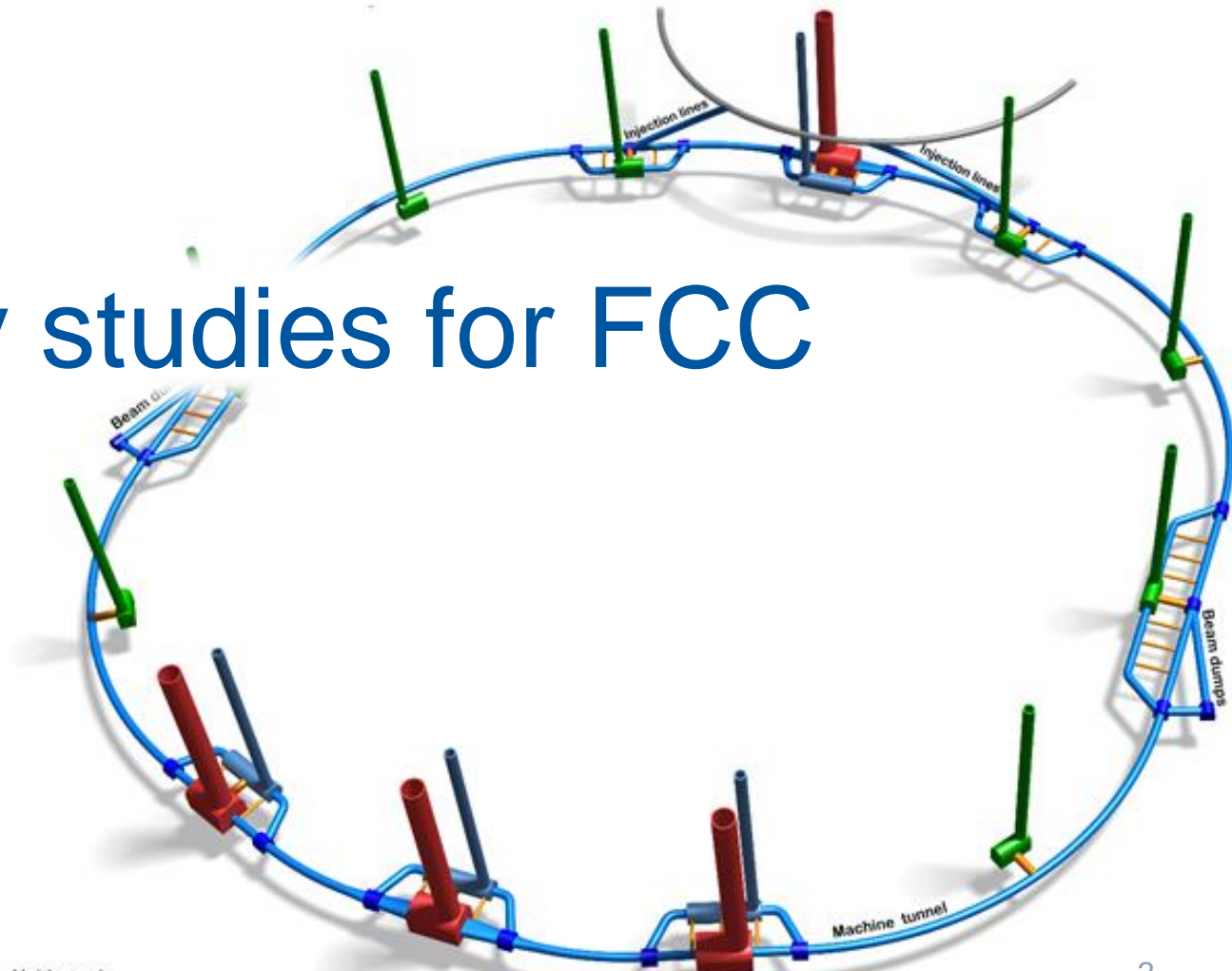




Availability studies for FCC

Arto Niemi



Not to scale
Frequency of connection tunnels for illustration only

(FCC 3D Schematic J. Osborne, C. Cook, A. Navascues)

Contents

- Scope of the study & resources
- Collider operations more than availability and reliability
 - Accelerator schedules
 - Operational cycle
 - Production function
- Modelling
 - State based chain model
 - Phase dependent fault trees
 - System fault trees
- Planned work
 - Injection phase model
 - FCC challenges and availability goals
 - Database environment concept

Scope of the Study

- ❑ Evaluate the suitability of **industrial reliability methods** for the domain of particle accelerators...
- ❑ ...taking the **LHC as a case study**
- ❑ Identify and analyse possible **design and operational scenarios** for a h-h Future Circular Collider
- ❑ Identify **key impact factors** on availability and luminosity production
- ❑ This reliability & availability study DOES NOT intend to give specific guidelines for individual system design and optimization

Collaboration Contributions



CERN

Coordination, modelling
simulation, analytics,
data management,
use-case definition,
technical infrastructure



Ramentor Oy

Modelling and simulation
Software, training



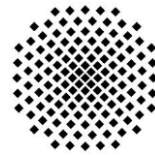
Tech. Uni. Delft

Analytics, cryogenics
system modelling



Tampere U. of Tech.

