Reliability and life-cycle of accelerators

Samuel Meyroneinc – Institut Curie – Centre de Protonthérapie

ECPM – PSI – 9th May 2012

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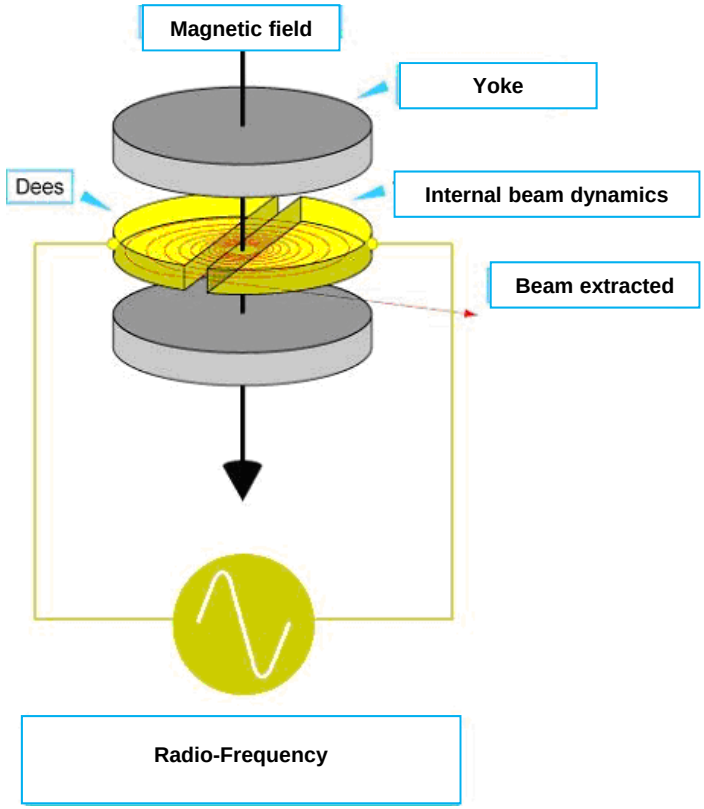
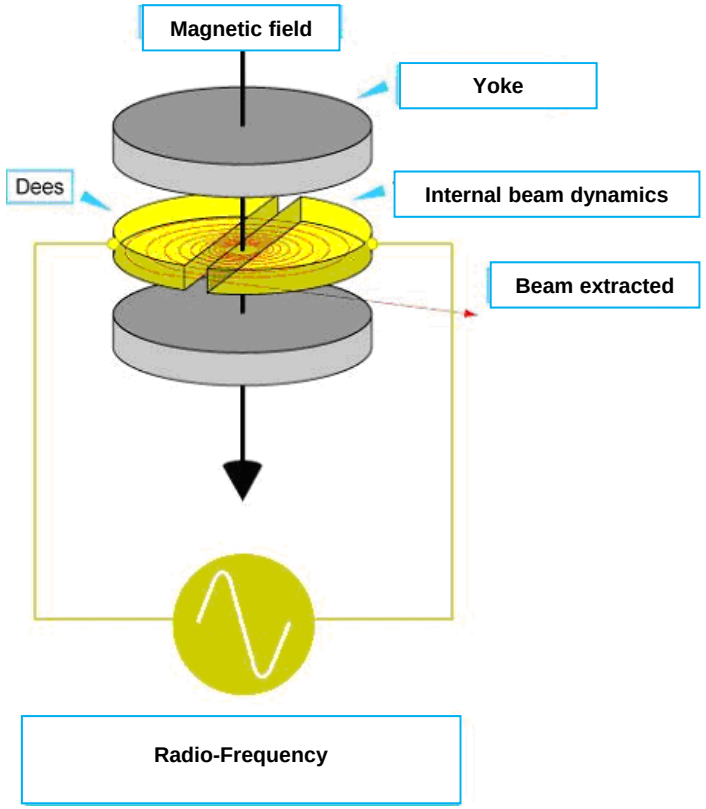
Cyclotrons as …

… systems



Cyclotrons as …

… systems



…stories

- **This talk is about reliability & life-cycle of accelerators**

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Centre de Protonthérapie d'Orsay

1991-2010: 5000 patient treatments
From 2010: treatments with upgrade facility

Gantry room

CYCLOTRONS

Synchrocyclotron 200MeV
1978-2010

C230 (IBA) 230MeV
2009- …

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CYCLOTRONS

Synchrocyclotron 200MeV
1978-2010

C230 (IBA) 230MeV
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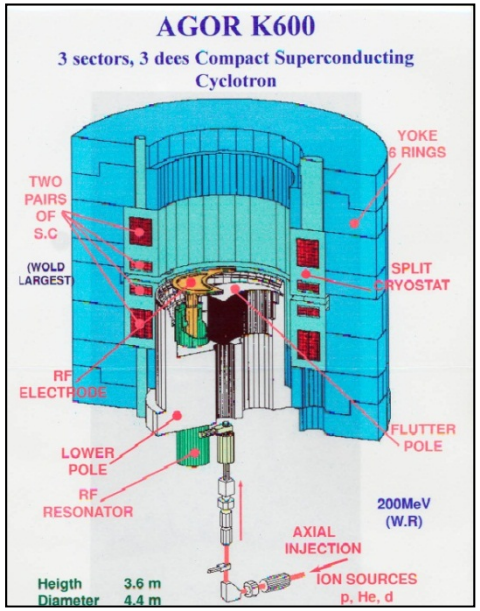
Cyclotron 200MeV
1996- …



Cyclotron for Radiopharmacy (2012)
Production of:
^{18}FDG, ^{11}C, ^{18}F

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Inspired from

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Centre de Protonthérapie d'Orsay

IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

ARW2011
Accelerator Reliability Workshop
10 - 15 April CAPE TOWN

summary

1. Reliability & Accelerators

2. Life-cycle of accelerator

3.Paradoxes about reliability

4. conclusion

Questions/discussions

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Definition of reliability

The reliability is the ability of a system or component to perform its **required functions** under stated conditions for a **specified period** of time

The reliability (R(t)) is the **probability** to have **no failure** at the time **t.**

MTBF: ***Mean Time Between Failures***
MTTR: Mean Time To Repair

The **availibility** of the system is the ratio of the time when the system is operational by the time it was supposed to be operational

Availibility = MTBF / (MTBF+ MTTR)

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Reliability and Particle Accelerators

- **Critical and/or sensitive Technologies**

  Radio-Frequency, vacuum, electronics, cryogenics, software, …

- **Power & Energy**

  Electricity, cooling

- **Risks**

  radiation-protection, costs, …

- **Complexity**

  mix of technologies, %research%production, regulations

- **Using &Users (Customers / Providers)**

  beams: current, energies, duration, …

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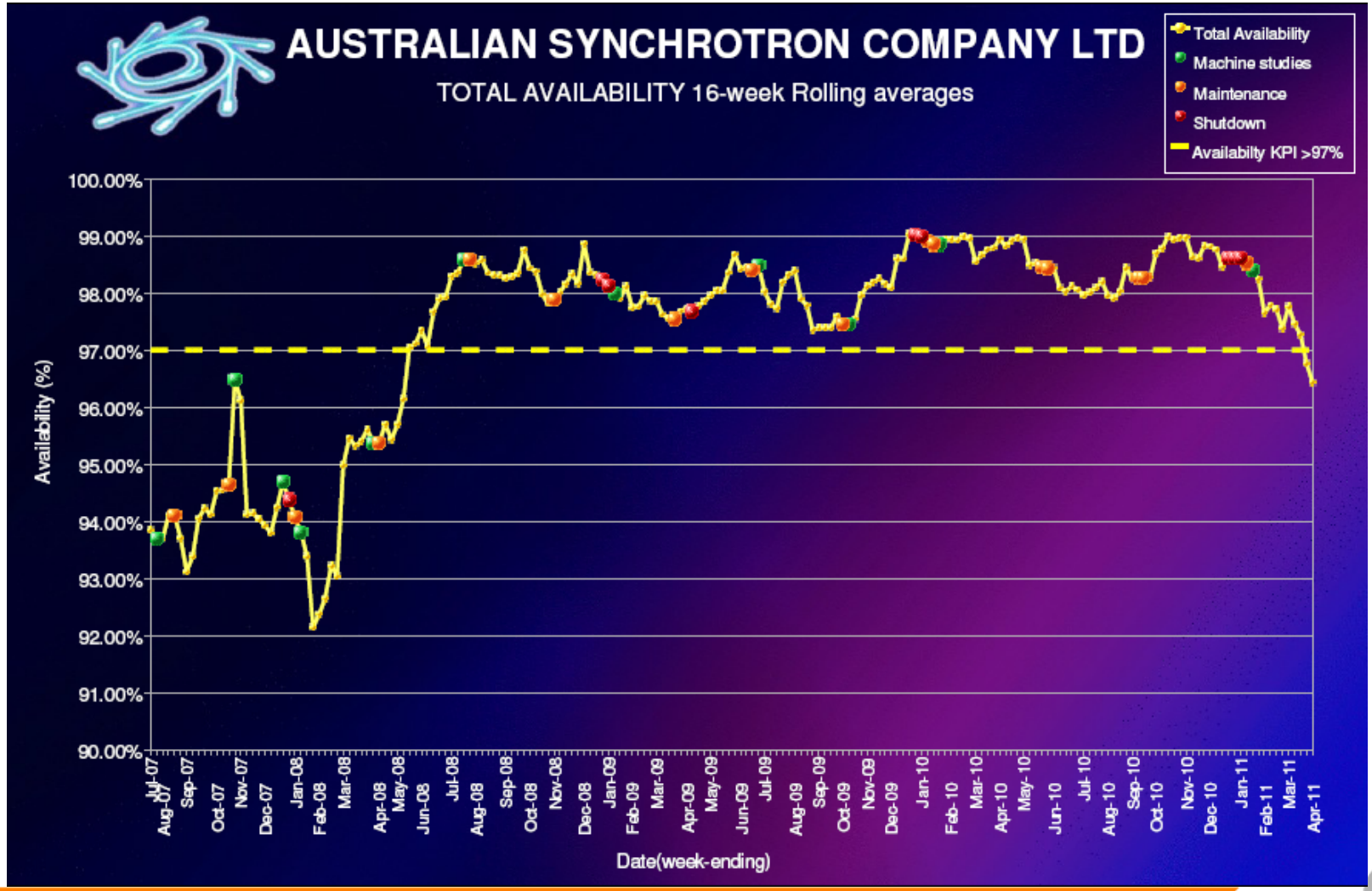
Reliability for synchrotron



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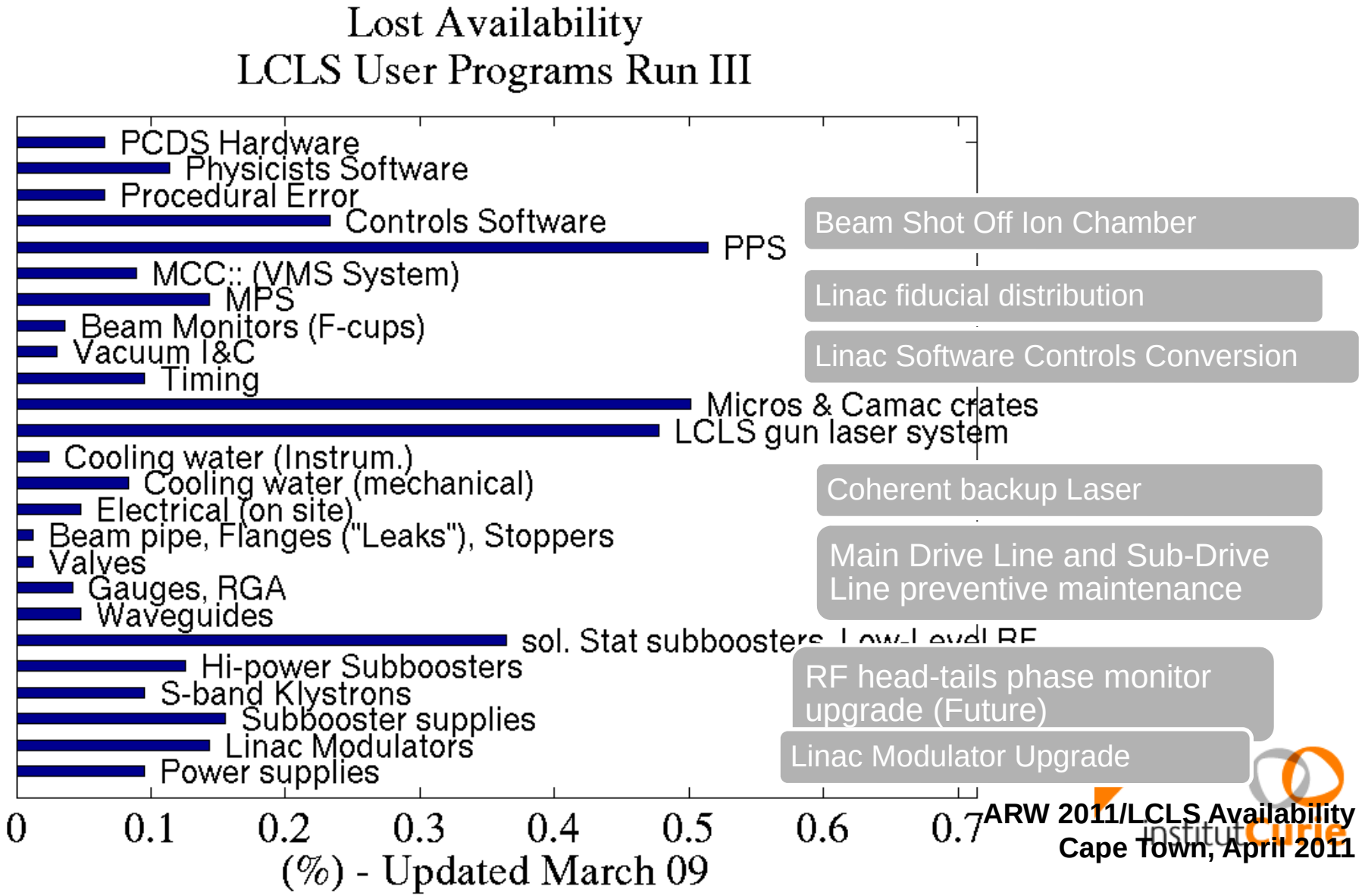
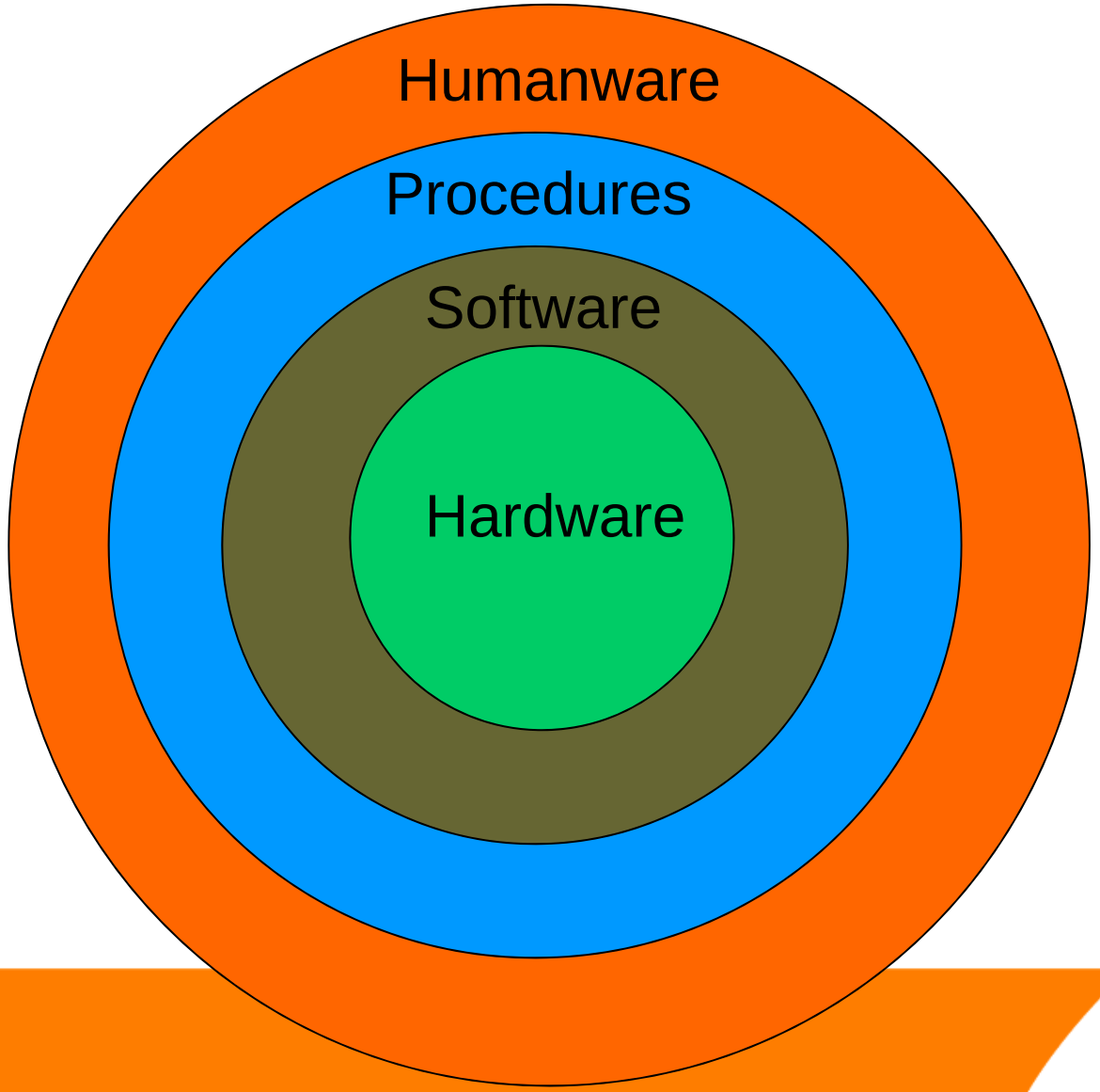
Downtime Statistics and future upgrades



