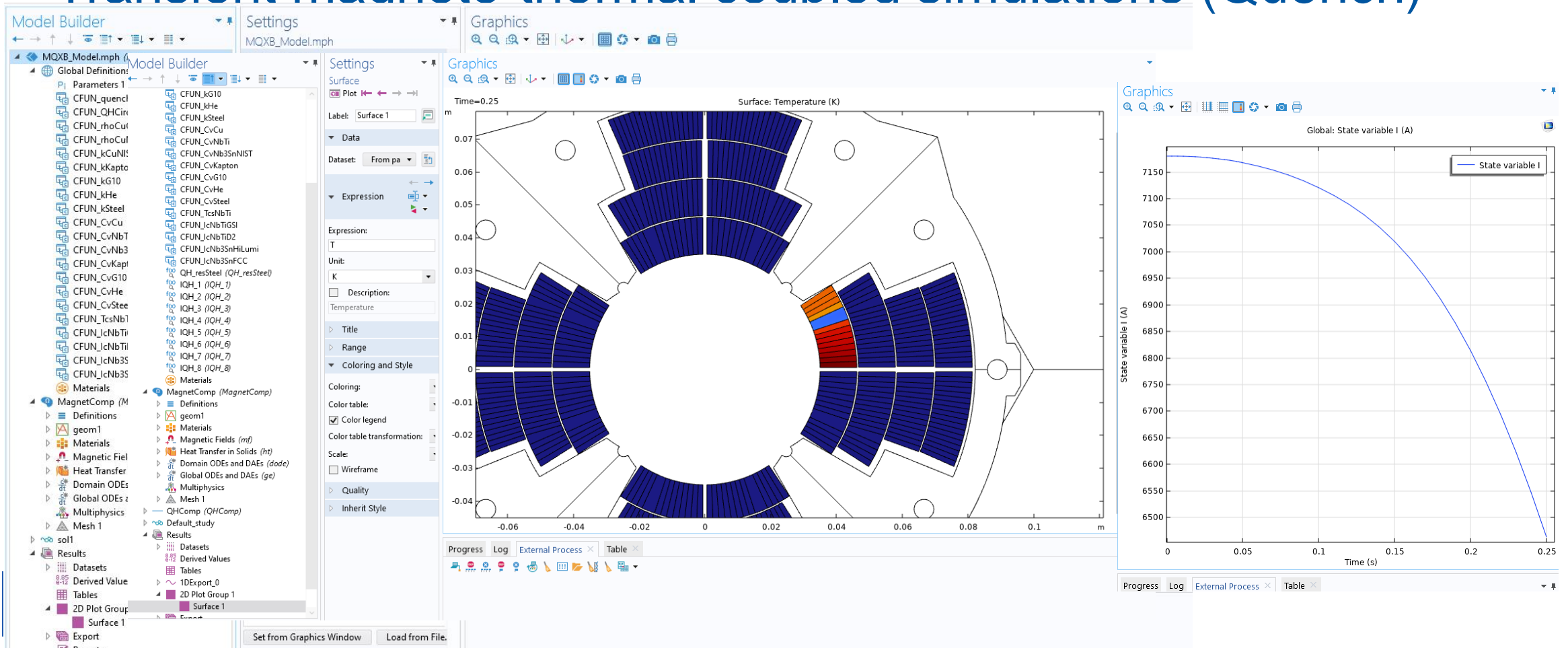 - Jar file – compact version SIGMA project (Zip file)

Generated Magnet Model

Examples of Solutions with SIGMA

- Magnetostatic field solver

- Transient magneto-thermal coupled simulations (Quench)
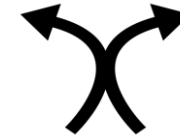
So, what was the problem?

Single jar file in STEAM-SDK:

Jar unversioned:
- No connected repository to generated jar

Scattered source code:
- 4 repositories with multiple branches each

Broken gradle dependencies:
- Dependencies when building SIGMA broken.