Method and tool
consultancy



Uni. Stuttgart:

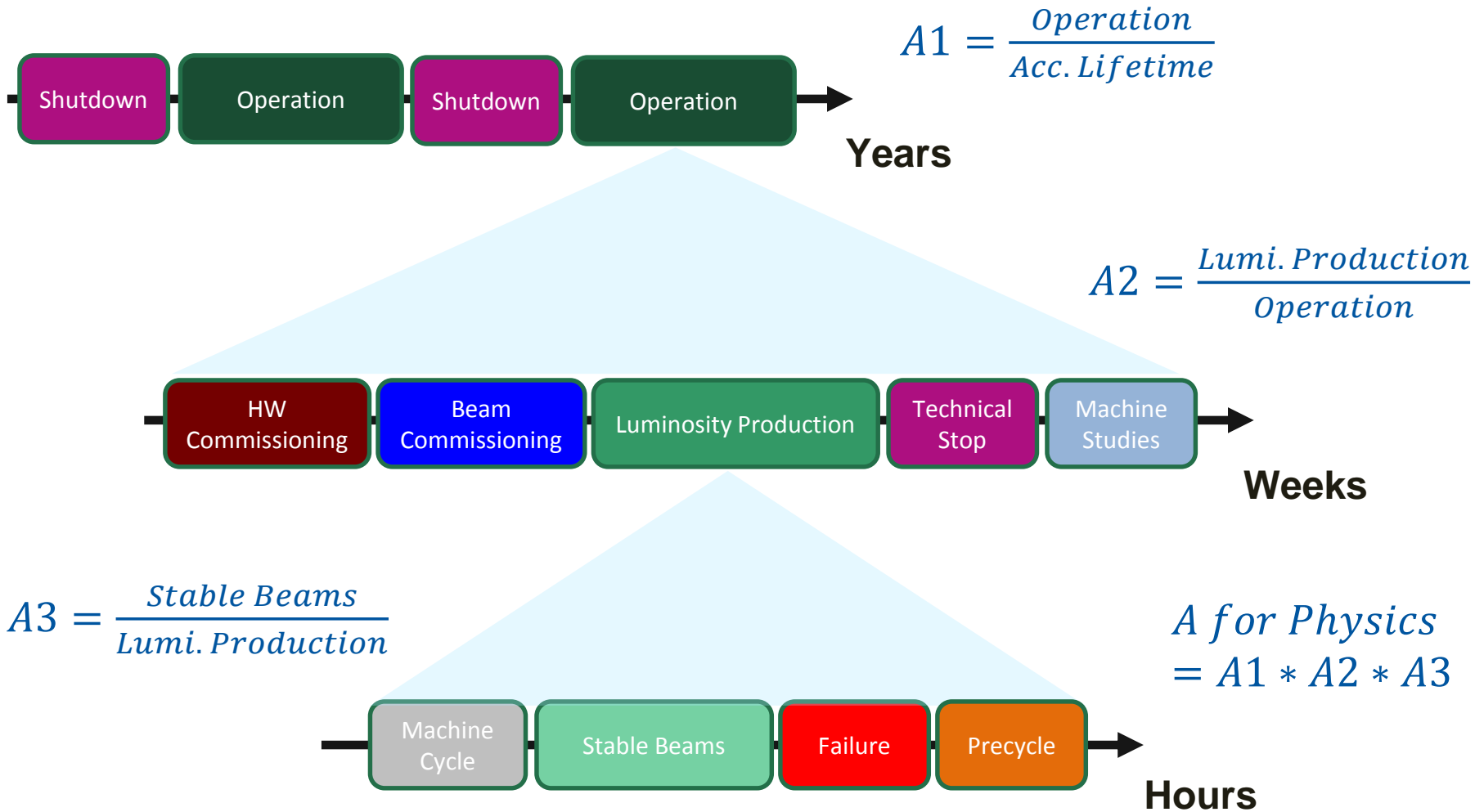
Method and tool
consultancy, training



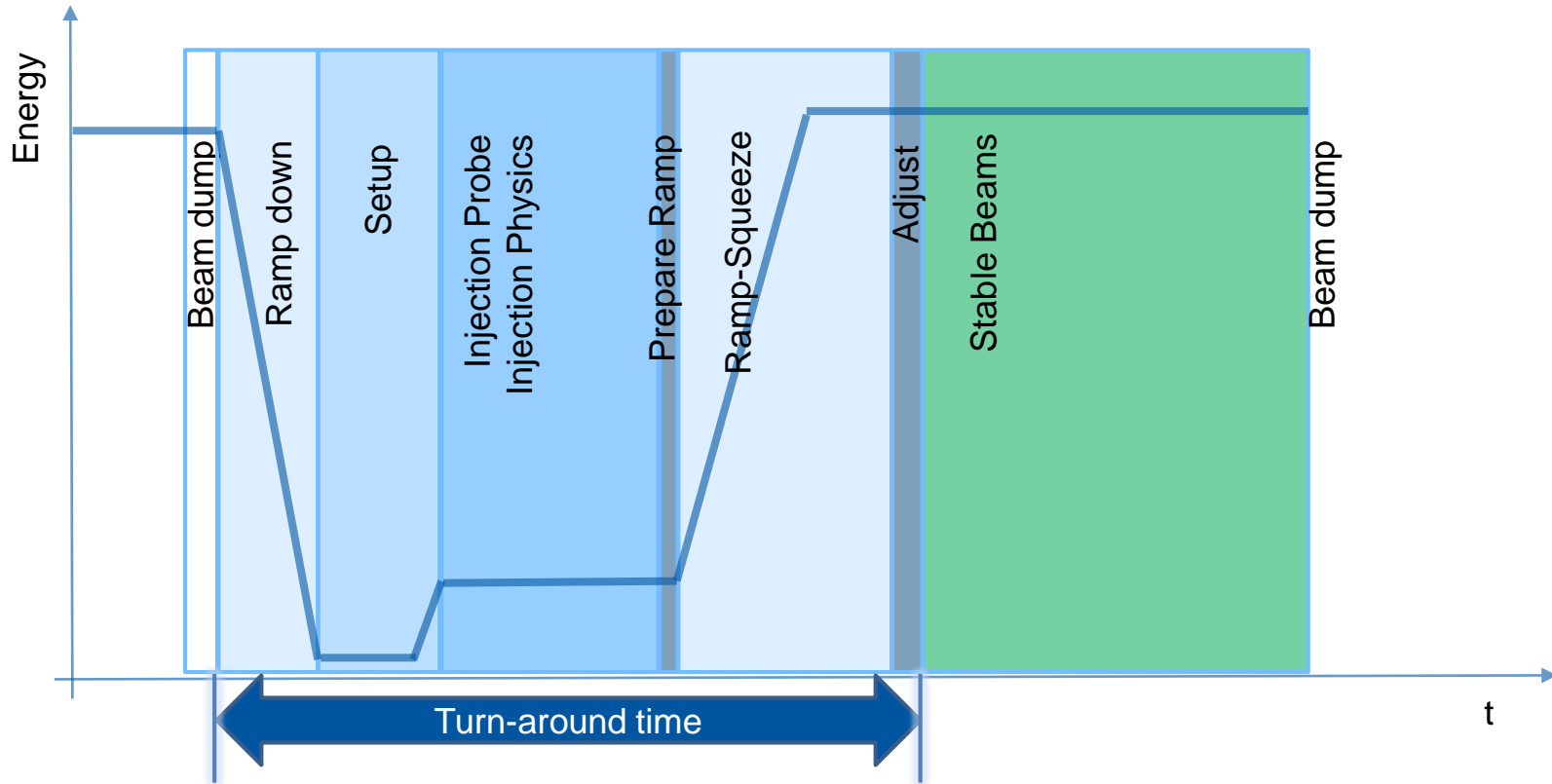