the 4 layers of reliability



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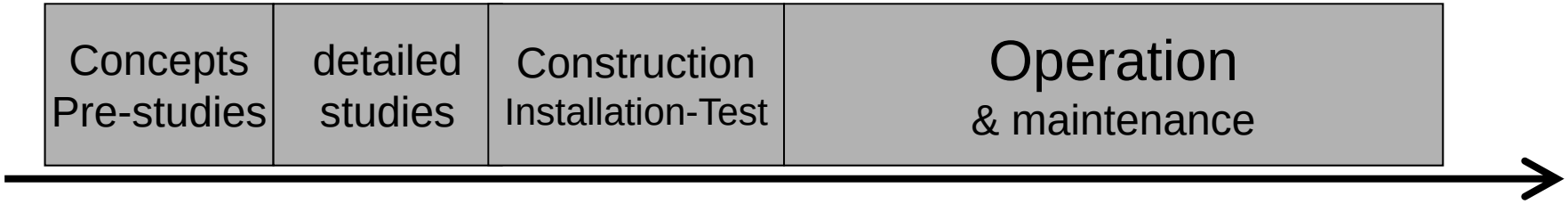
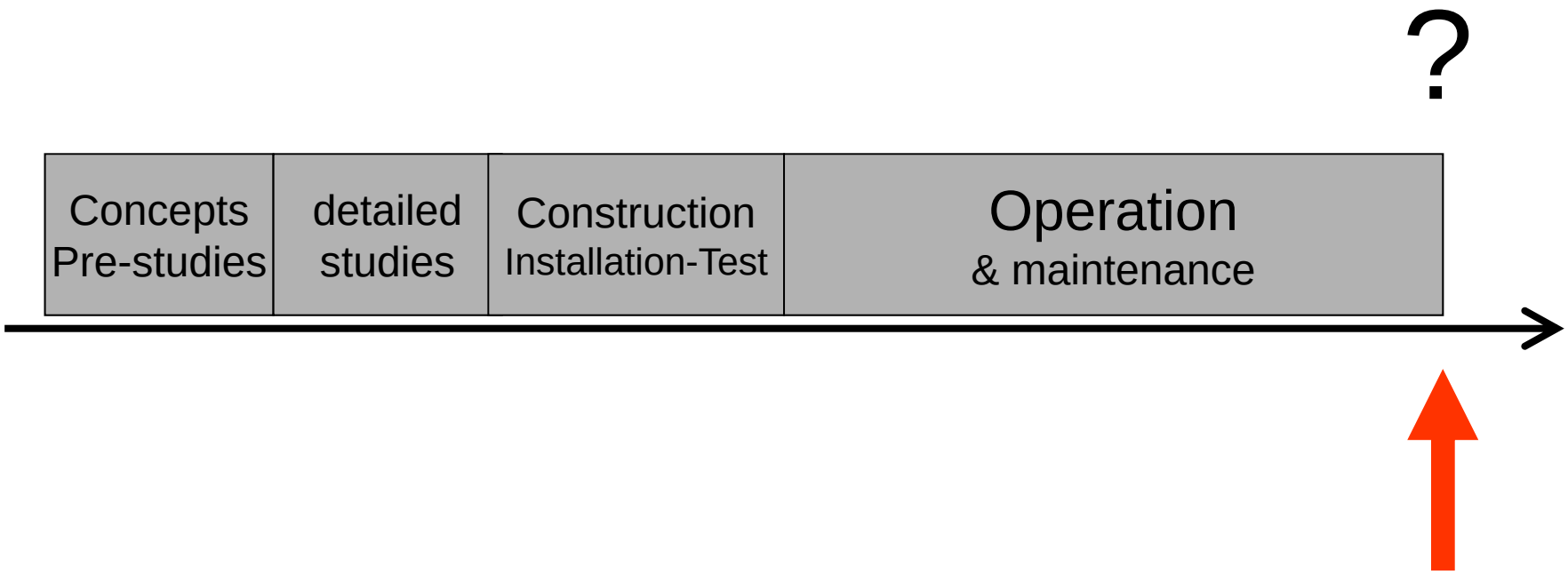
2. Life-cycle of accelerator

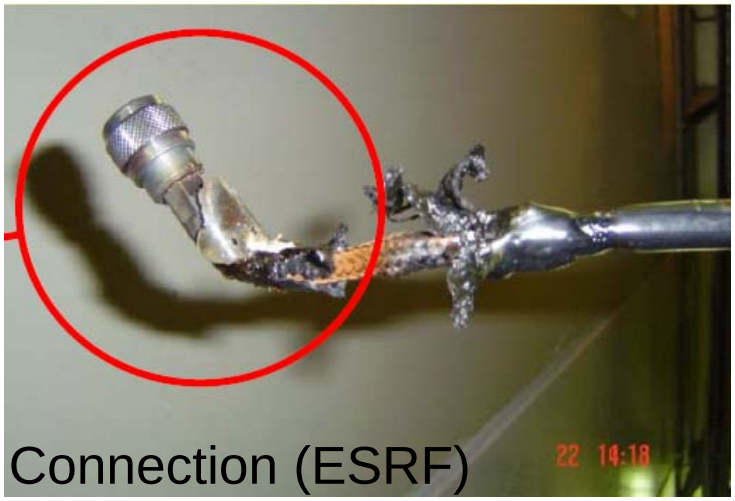
Life-cycle of an accelerator



Life-cycle of an accelerator

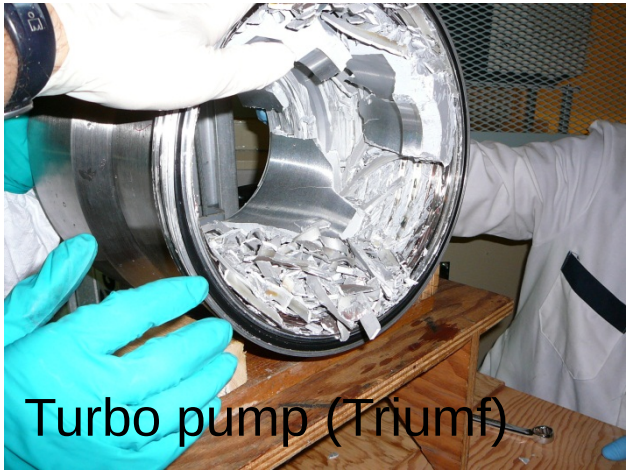


A failure – a small (or big) death



Connection (ESRF)


Main coil (SC200)


Turbo pump (Triumf)

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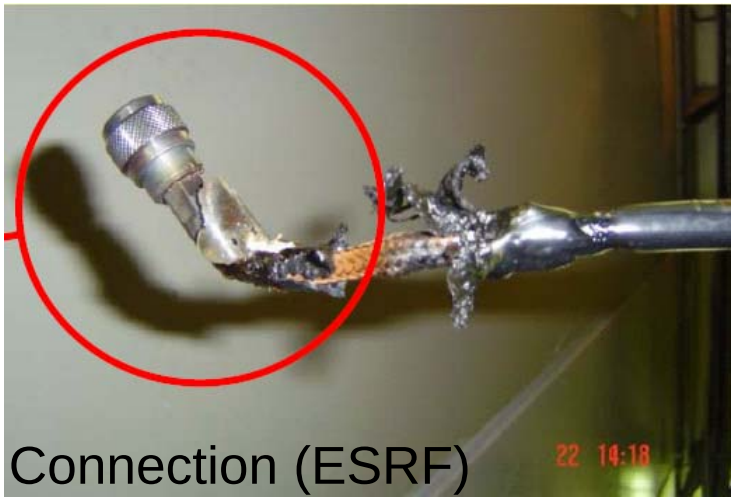

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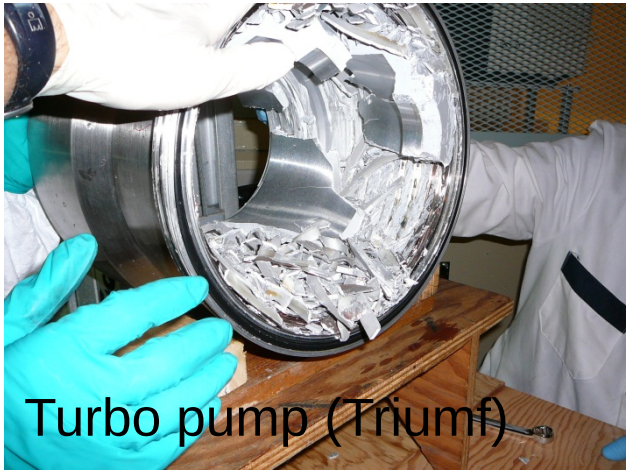
Turbo pump (Triumf)


Orphan system

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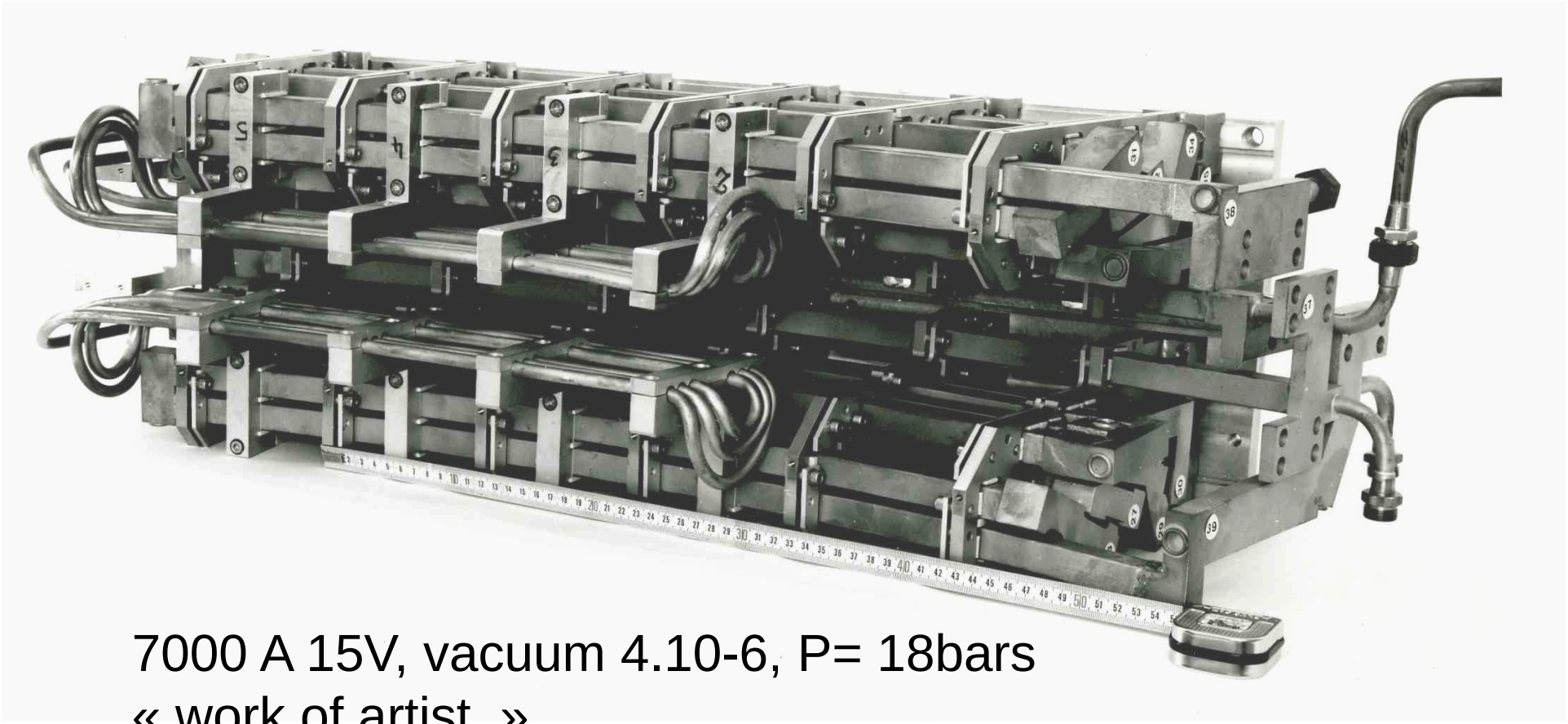
Electromagnetic channel (with septum) of synchro-cyclotron of Orsay