No verification:
- Simulations accurate?
- For which magnets does SIGMA work?
- Missing functionalities

First stage: Revive SIGMA

- How to recover source code?

- Retrieve SIGMA source code by decompiling .jar file

- Remove redundant gradle dependencies to build jar

- Generate and solve model in COMSOL with new jar

- Migrate latest features from repositories to SIGMA including tests
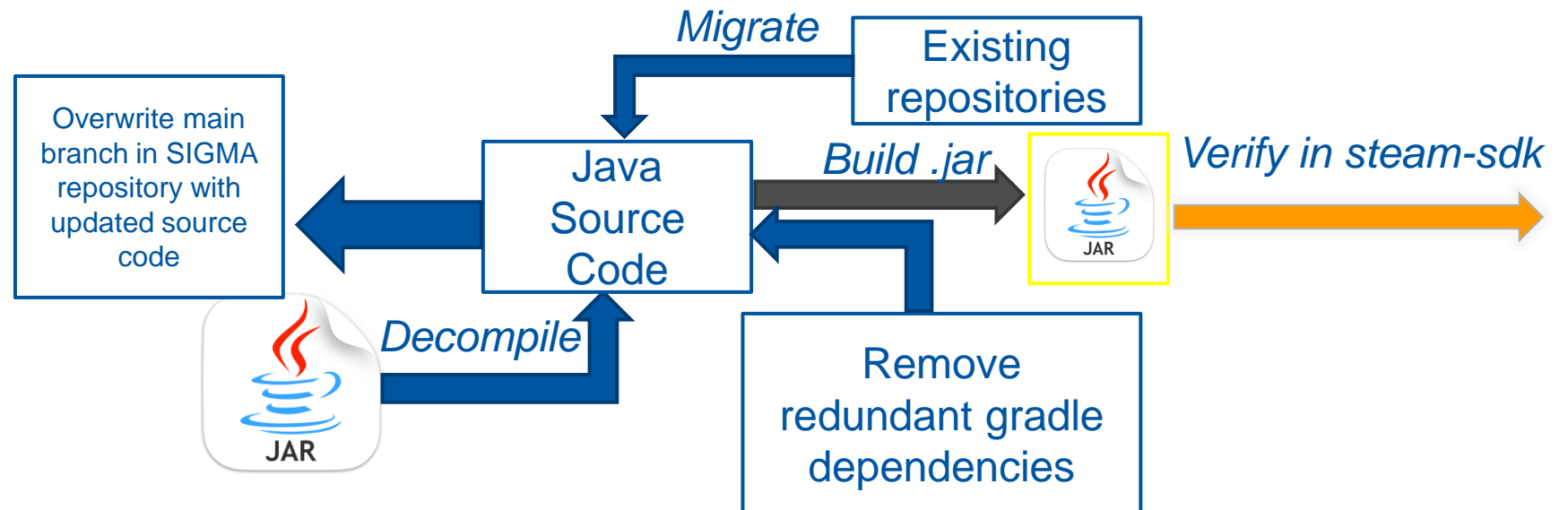
Second stage: Automation of Quench Simulations & Upgrade COMSOL version

- Only COMSOL 5.3a version supported (2017)
  - COMSOL not backward compatible
  - Implement SIGMA support COMSOL 6.0

Example: 5.3a vs 6.0

Second stage: Automation of Quench Simulations & Upgrade COMSOL version

- Only COMSOL 5.3a version supported (2017)
  - COMSOL not backward compatible
  - Implement SIGMA support COMSOL 6.0
- Missing features set from input files:
  - Quench initialization
  - Quench heater positions
  - Propagation of settings from steam-sdk for quench simulations

Missing Features & Propagation of Input Parameters

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- No automatic execution of simulations

Execution problem:

Execution from python possible!