Uni. Wien

Data analytics platform
development

Accelerator Schedule

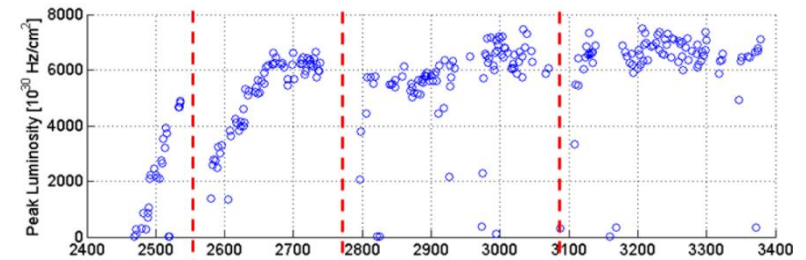
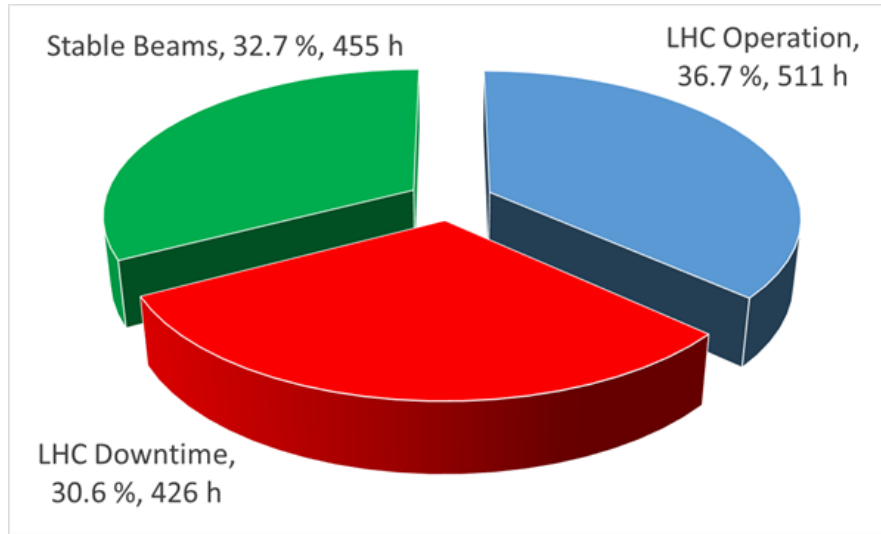