7000 A 15V, vacuum 4.10-6, P= 18bars
« work of artist »

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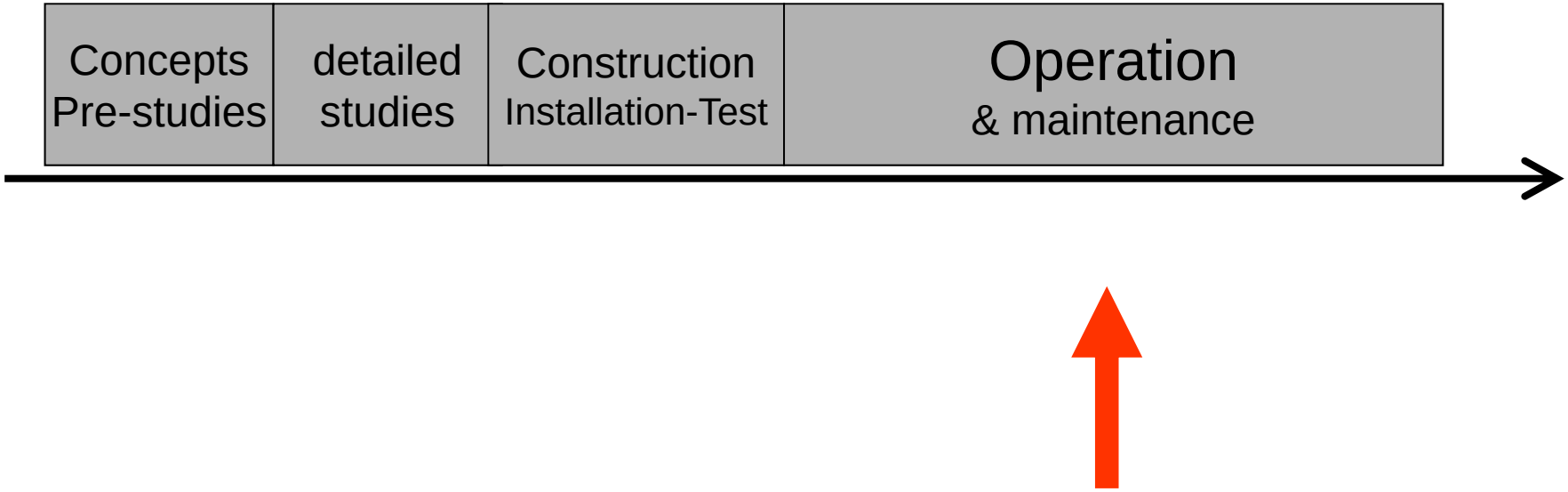
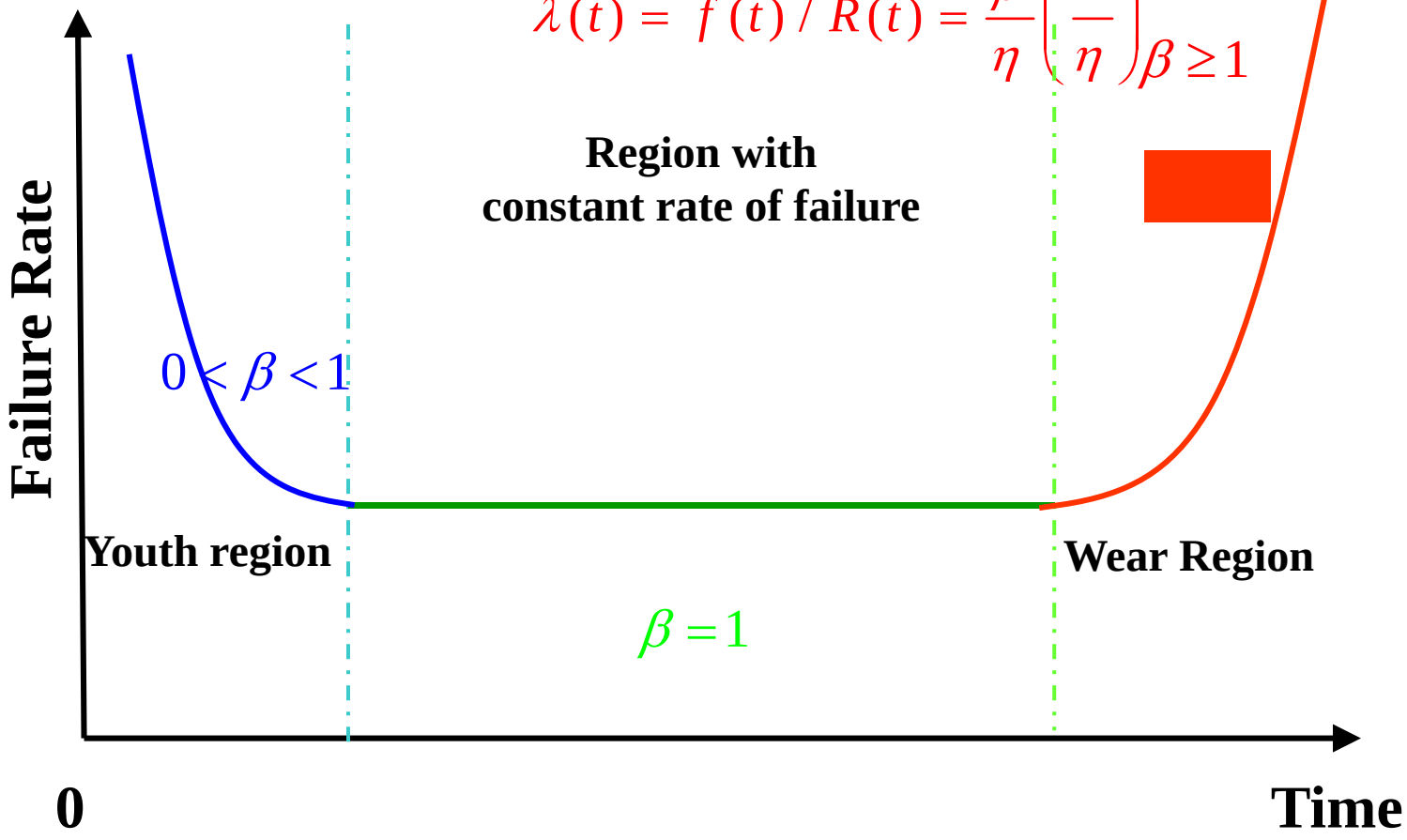
Life-cycle of an accelerator



Weibull Model

Failure rate

$$\lambda(t) = f(t) / R(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1} \quad \beta \geq 1$$



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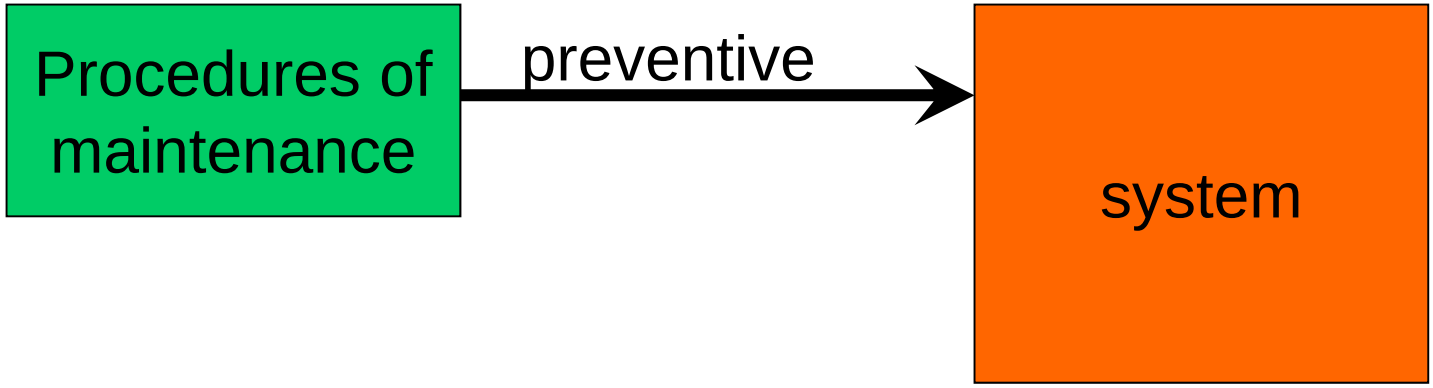
Maintenances

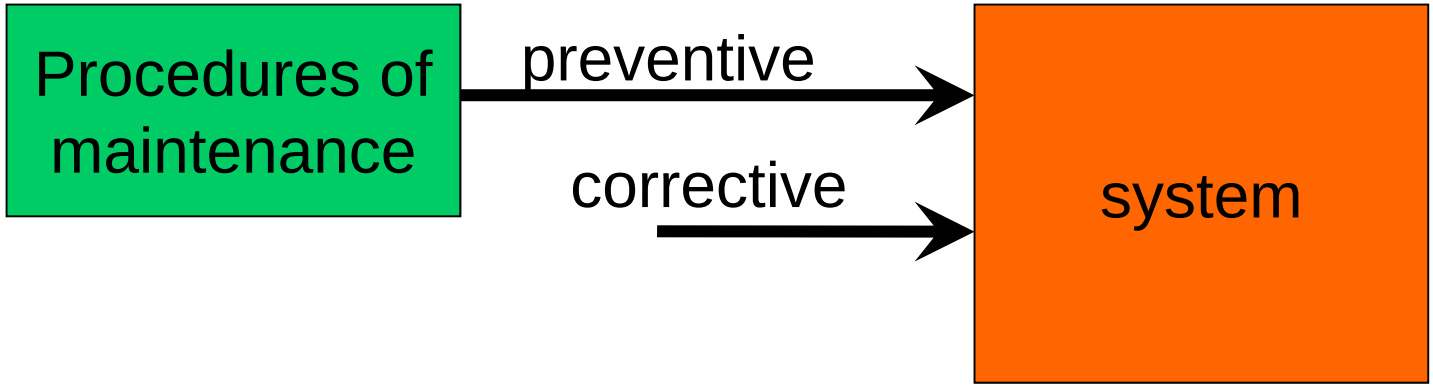
Modelisation, experience



Inspect, clean, check, lubrify, calibrate, read, replace, test ,…

Maintenances

Modelisation, experience



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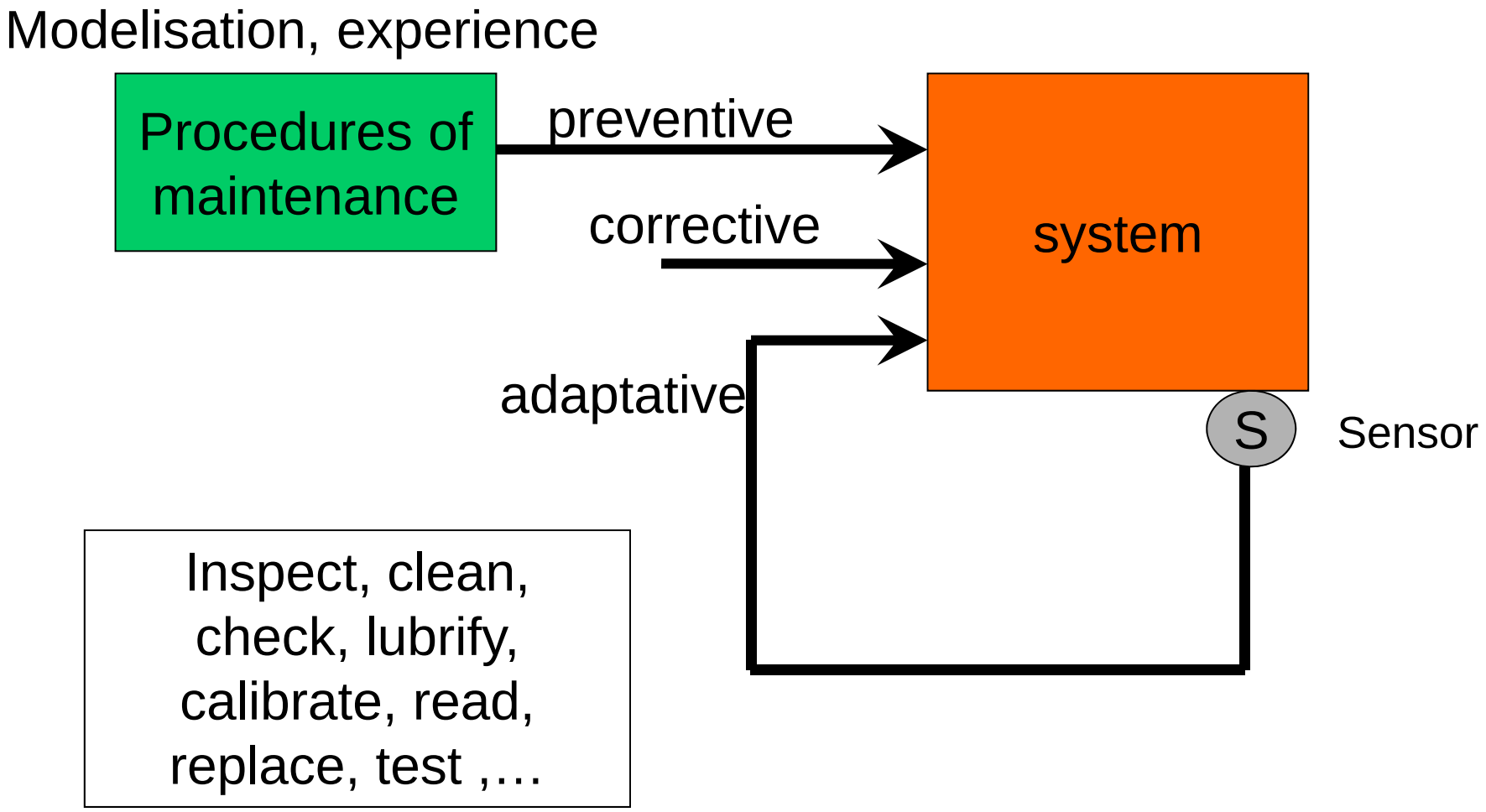
Maintenances



Thermography inspection C230 @ CPO

LIR

Cyclotron thermographie du 13 octobre 2011

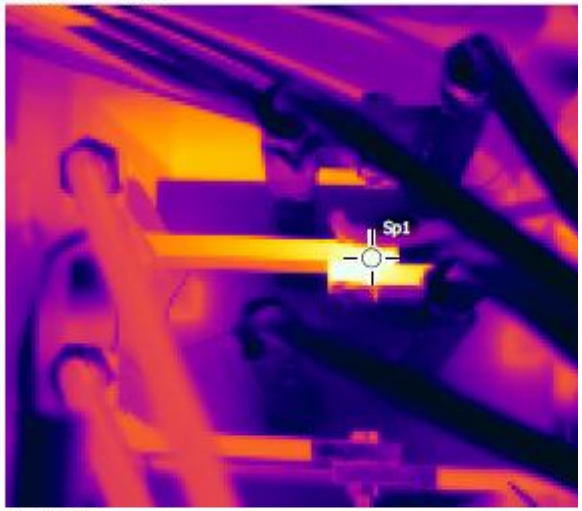
°C

70°C

	0.95
	20 °C

inter bobines 3 et 4
rieures. Point chaud
sp1 A surveiller

13/10/2011 06:32:34



IR_0069.jpg

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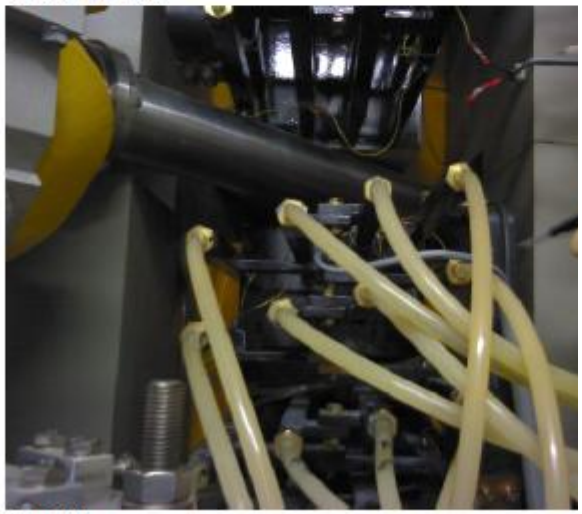