Second stage: Automation of Quench Simulations & Upgrade COMSOL version

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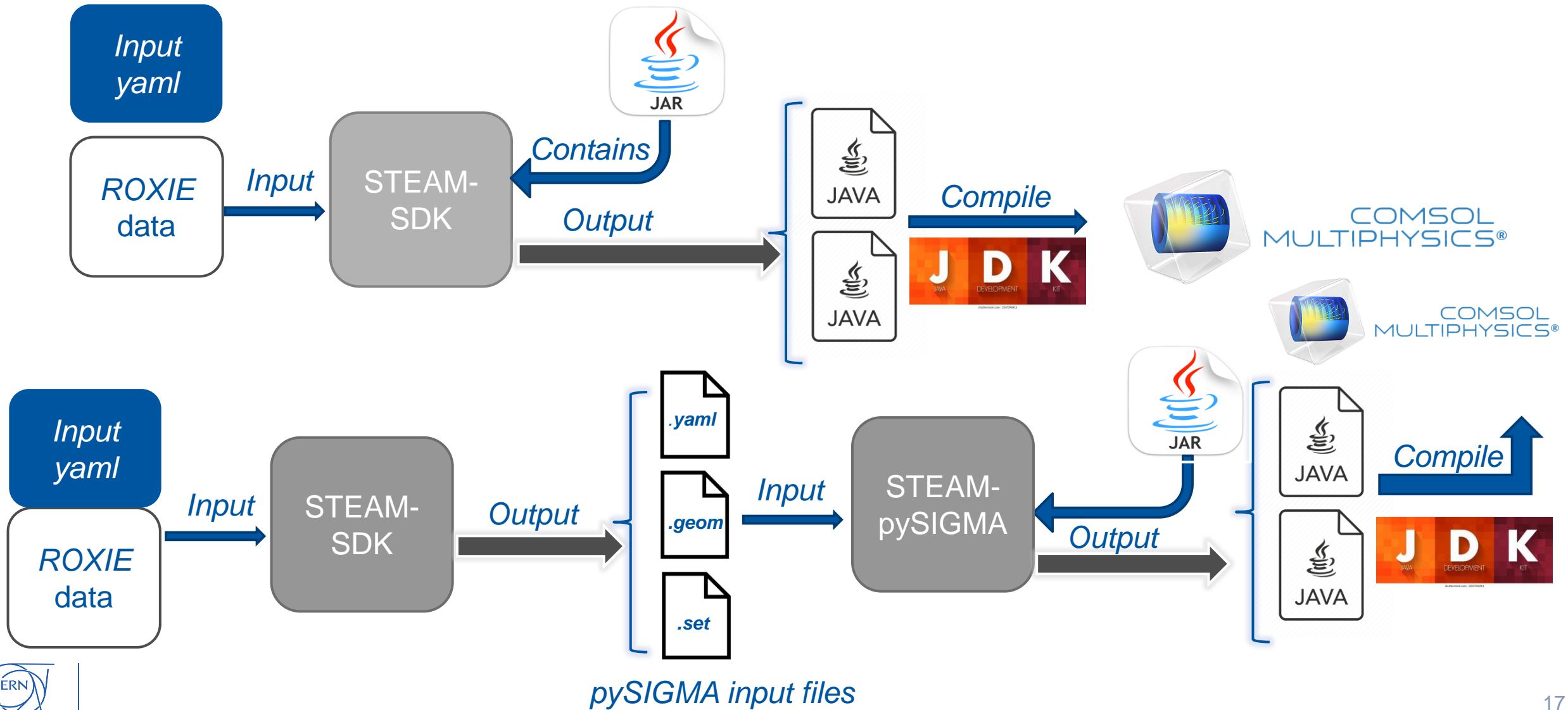- Problem: Architecture not in line with other steam-sdk tools
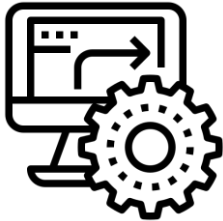
Stage 3. Update Architecture and Track Performance