Operational cycle

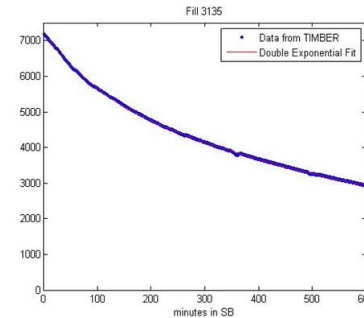


Reyes Alemany et. Al FCC week 2016

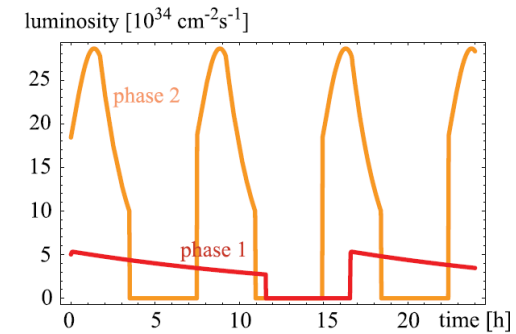
Production Function



2012 Peak luminosities



LHC Beam



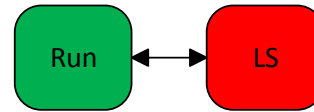
FCC Beams

Usually stable beams time is measured, but the production rate is not constant

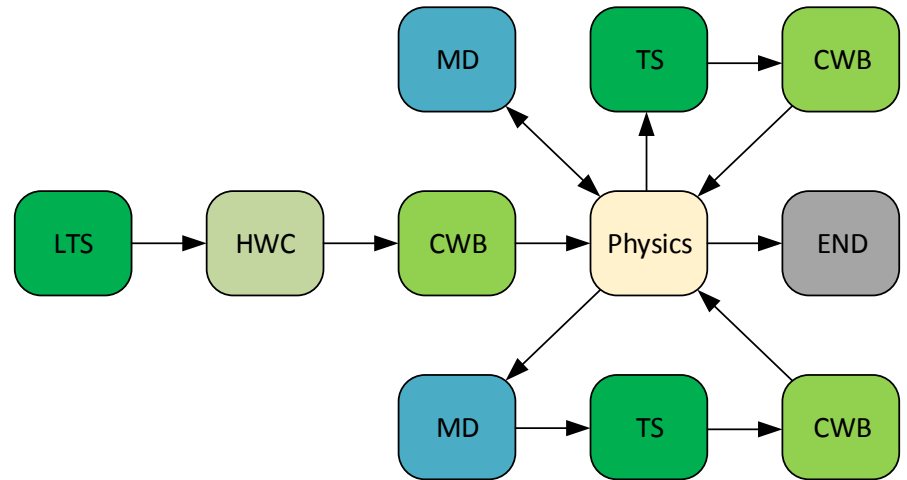
State based chain model

- Three level model
 1. Multi year schedules
 2. Operational modes within a year
 3. Cycles and cycle phases
- Each level acts as an inner process of the level above