DC_0070.jpg

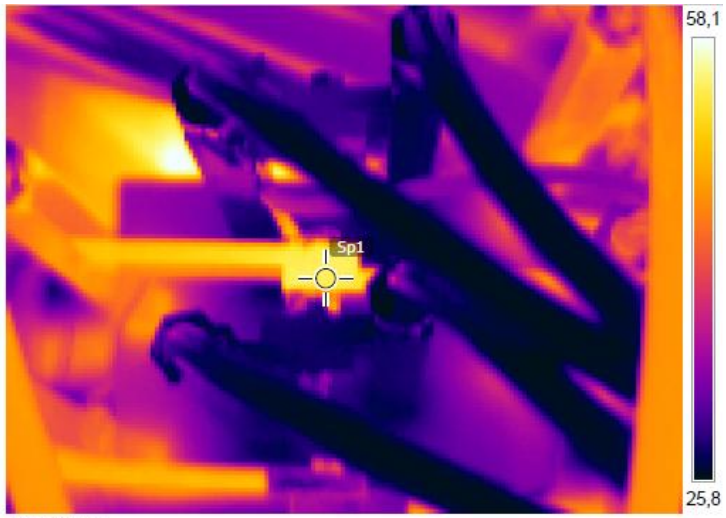
Sp1

54°C

Paramètres

Emissivité	0.95
Temp. réfl.	20 °C

Bobines inferieurs 3 et 4



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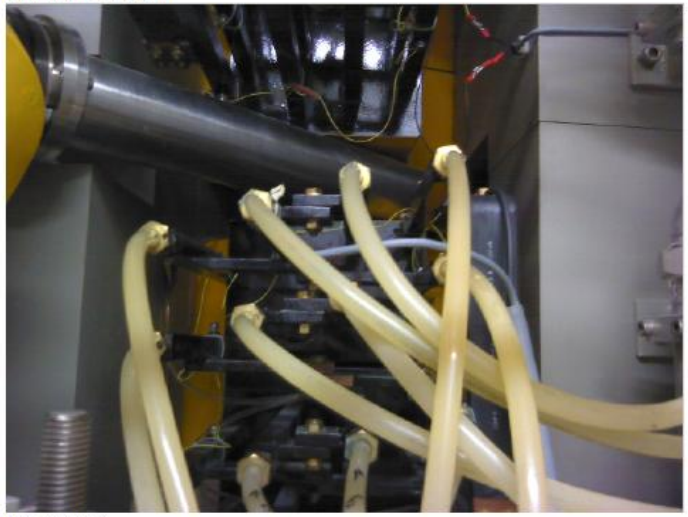
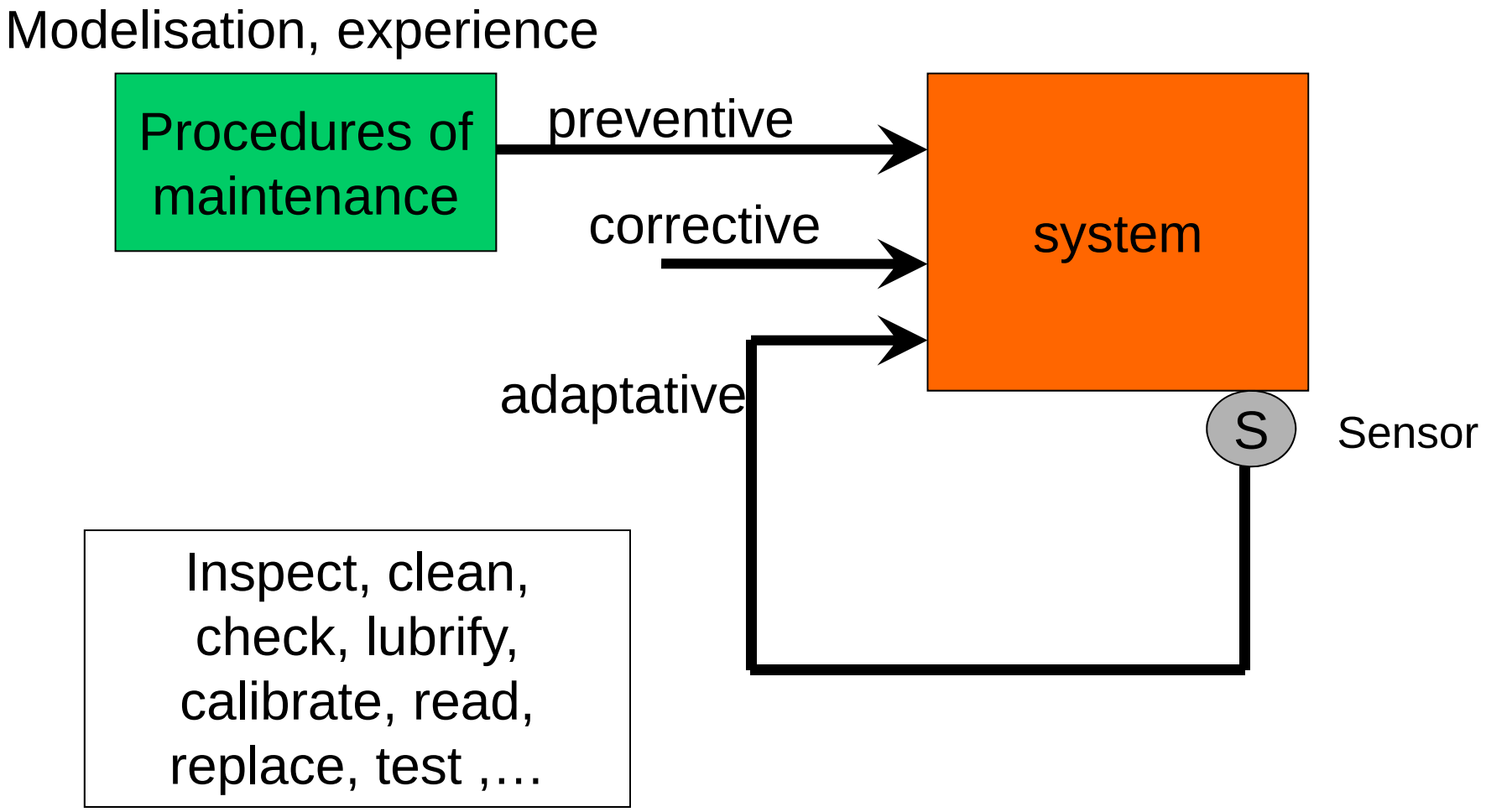


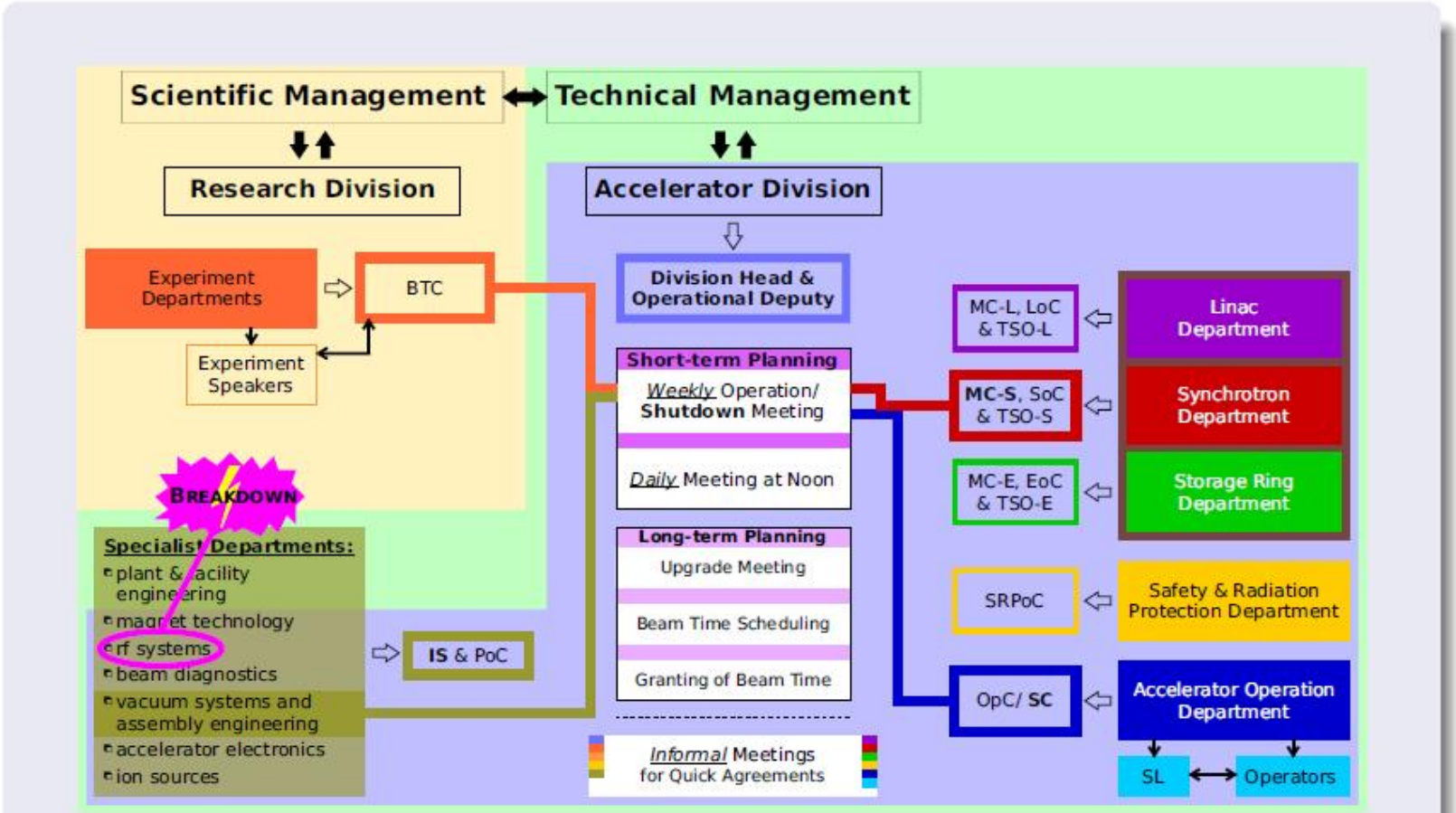
DC_0220.jpg

Maintenances

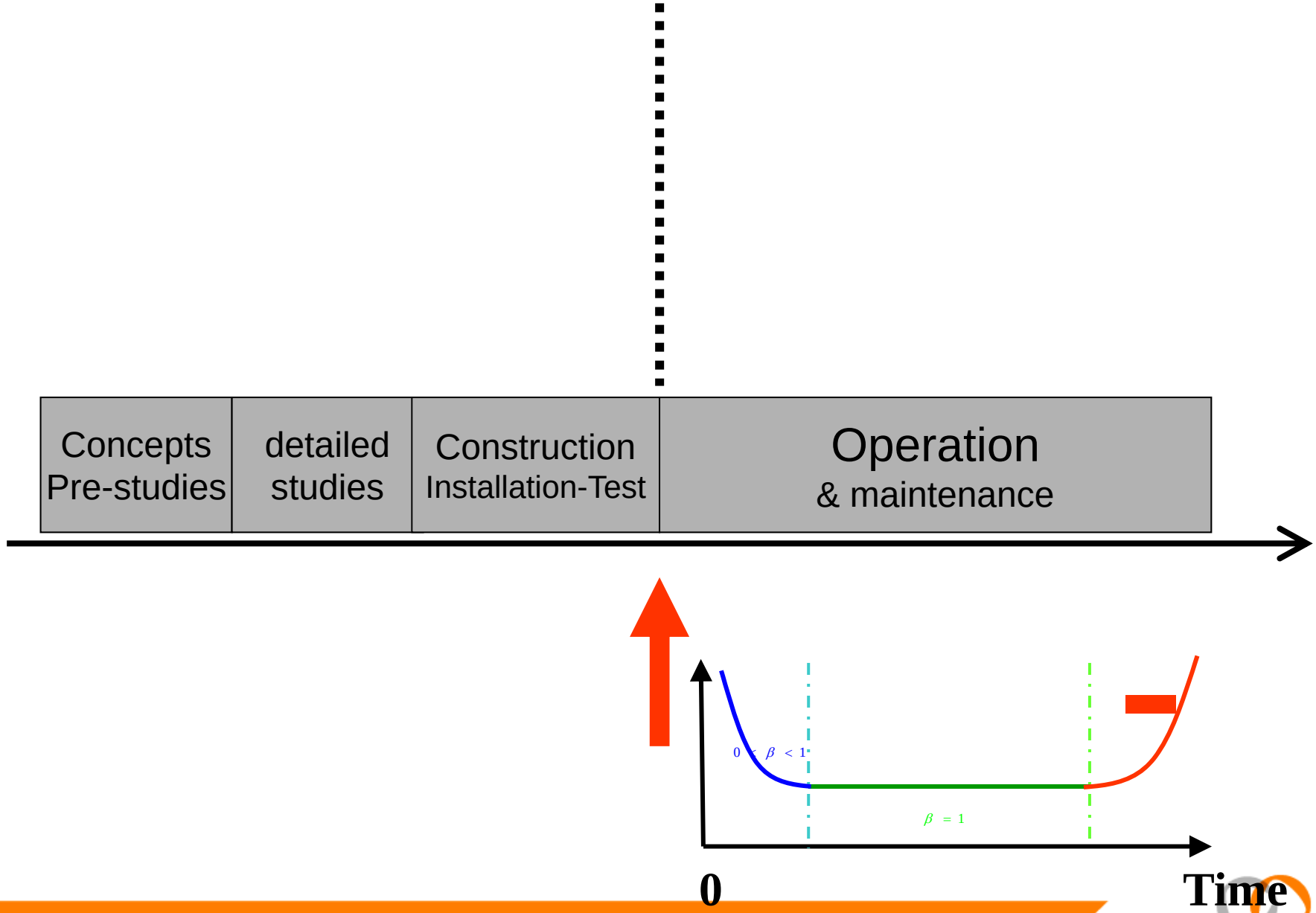


Reactivity of organisation–transmission of information

Example of Failure Handling – Short-term Planning



Updated shutdown schedule discussed in shutdown meeting, beam time coordinator informed



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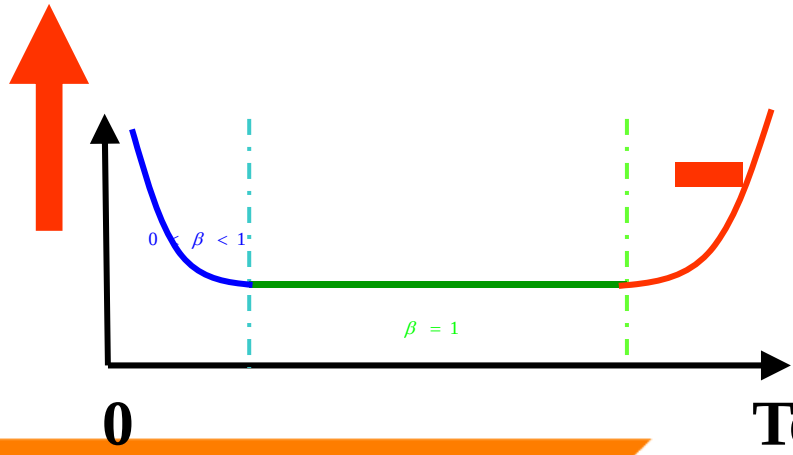
Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance



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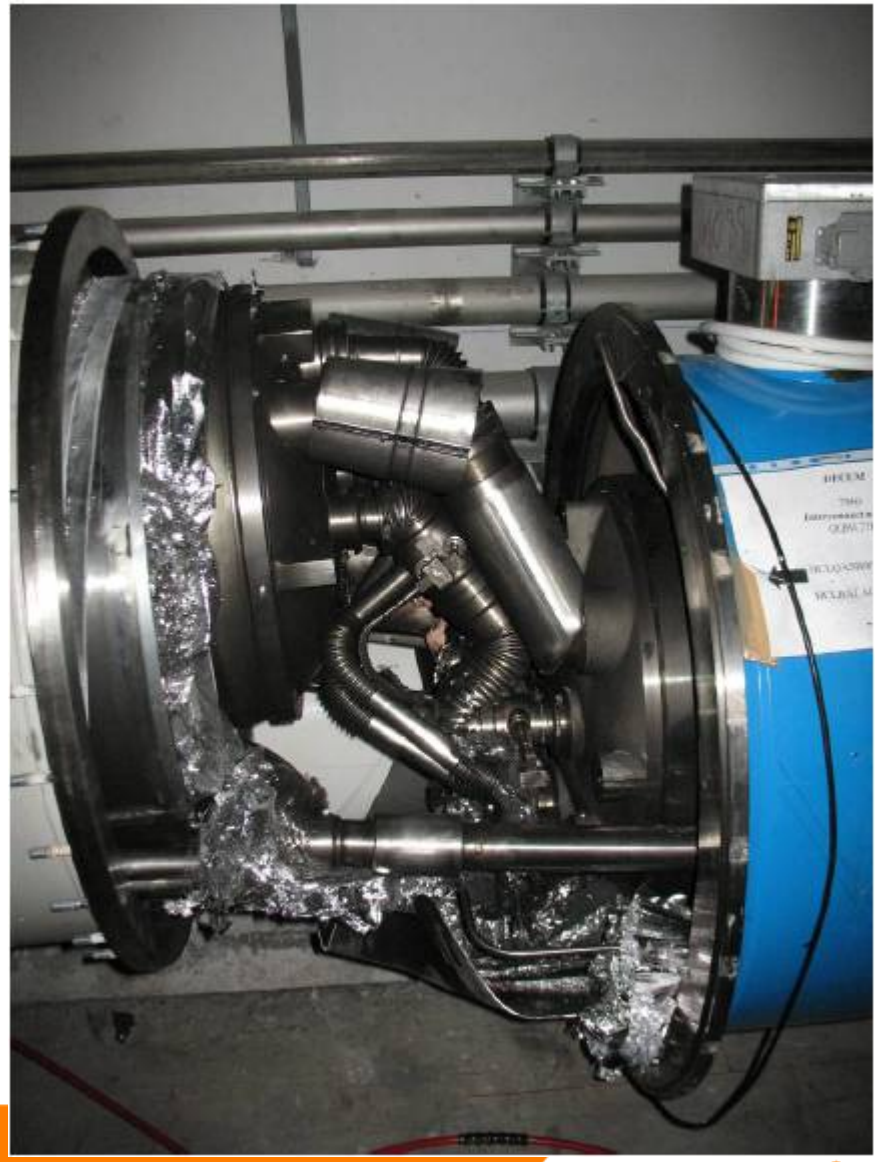
« the» CERN event (september 2008)



Why transition « project » to « operation » so critical ?