- Problem: Architecture not in line with steam-sdk tools
  - Builder_'tool'.py generates input files
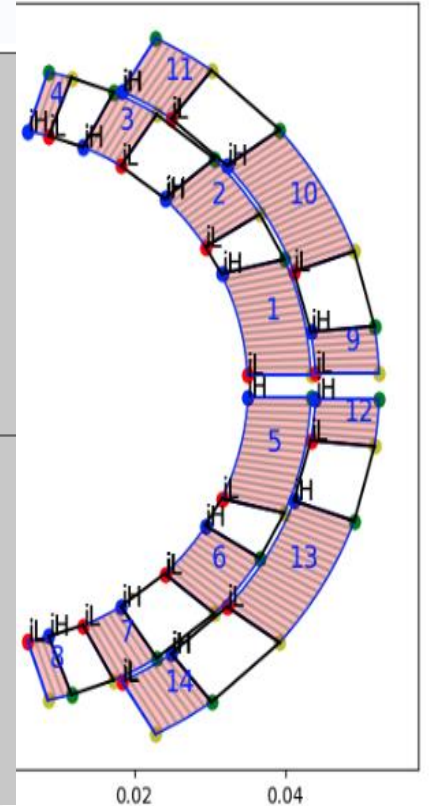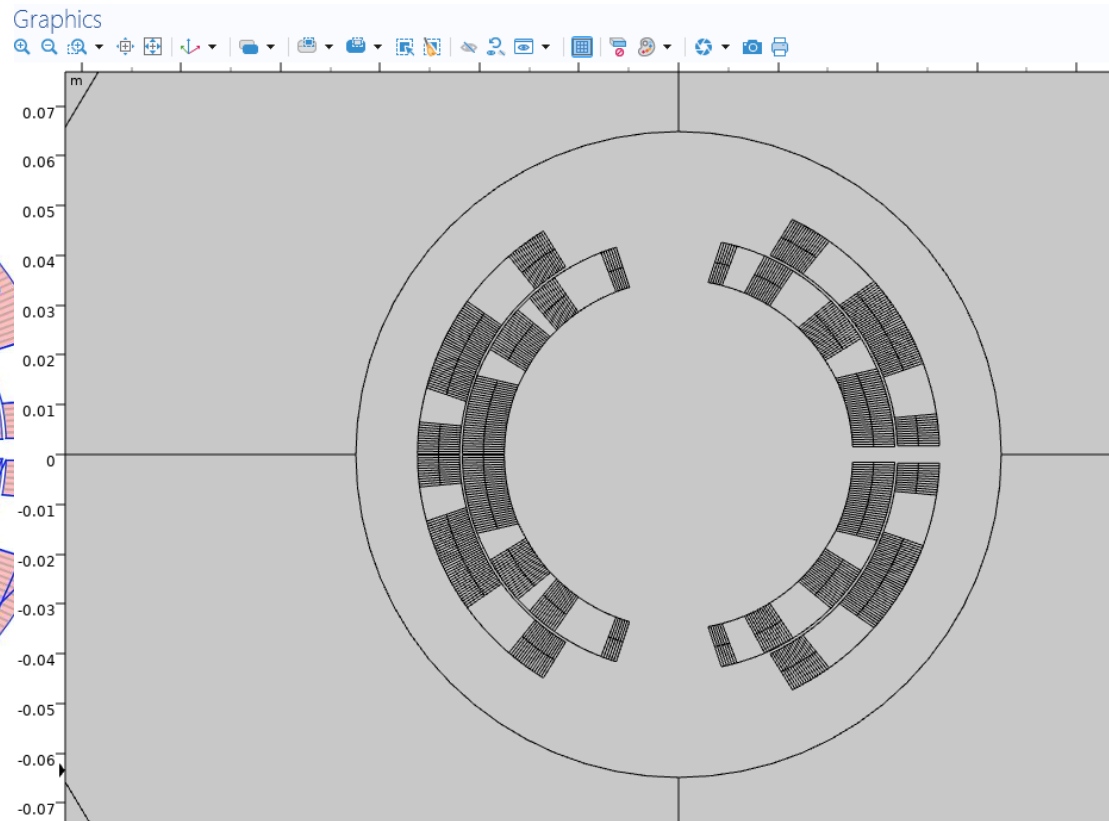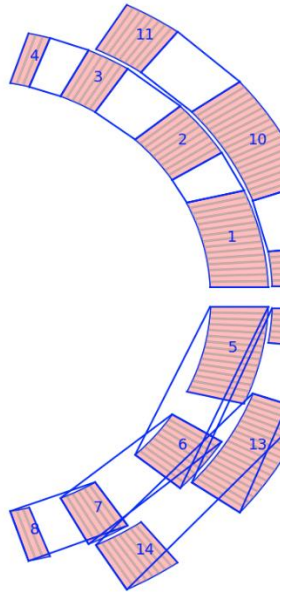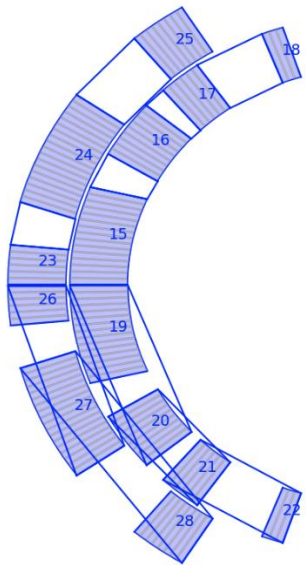 - Not the case for BuilderSIGMA.py