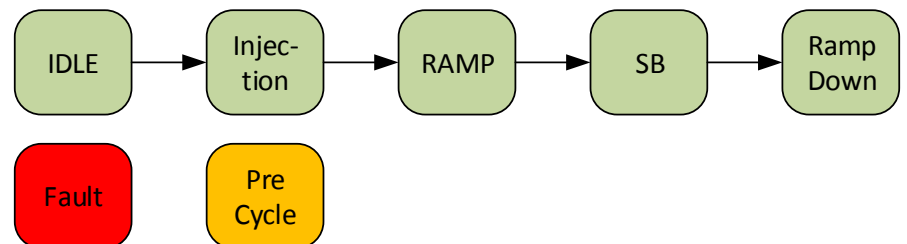
LEVEL 1



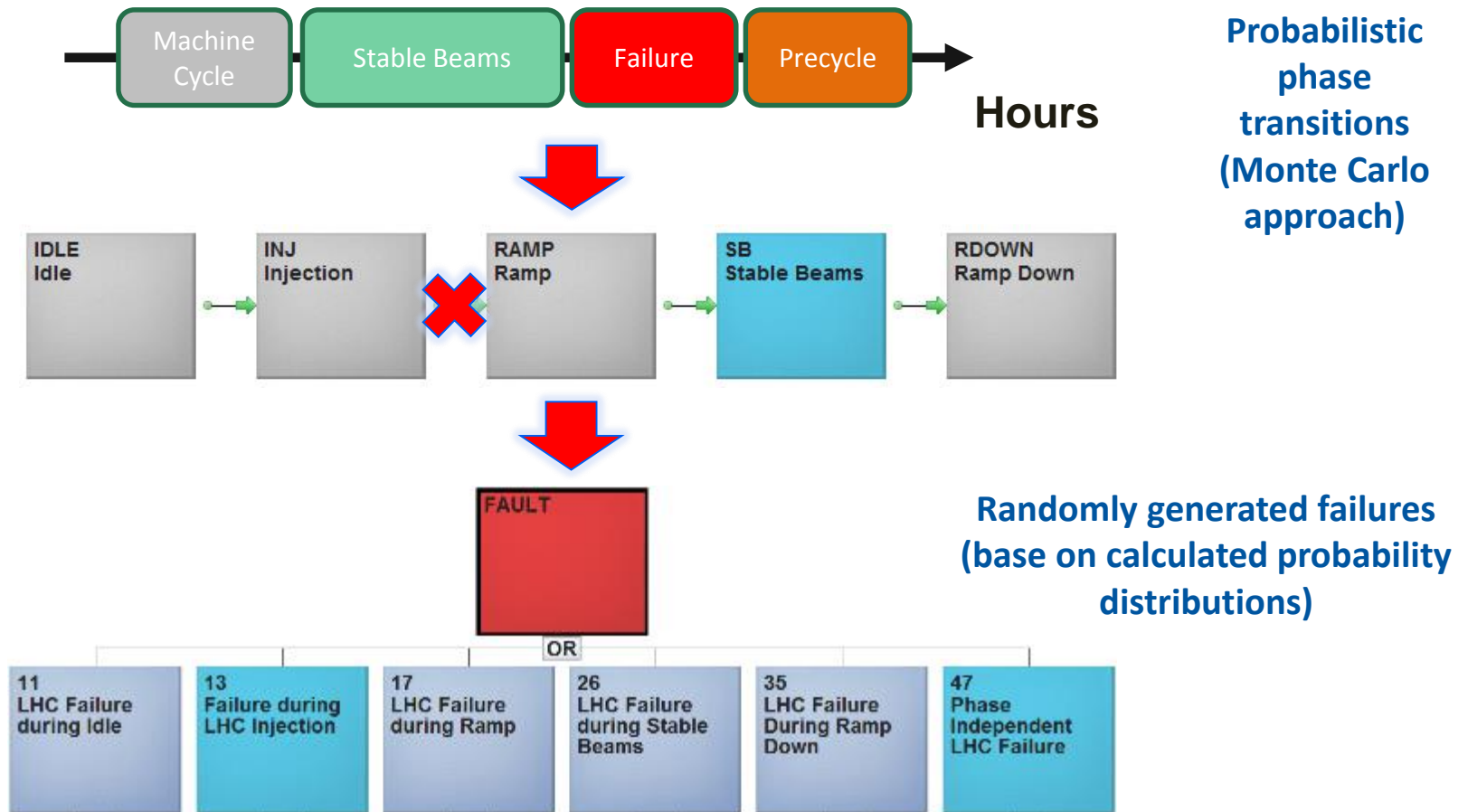
LEVEL 2



LEVEL 3

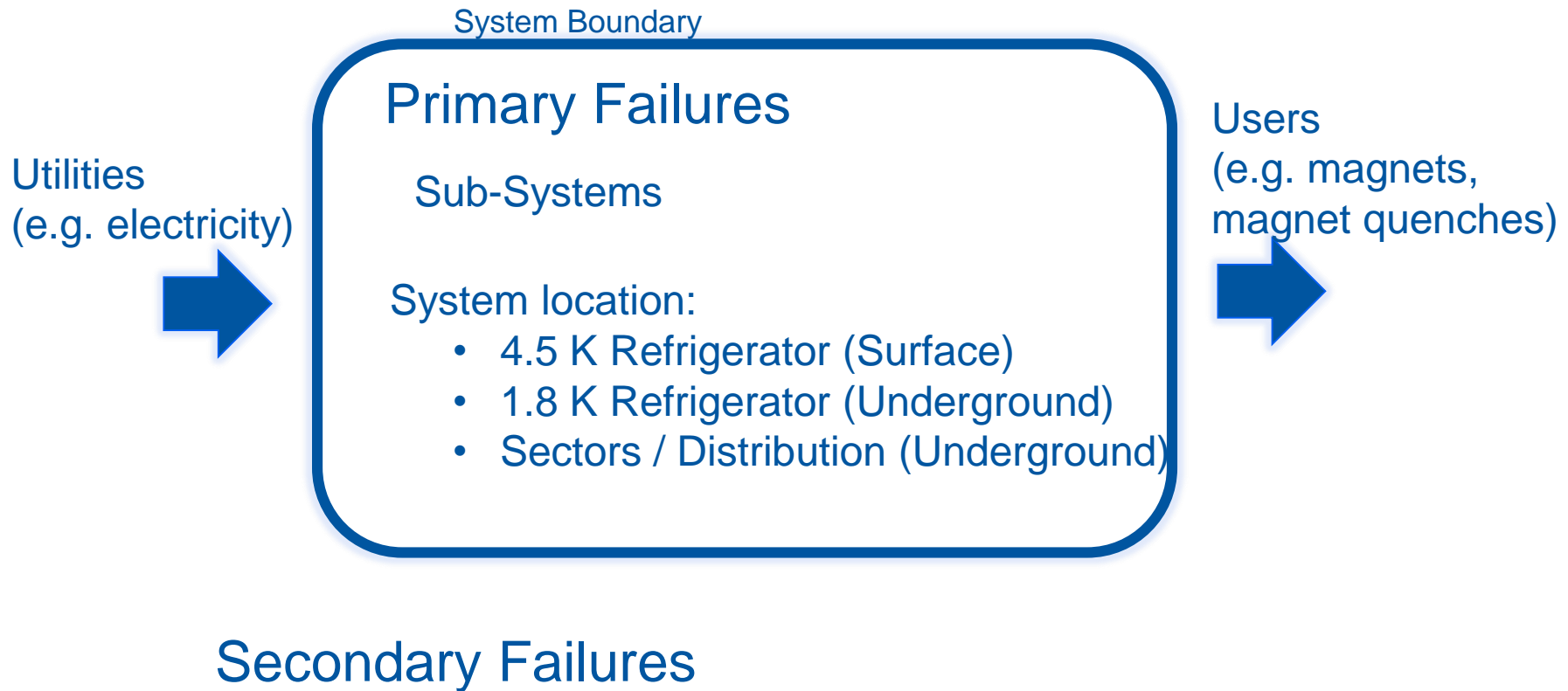


Model Implementation

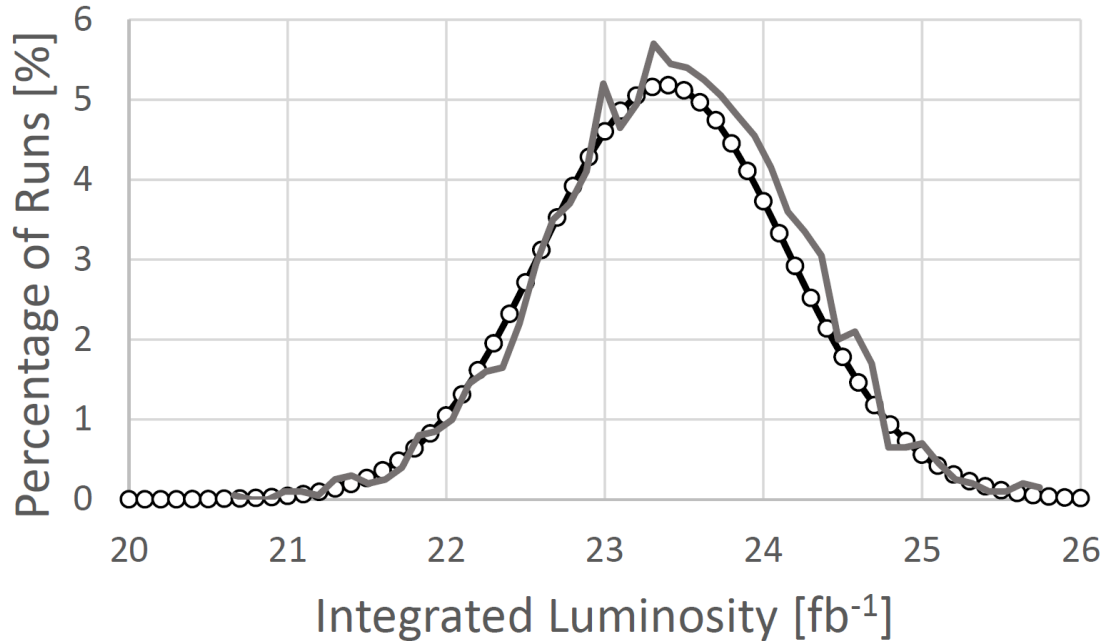


- Example: Failures in Injectors only relevant at Injection from the LHC perspective