- **ALL** the systems must be ready **AND** OK (ancilaries, control system, …)

- often, the first time in « **REAL** » conditions

- Atmosphere of « **pressure** »:
  - Important milestone for contract (penalties)
  - users « wants » the beam

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~~Maintenance~~ ➡ Projects to set, keep, improve the operations

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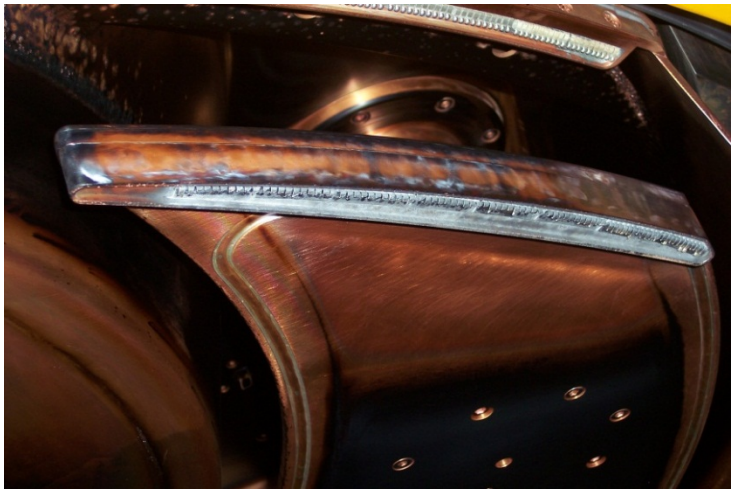
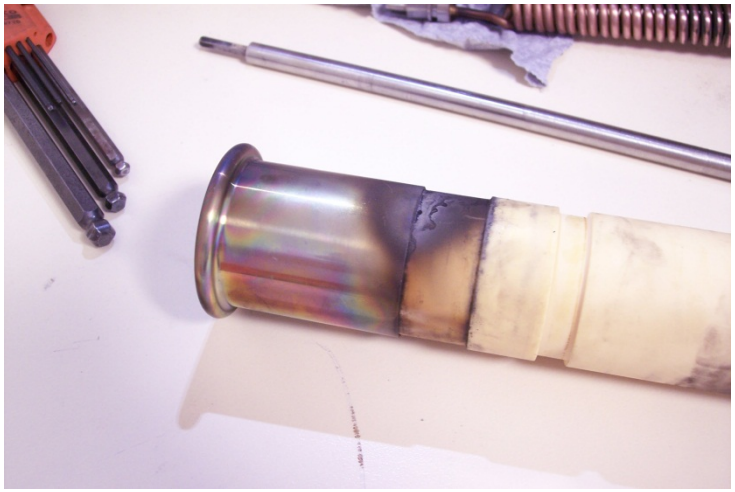
Event @CPO: july 2010, Cyclotron C230





Ion Source pollution
+ RF event
+ deflector pollution
+ RF tube + PS RF …

5 days OFF

small RF event
+ mix of <u>simultaneous</u>
inappropriated conditioning
(Ion Source ,RF, Deflector)

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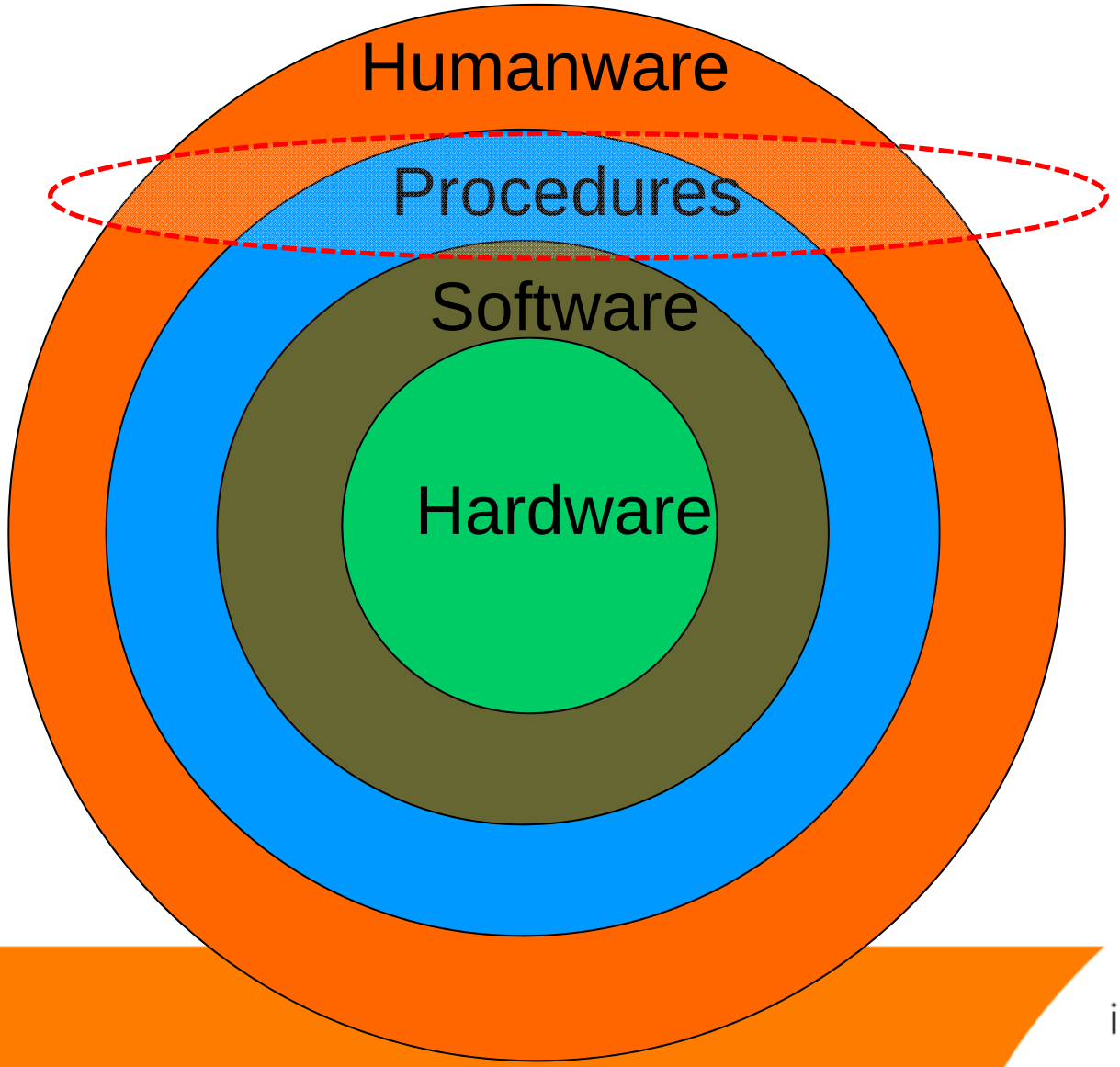
The 4 layers for reliability



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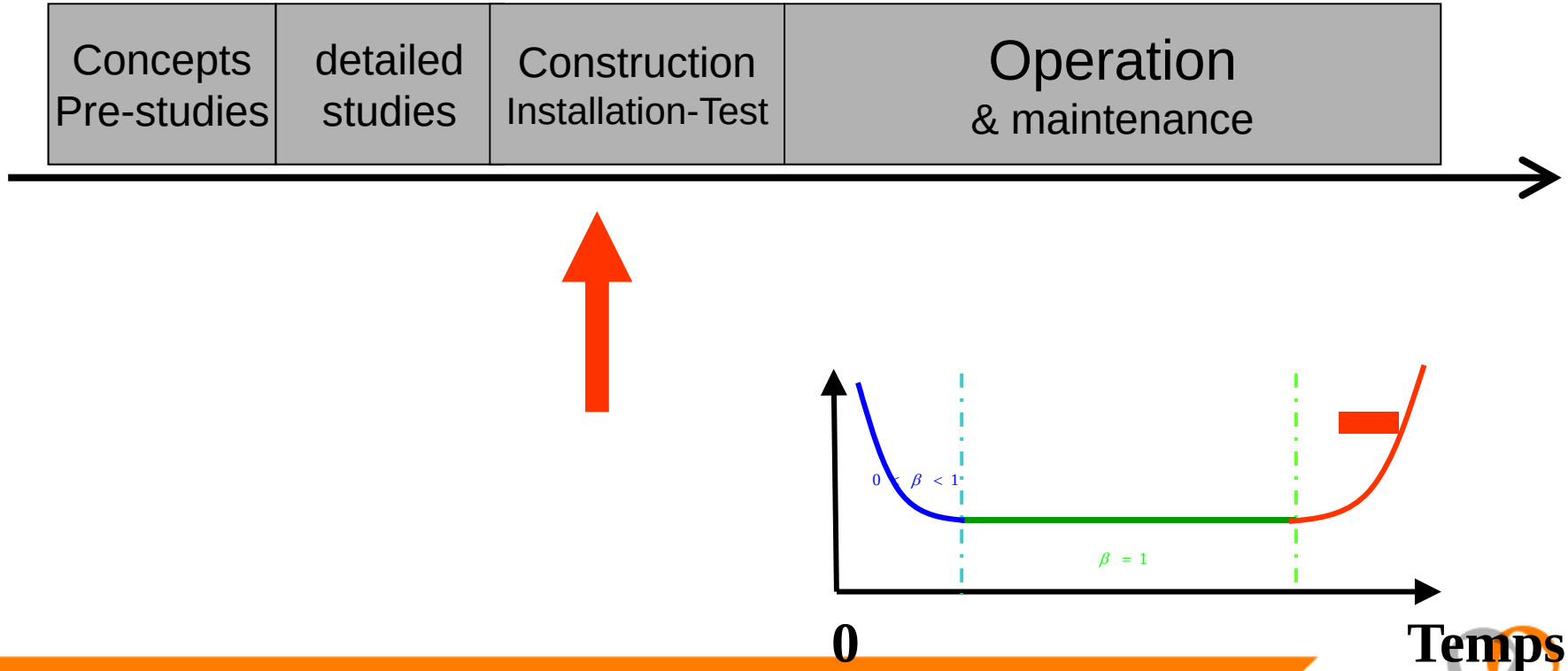

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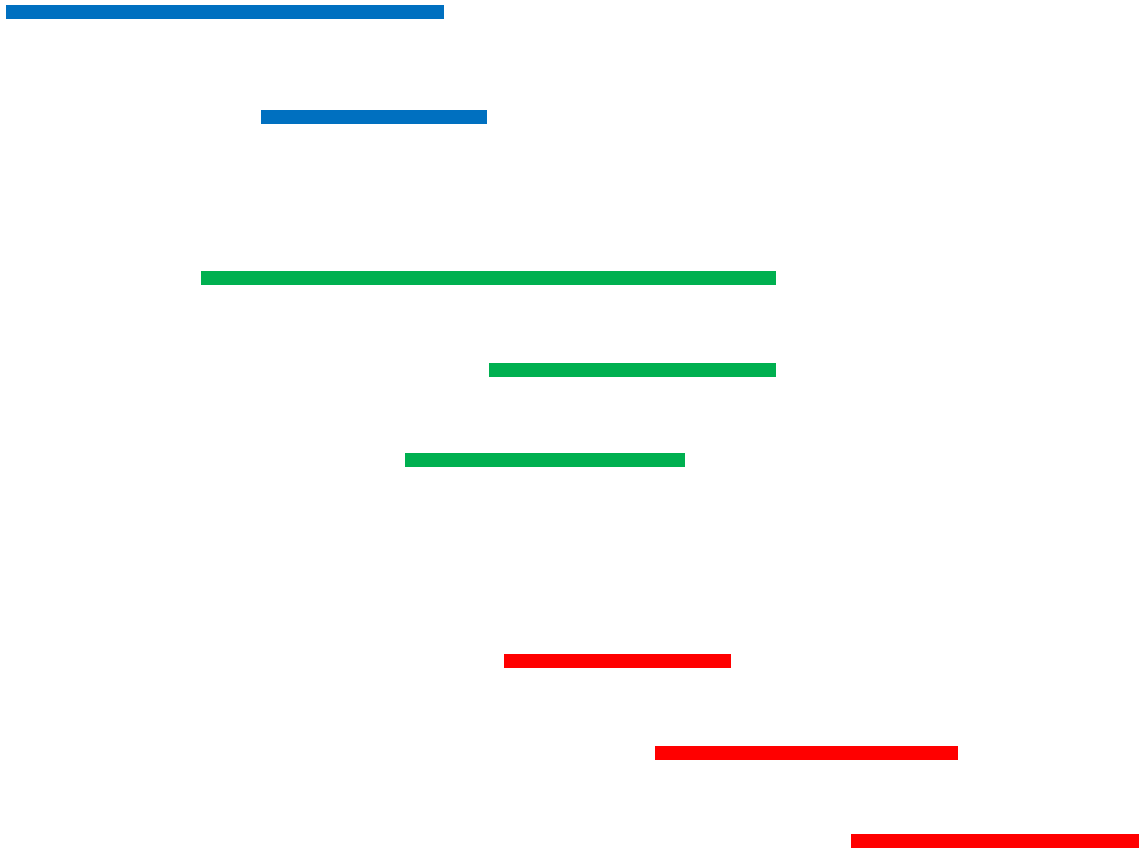
planning

Building
Ancilaries

Magnet
RF
Power Supplies

Integration
Test
Commissioning



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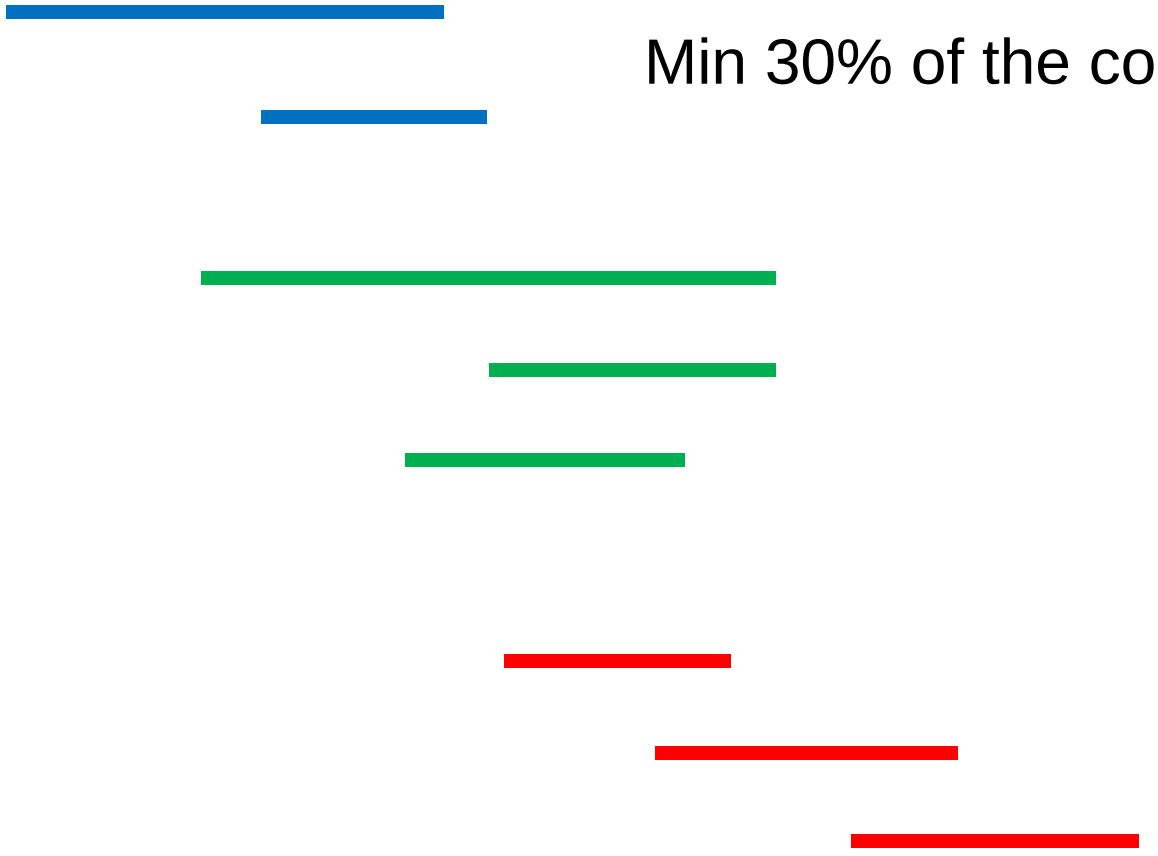
planning