Change of Architecture

Benefits of new Architecture

- Example: MED_C_COMB magnet

  - Goal: Fix in FiQuS

  - SIGMA, FiQuS share same geom file => SIGMA fixed too!

- Maintainability

Third Stage. Update Architecture and Track Performance

- Problem: Architecture not in line with steam-sdk tools

  - Builder_'tool'.py generates input files

  - Not the case for BuilderSIGMA.py

- Analysis file to run through magnet library

  - Which magnets work in SIGMA?

  - What error to Roxie?

WIP: SIGMA status sheet

Magnet name	Work for COMSOL 5.3a and 6.0	Stationary work	Transient work	Bmod_difference_max stationary (T)	Comment
MB_2COILS	Yes	Yes	Yes	0.49041654	
MBH_1in1	Yes	Yes	Yes	0.346706827	
MBH_2in1				0.4	
MBRB	Yes	Yes	Yes	0.8	
MBRC	Yes	Yes	Yes	0.6872	
MBRD	Yes	Yes	Yes	0.338124228	
MBRS	Yes	Yes	Not for 5.3a with default input	0.630181906	
MBX	Yes	Yes	Not for 5.3a with default input	0.693816773	
MBXF	Yes	Yes	Yes	0.426043698	
MQY_2in1	Yes	Yes	Yes	1.12656387	High field difference
MQ_1AP	Yes	Yes	Yes	0.805922383	
MQML_2in1	Yes	Yes	Not with default input	0.26578566	
MQMC_2in1	Yes	Yes	Not with default input	0.26578566	
RMM_V1	Yes	Yes	Yes	0.304899581	
MCO	Yes	Yes	Yes	0.149070424	
MED_C_COMB	Yes	Yes	Yes	0.083625566	
MQXB	Yes	Yes	No convergence 6.0	0.410811943	
MQXA	Yes	Yes	Yes	0.263152777	
MQXF_V2	Yes	Yes	Yes	0.49051579	
ERMC_V1	Yes	Yes	Yes	0.471448028	
MCBXFH	Yes	Yes	Yes	0.6	High field difference
MQM_2in1	Yes	Yes	Not for 5.3a with default input	3.007019248	High field difference
HEPDipo_4COILS	Only 6.0			2.642629678	High field difference
FERMI_20T_5				90T	High field difference
MO_1AP					
MO					Fix mesh tolerance
MCDO					Fix mesh tolerance
MQT_1AP					
MQTLH_1AP					
MQTLI_1AP					
MQS_1AP					
MBRD_short					Fix iron as for MBRD
MCBH_1AP					data file naming error
MCD					Geom error debug parserRoxie
MCS					Ribbon cable not supported
MCBX_HV					Ribbon cable not supported
MCBXH					Ribbon cable not supported
MCBXV					Ribbon cable not supported
MCBYH_1AP					Ribbon cable not supported