Cryogenics Fault Tree Principle



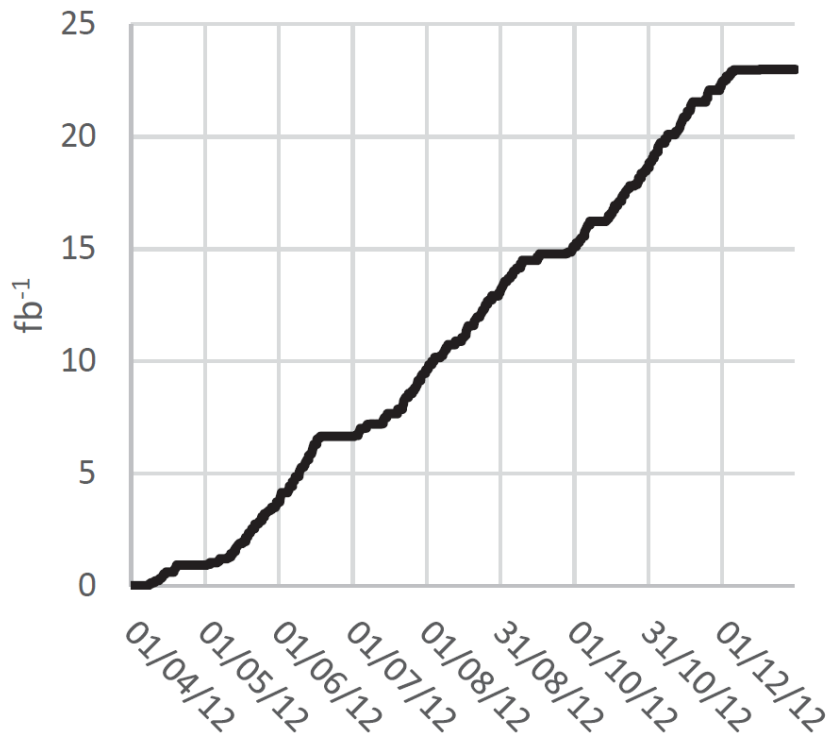
Results 1



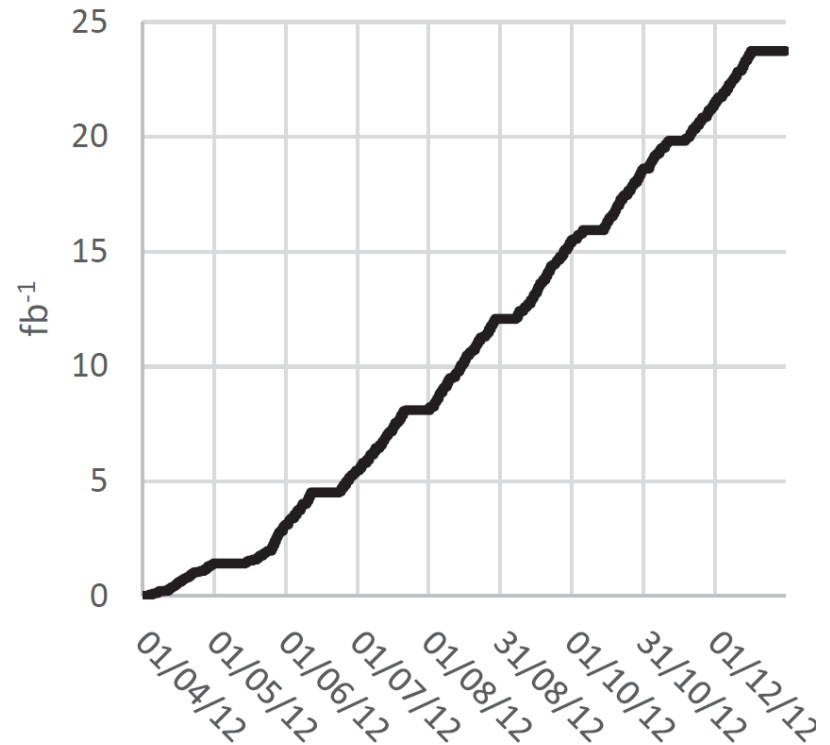
- Monte-Carlo method → result distribution
- Validation with 2012 fault data gave mean value near the actual production
- Actual 23.27 fb^{-1} simulation mean $23.38 \pm 0.05 \text{ fb}^{-1}$