Building
Ancilaries

Min 30% of the cost

Magnet
RF
Power Supplies

Integration
Test
Commissioning



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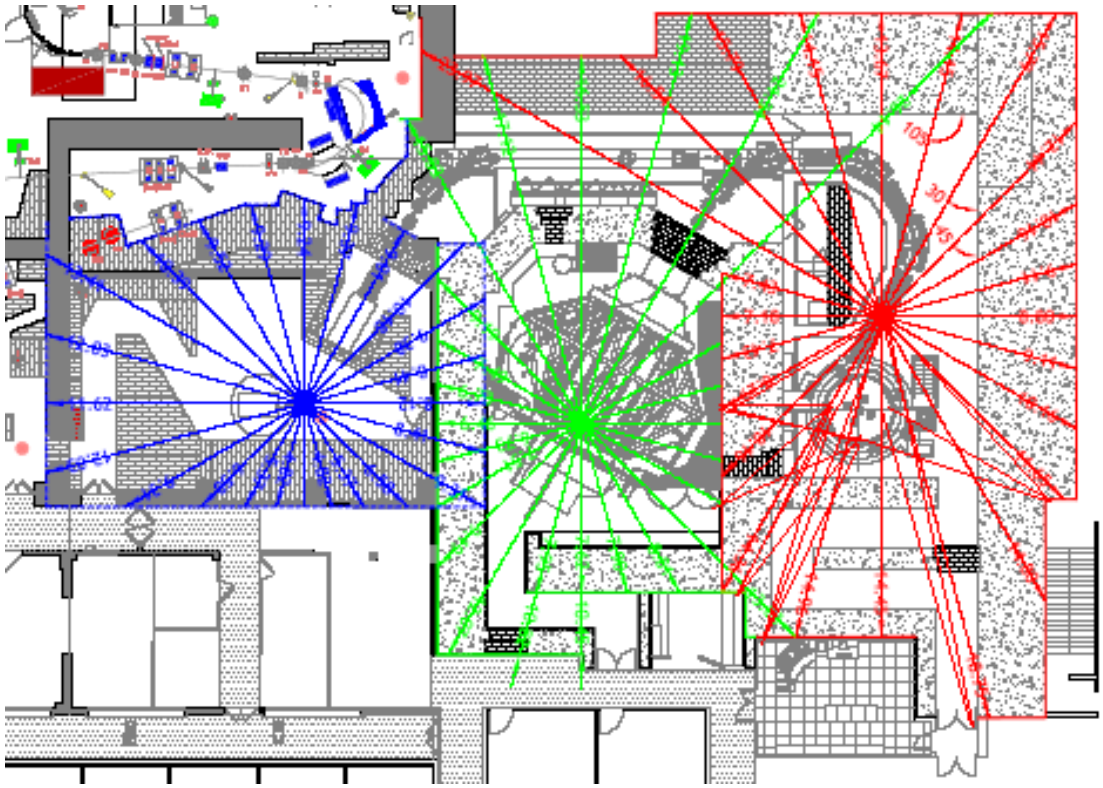
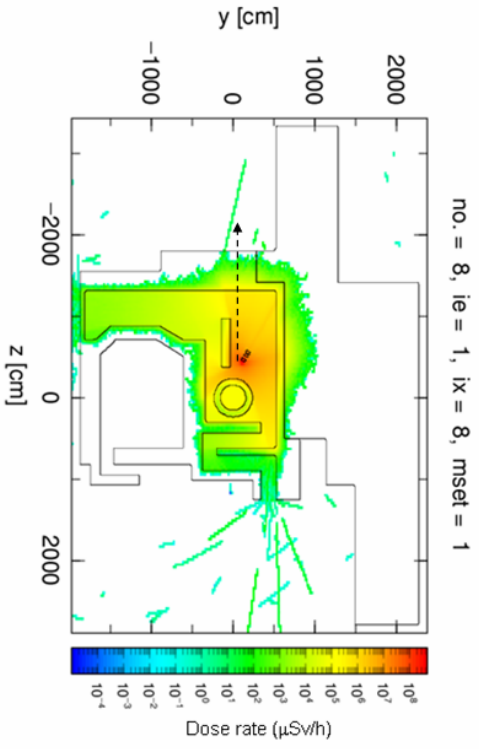
Radiation – protection

- calculation of shieldings
- source points (to provide)
- proof of concept to dismantle





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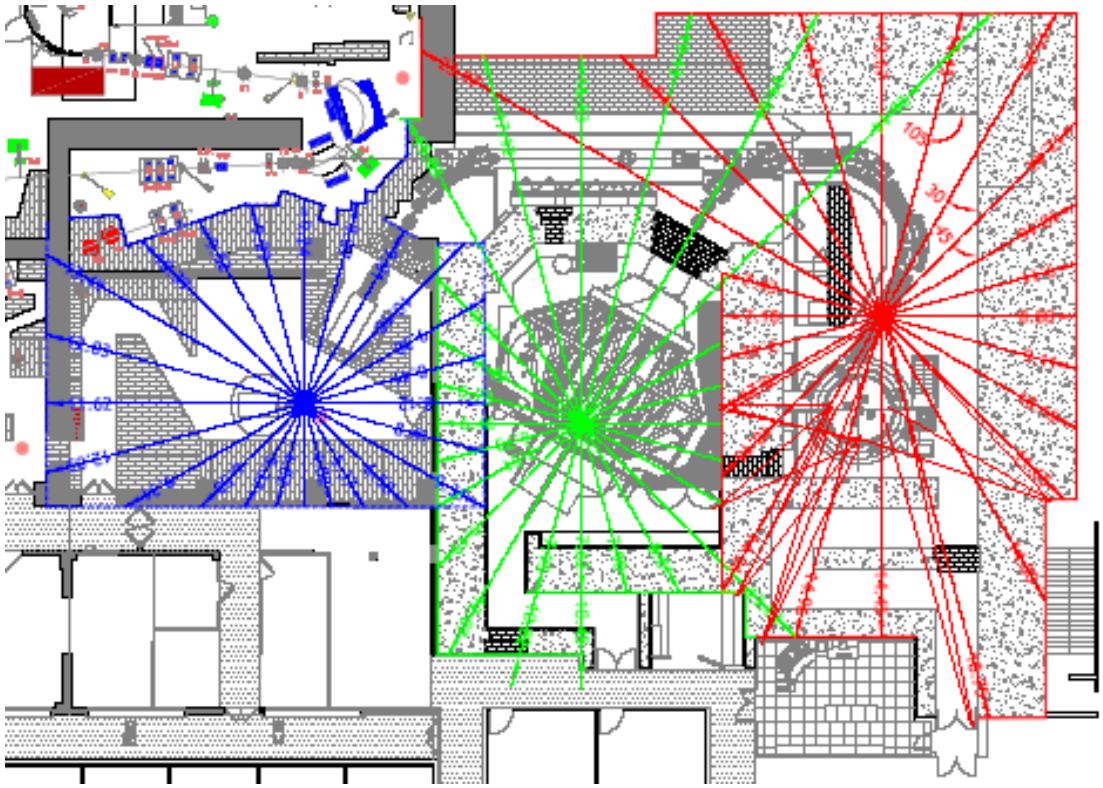

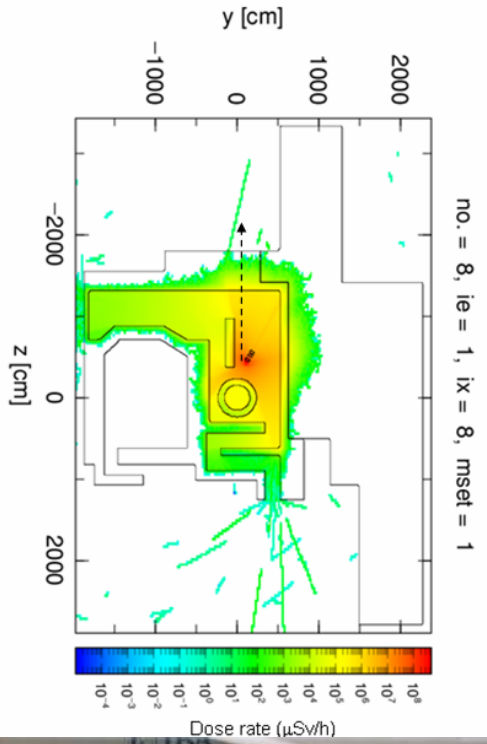

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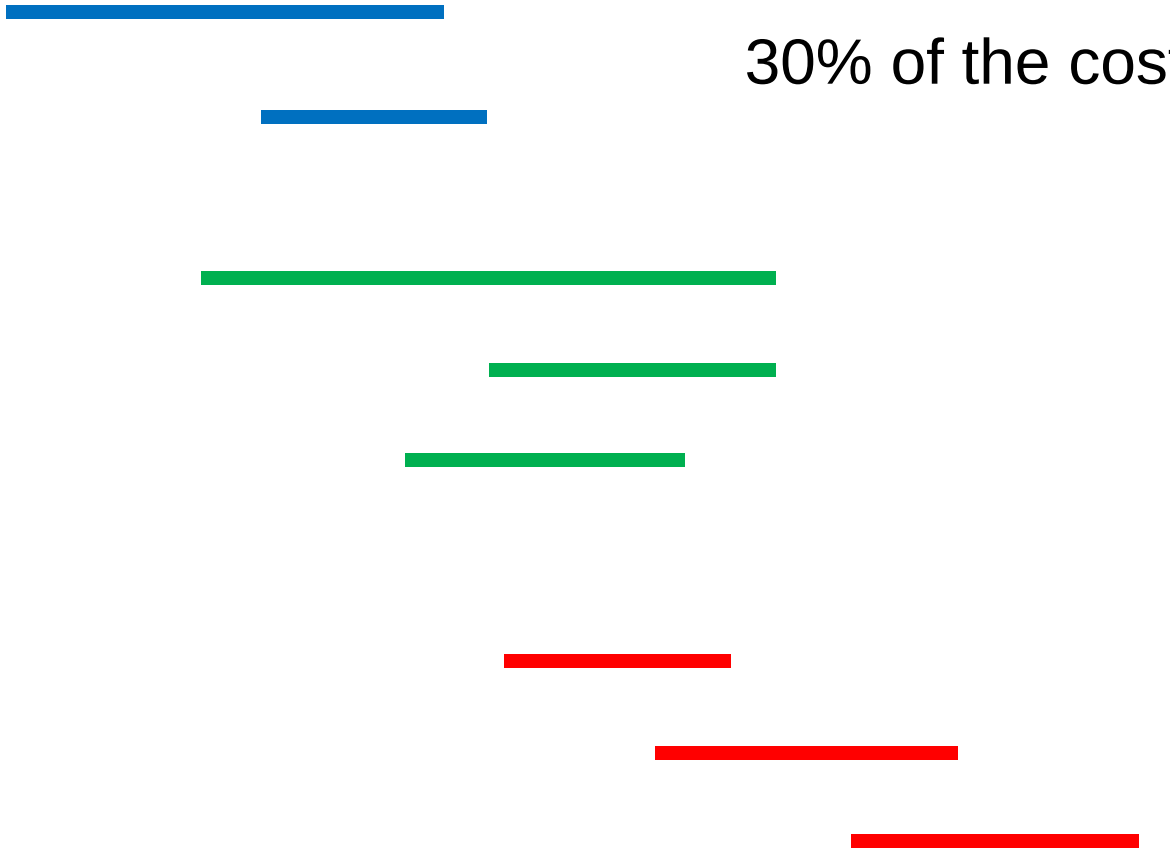
planning

Building
Ancilaries

30% of the cost

Magnet
RF
Power Supplies

Integration
Test
Commissioning



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planning

Building
Ancilaries

30% of the cost

Beam ?

?

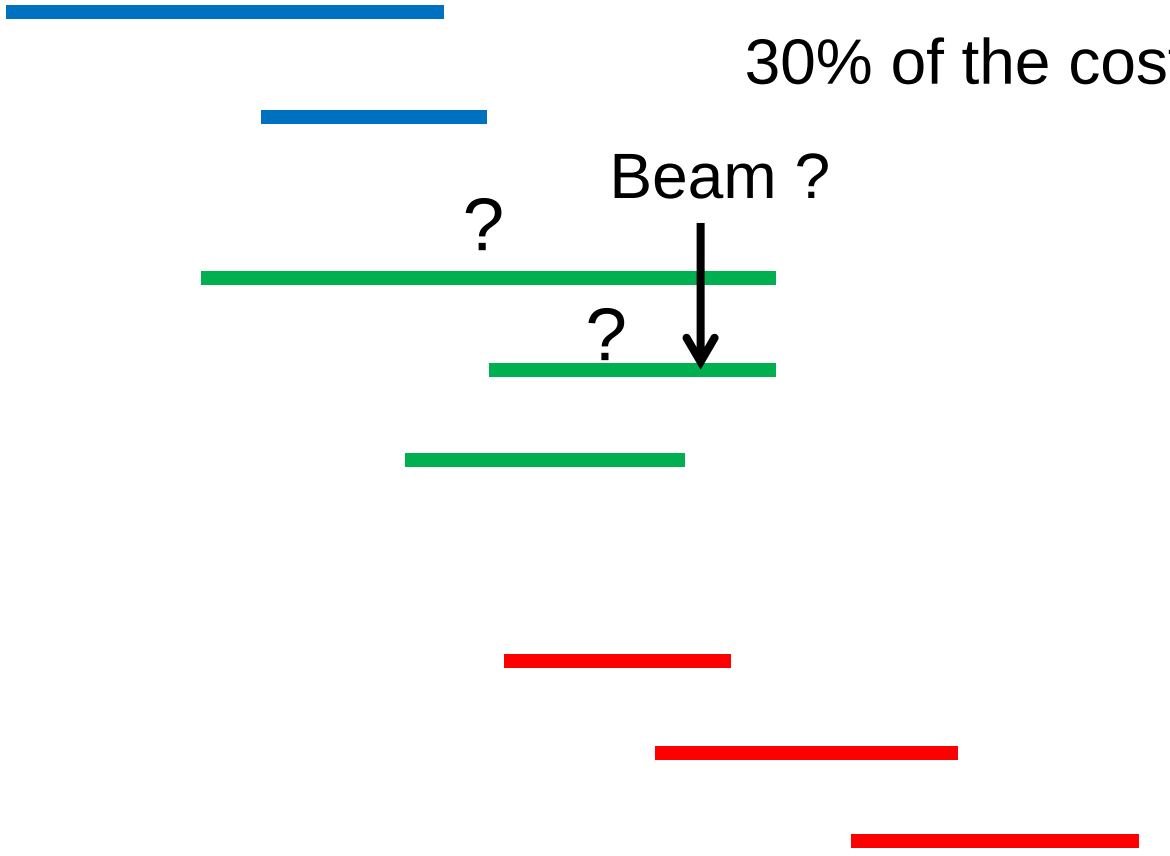
Magnet

?