Lessons learned and future of SIGMA

- Providing a simple interactive model in COMSOL
  - Many applied physicists already know how to use COMSOL
  - Edit geometry, mesh, QH and materials within COMSOL
- SIGMA use-cases:
  - Starting point with correct geometry of accelerator magnet in COMSOL:
    - Magnetostatic
    - Transient
  - Possibility to extend model within COMSOL limitations using GUI or API
- No SIGMA use-cases:
  - Heat propagation between layers manual operation in COMSOL GUI - Optimizing certain params not feasible
  - Large models (Ribbon) and computationally heavy simulations
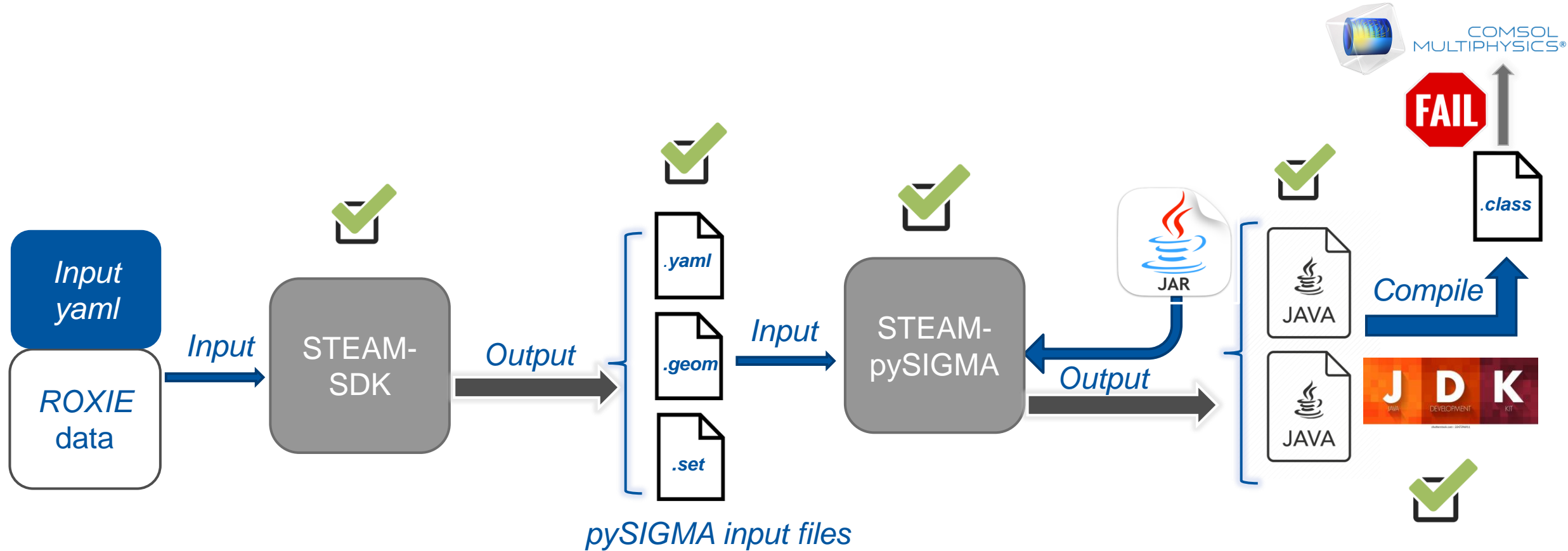- Workflow makes SIGMA development slow – No possibility of debugging from Python