Results 2

2012 luminosity production



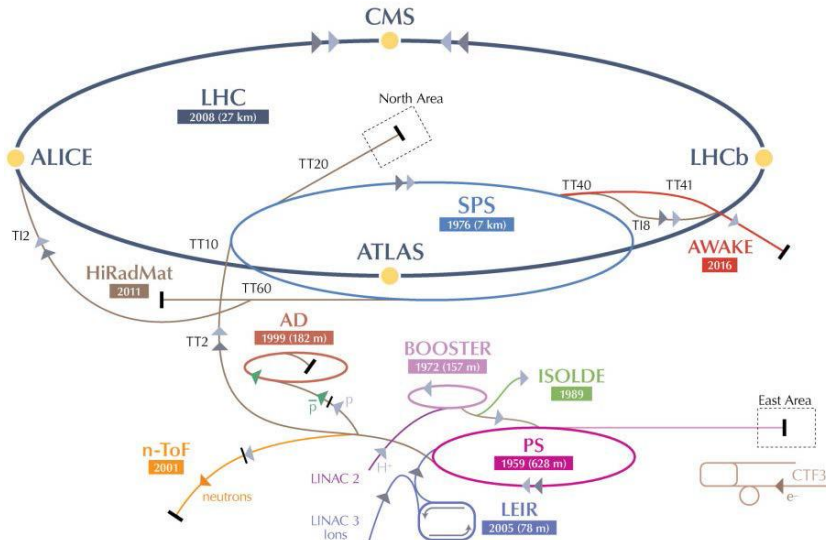
Production in simulation



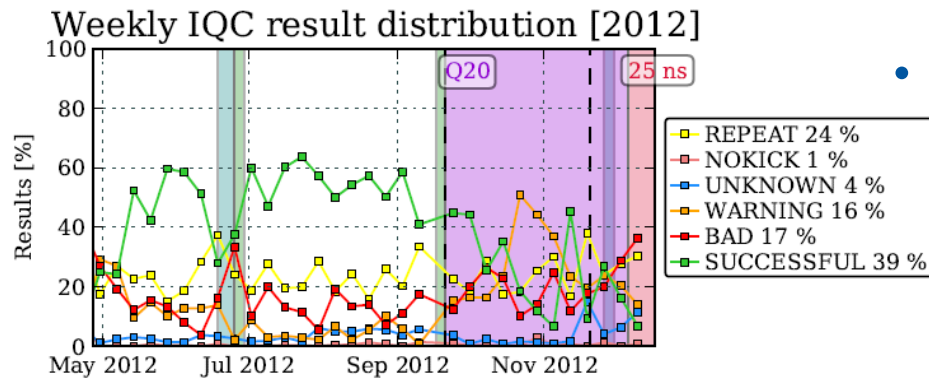
- Intensity ramp up affects the production rate at start of the year
- In simulation technical stops are now in constant intervals

Planned work, ideas and concepts

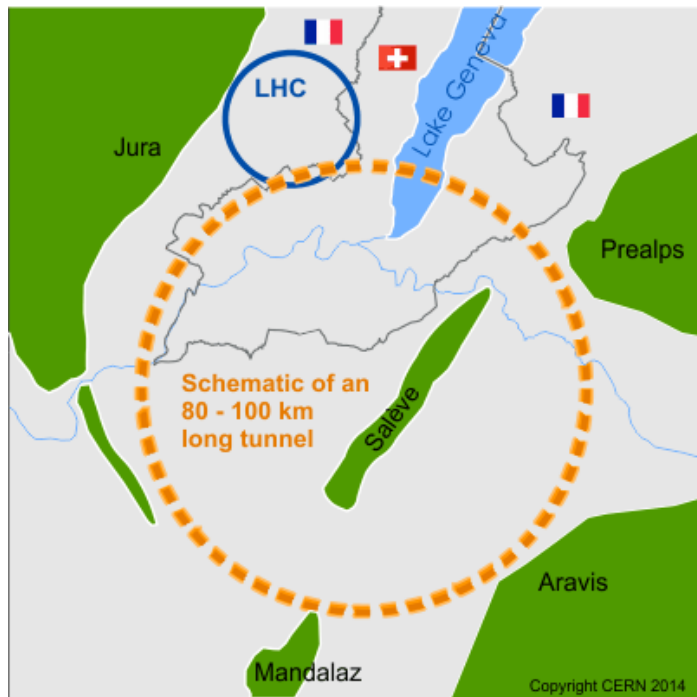
Injection phase process



- Injection length is not just hardware availability
- Length of process phases
 - Pilot bunches
 - Injection of physics beams
- Filling scheme
- Injection success probability