RF

Power Supplies

Integration
Test
Commissioning



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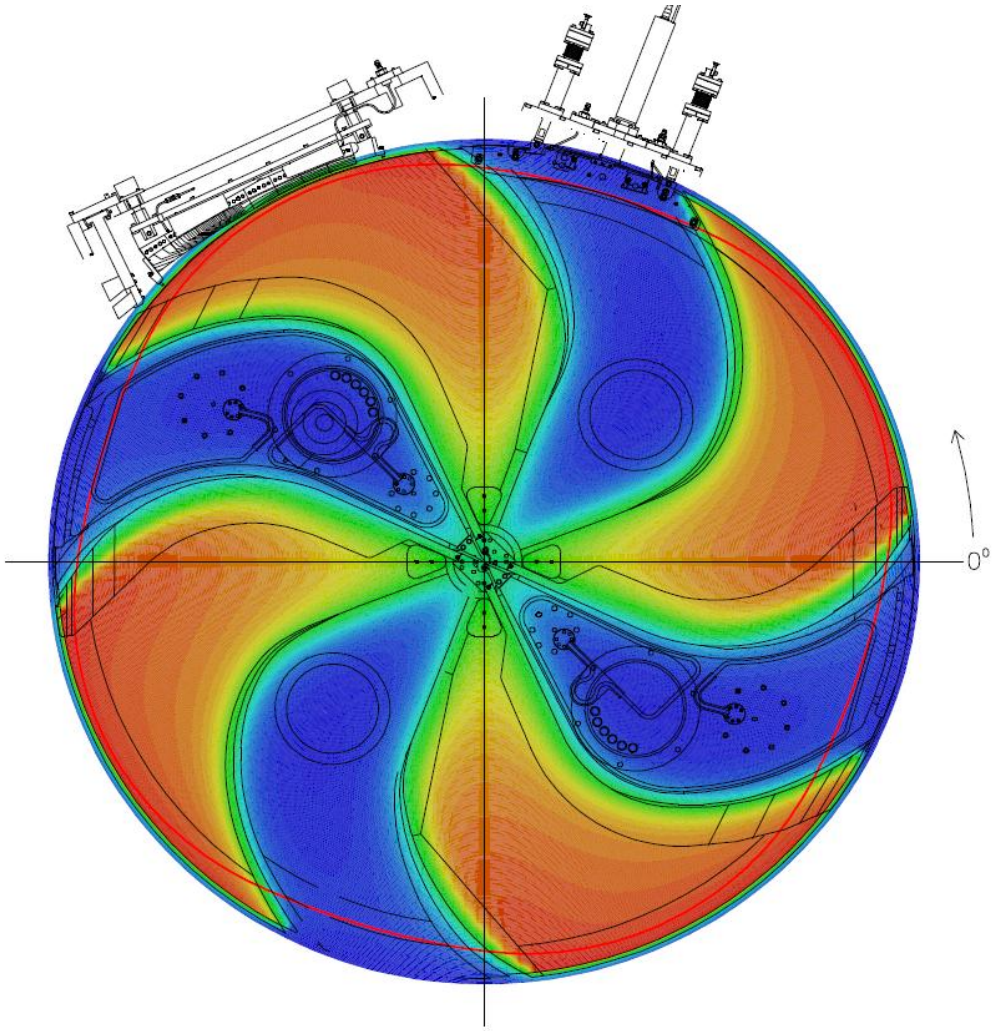
Mapping C230



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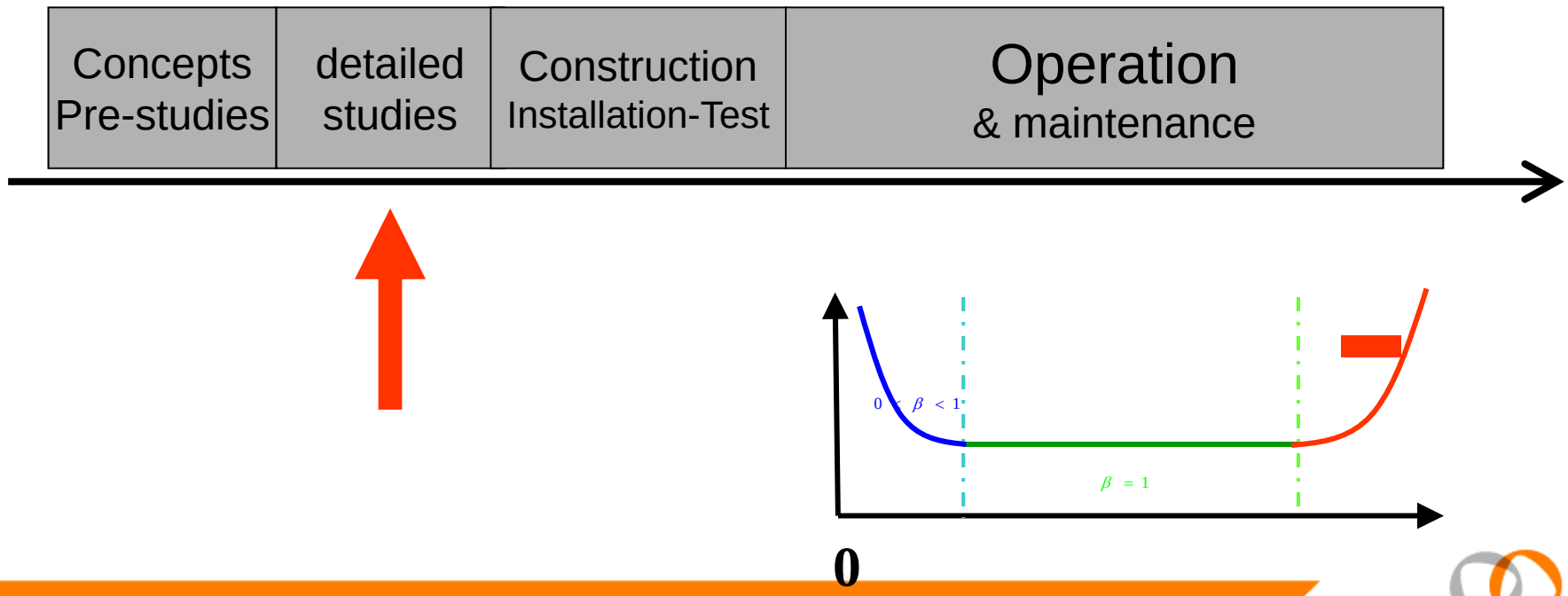

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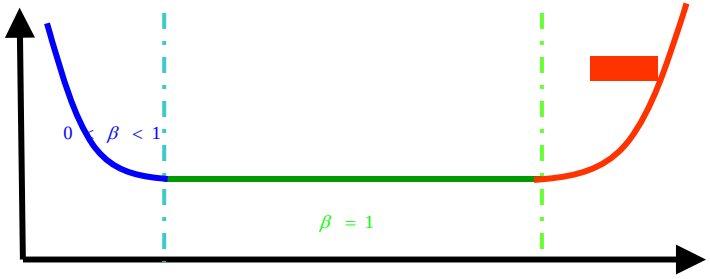
Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance



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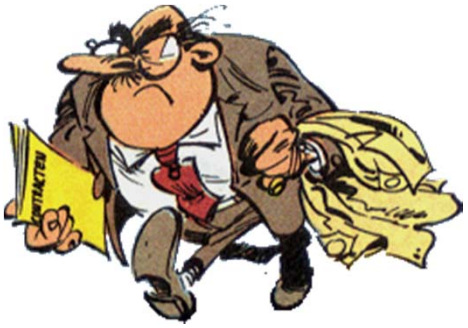
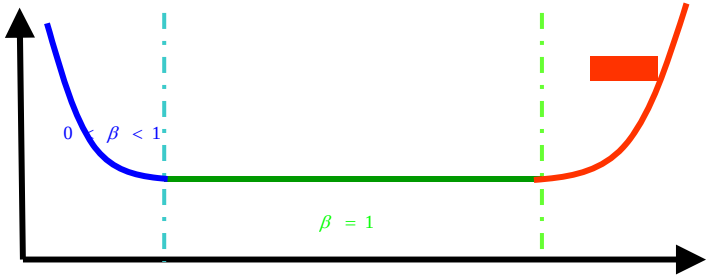


Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance

contract



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Contracting with

With the provider of the accelerator

- performances and acceptance tests (conservative / innovation)
- contents and limits of interface (beam, building , control, …)
- training - documents
- budgets (bonus / penalties)
- maintenance

With the provider of building and ancilaries

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Contracting with

With the provider of the accelerator

- performances and acceptance tests (conservative / innovation)
- contents and limits of interface (beam, building , control, …)
- training - documents
- budgets (bonus / penalties)
- maintenance

With the provider of building and ancilaries

With the users (« real » needs, constraints, freedoms, evolutions…)

With the payers (budget and resources)

- for investment
- for ramp-up and contengencies
- for operations, maintenance, …

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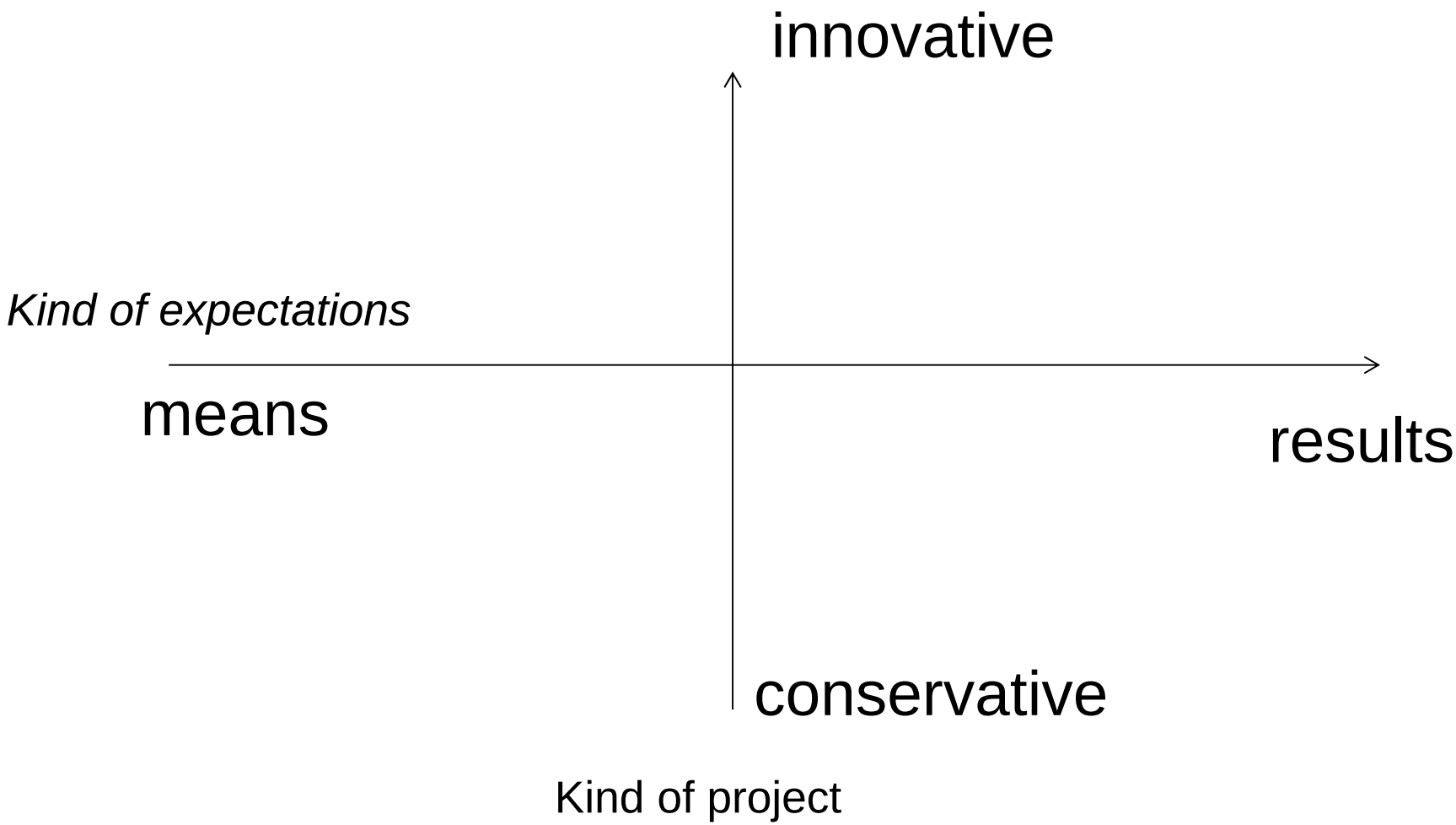
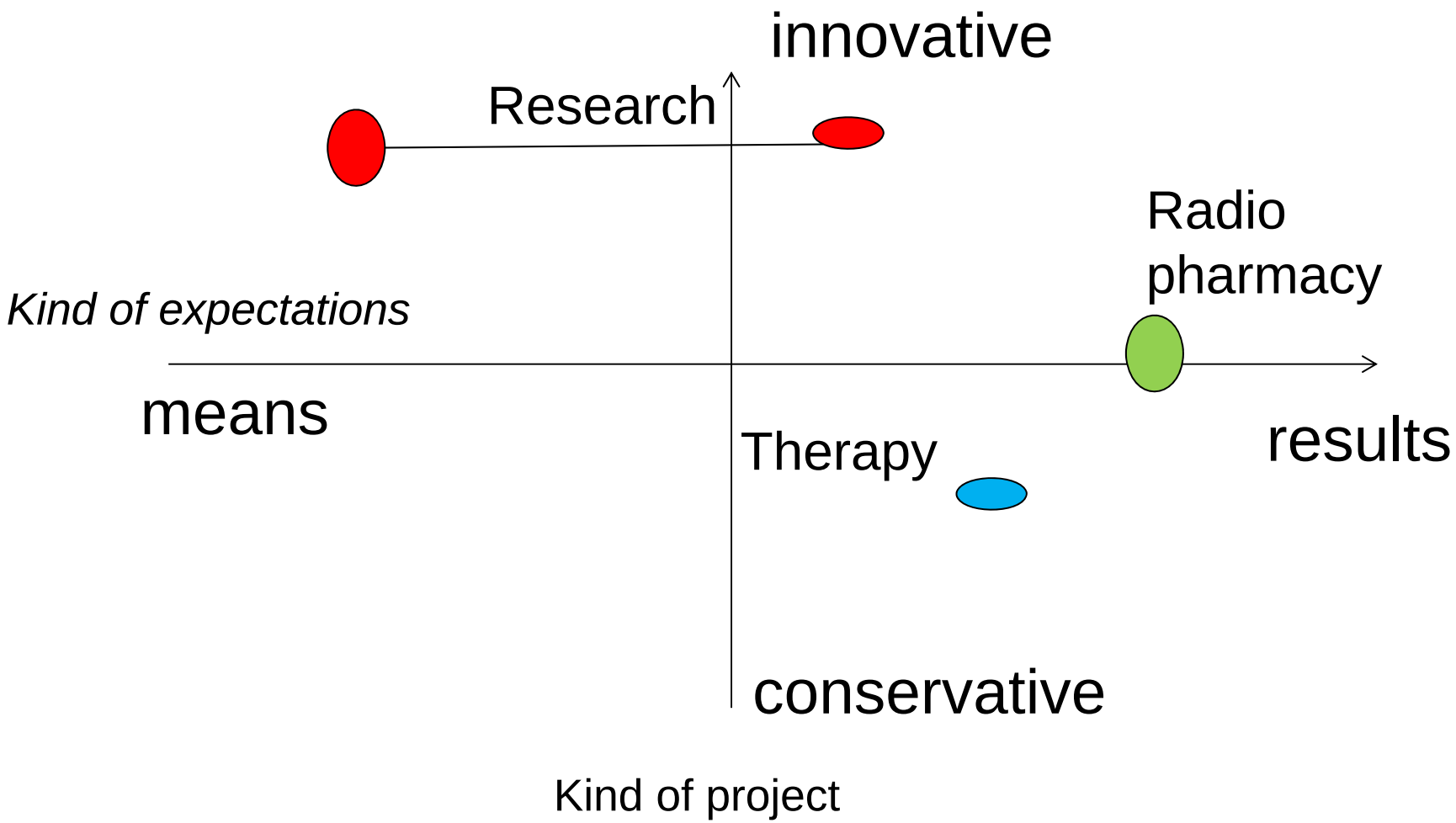

innovative
Kind of expectations
means
results
conservative
Kind of project

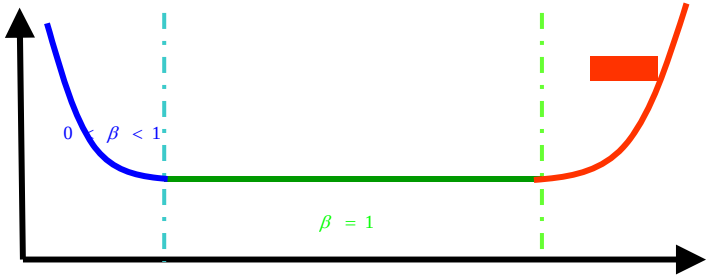

innovative
Research
Radio
pharmacy
Kind of expectations
means
Therapy
results
conservative
Kind of project