Example

Thickness of QH insulation to the coil
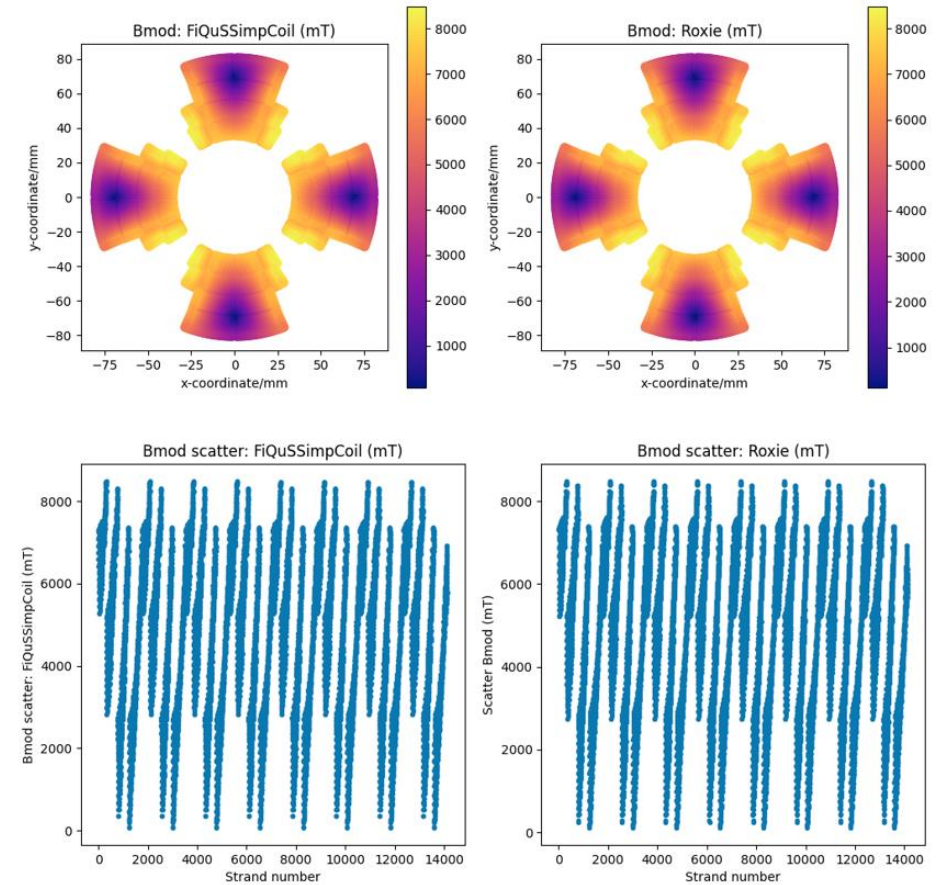
10 Minutes to find Input problem!