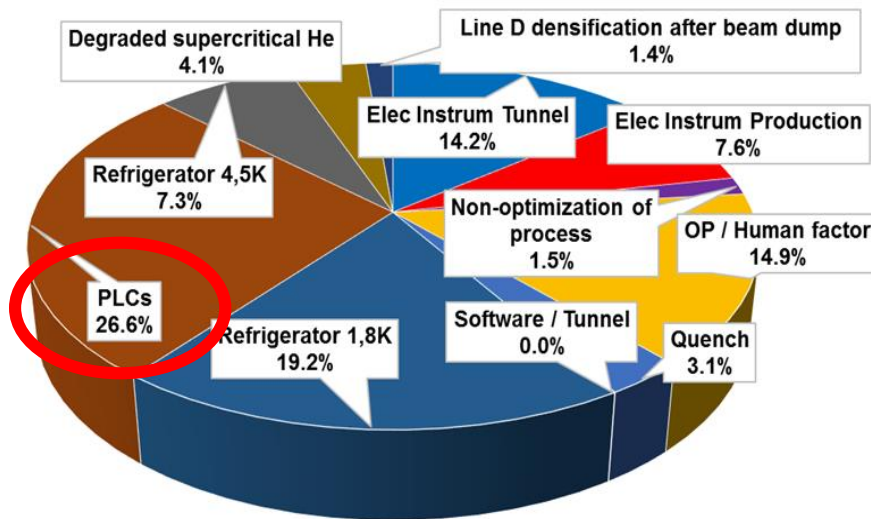


FCC-hh challenges & availability goals



- Four times larger ring with 100 TeV energy
- Injection into LHC, three options
 - LHC 5x
 - SC-SPS
 - Injector @ FCC tunnel
- Optimal SB length ~4 hours with ultimate parameters
- Much injections (4 LHC cycles + ~258 injections LHC → FCC)
- Challenge from availability goals for:
 - **FCC** = Scaling up the LHC
 - **LHC 5x** = Modifying the LHC
 - **SC-SPS** = Scaling down the LHC

Cryo PLC Example



No cryomaintain = 273 h 29 min

*Does not include cryo-start

- The goals should be based on what **can be** achieved...
- 2015 cryo PLCs caused **79 h*** of downtime, 4 failures
- Focused study:
 - 1 failure due to power supply, at point 4 (the only one without redundancy!)
 - Extra times in all failures (CPU upgrades, program bugs in restarting, long accesses)
- Without these total downtime would be ~ **18 h**

Additional interests

- Ability to measure value to cost ratio
 - Produced luminosity versus operational costs
- Long term time dependencies
 - Effect of the technical stops, commissioning
 - Learning and how experiences affects production efficiency
 - Aging

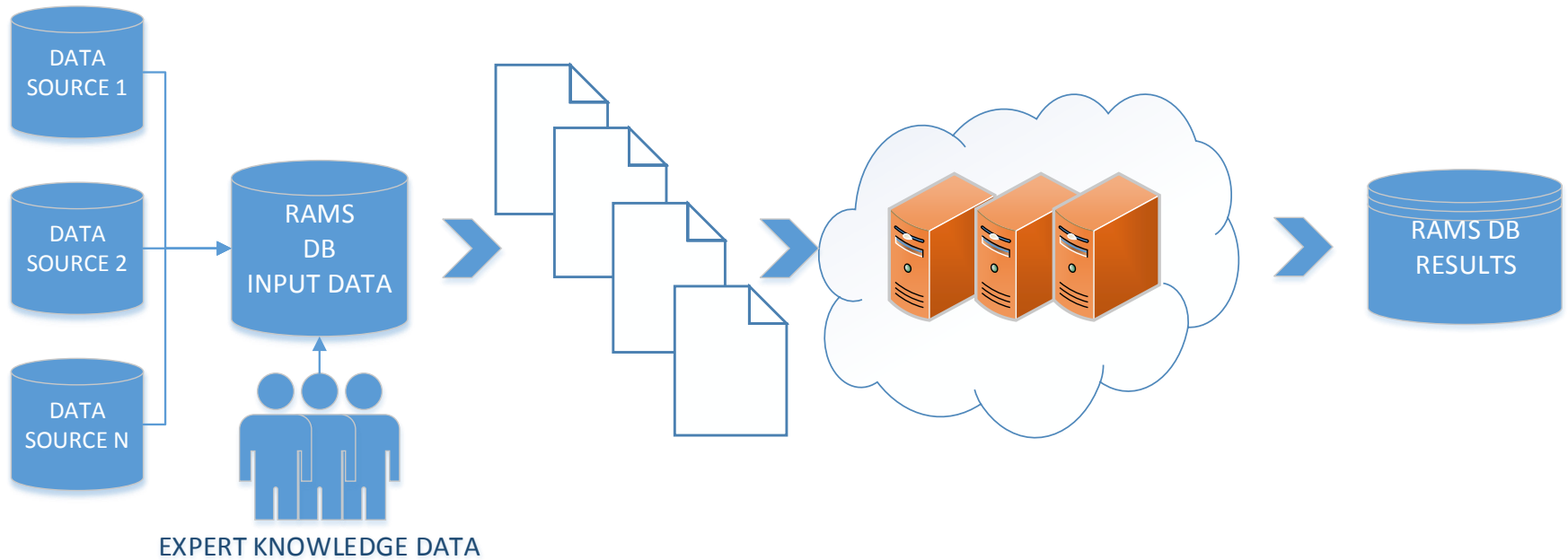
Concept on database model

Reliability data

Data into the model

Cloud computation

Storing the results





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