Additional Work

- SIGMA evaluation report:
  - Explaining errors in SIGMA compared to Roxie
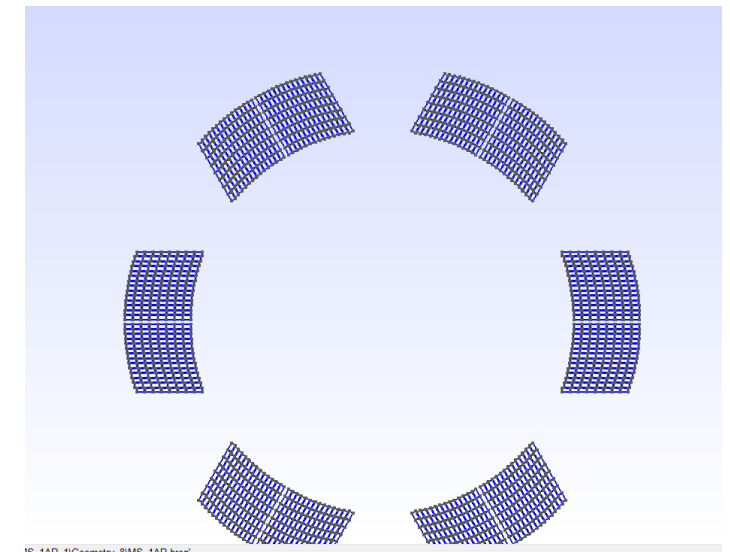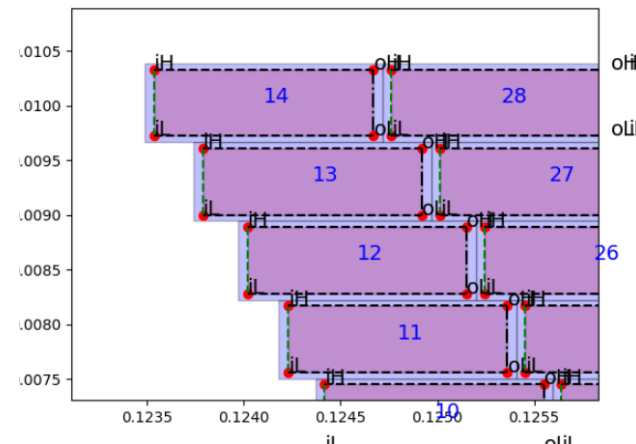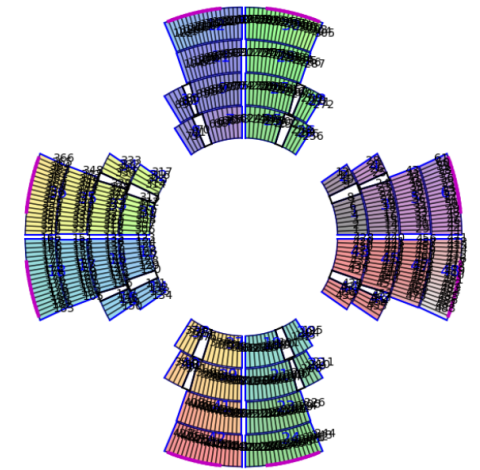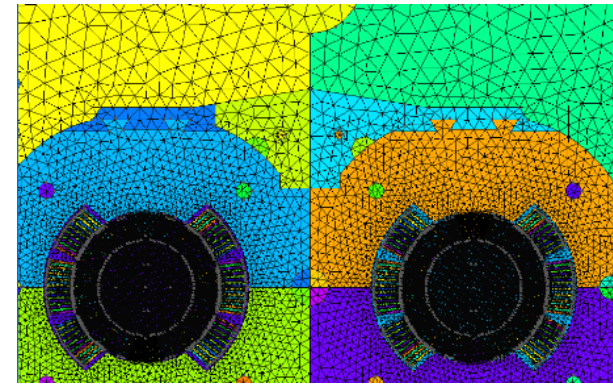- 2D plotter tools in steam_sdk
- FiQuS and SIGMA analysis files

Additional Work

- FiQuS development:
    - Increase robustness, meshing, visualization tools
    - Ribbon cable implementation for FiQuS

- Robustness in ParserRoxie e.g support asymmetric coils (FiQuS and SIGMA)

Thank you for your attention!

Special thanks: Andrea Vitrano and Mariusz Wozniak

&

Entire steam-team for a great year at CERN!

Links to SIGMA related repositories

- pySIGMA: https://gitlab.cern.ch/steam/steam_pysigma
- SIGMA: https://gitlab.cern.ch/steam/steam-sigma
- STEAM-SDK: https://gitlab.cern.ch/steam/steam_sdk

Questions?