+

Quality Assurance

Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance

contract



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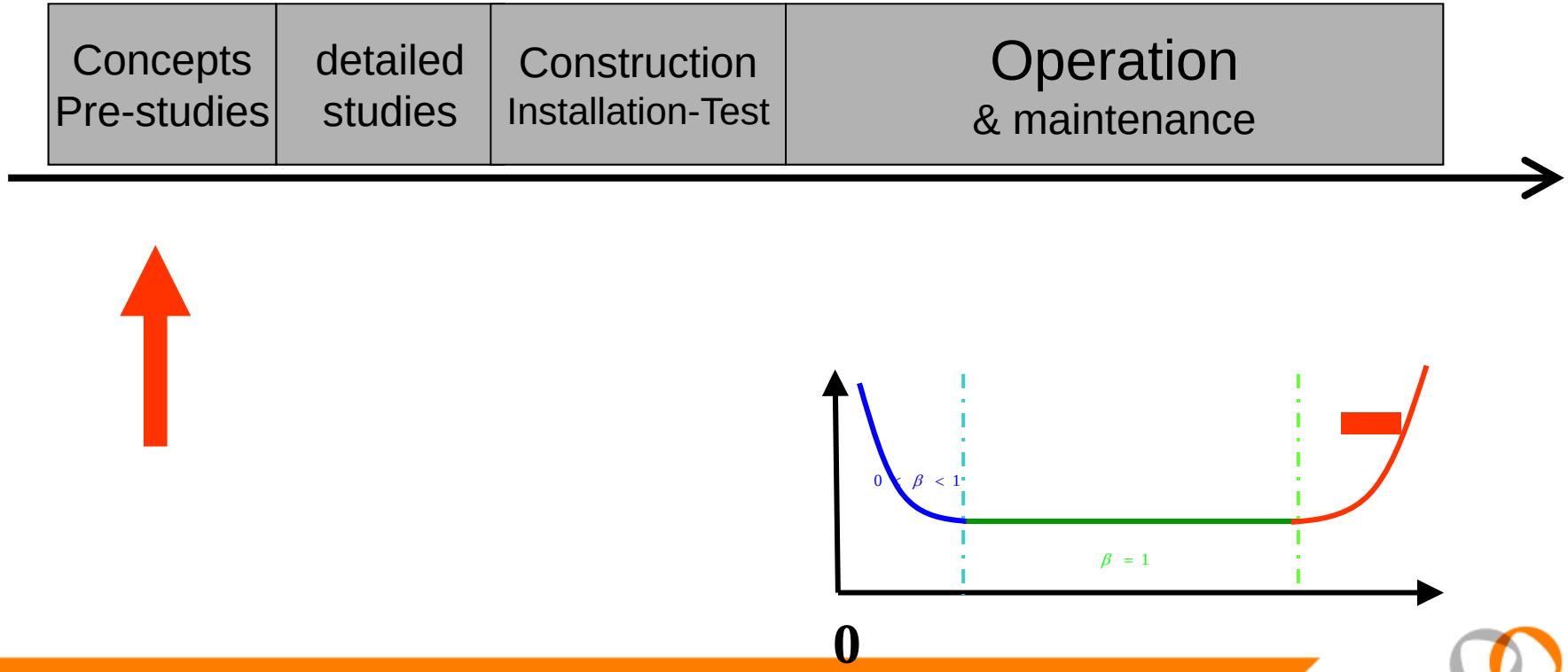
Life-cycle of an accelerator



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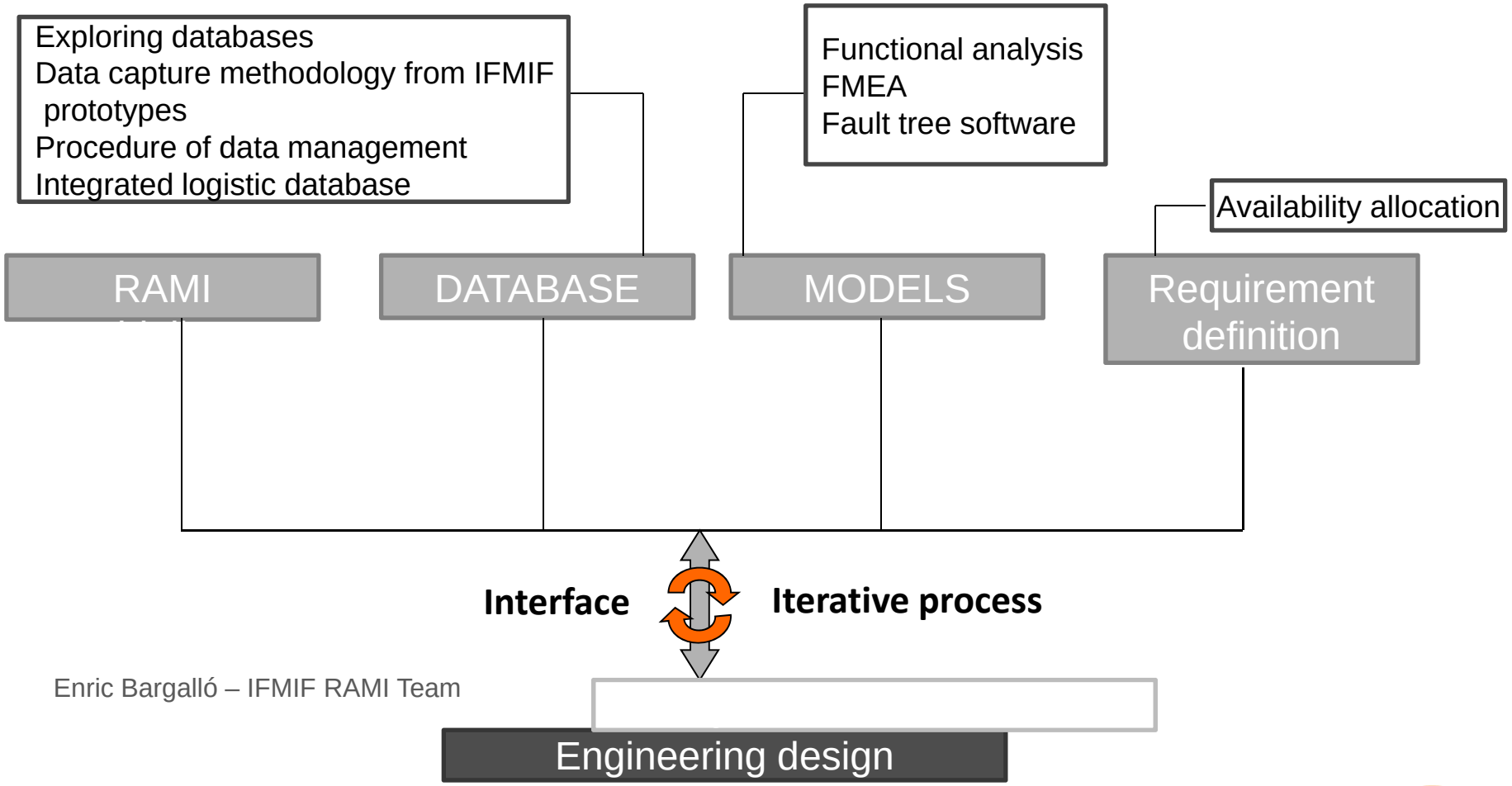
RAMI approach (Reliability, Availability, Maintainability, Inspectability) pour projet IFMIF



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Concepts and reliability

Principles to increase reliability:

- Redundancy
- accessibility
- over -engineering
- maintainability
- …

Parameters increasing **risks** on reliability

- Technological innovations
- Lonely experience
- Number of specific interfaces
- pressure on quality, budget, delay
- …

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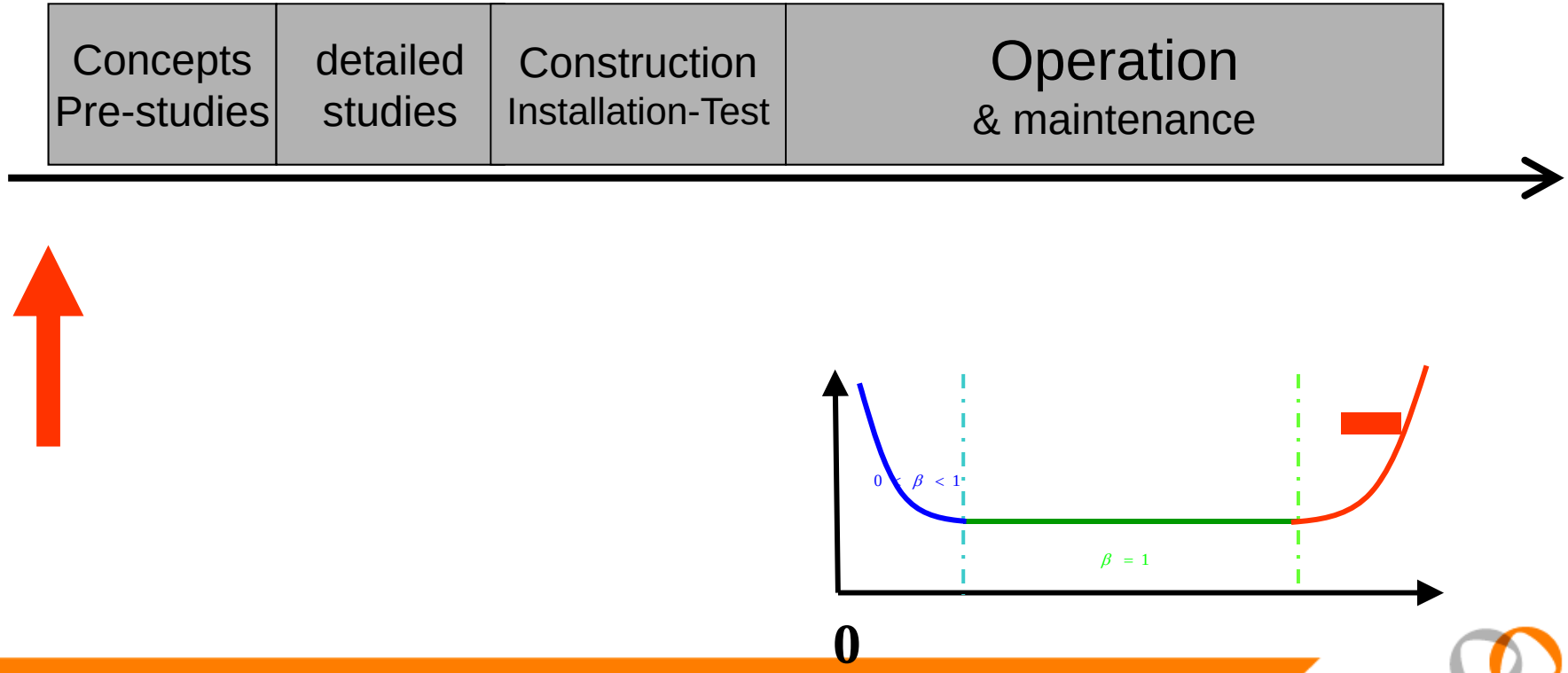
Life-cycle of an accelerator



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The (wellknown) recipes for a good reliability

A system (hardware & software) well designed

- specifications, model of developpement, tests
- principles of reliability, a lot of diagnosis

A well-maintained system

- Preventive, real, adaptative, reactivity for corrective
- Spare parts (a lot, ready for use)
- time dedicated for operations

Human resources and good organization

- people trained, skilled, enough, here when required
- efficient and clean organization, data-base, Knowledge Management

Briefly: resources (men, budget), consistency, willingness…

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Example on life-cycle

the AGOR cyclotron

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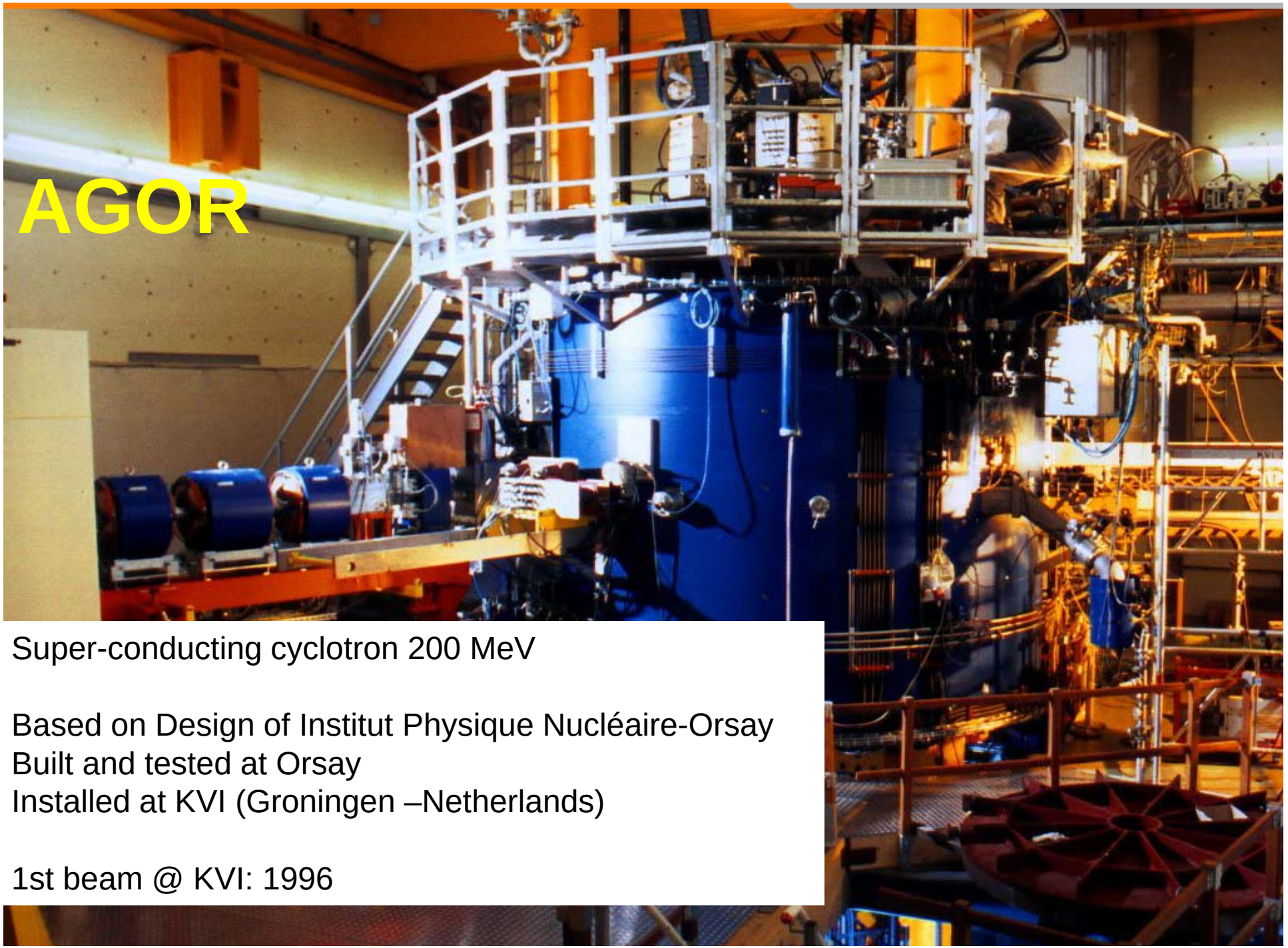


Super-conducting cyclotron 200 MeV

Based on Design of Institut Physique Nucléaire-Orsay
Built and tested at Orsay
Installed at KVI (Groningen –Netherlands)

1st beam @ KVI: 1996

Basic design:All ions
200MeV pol p and d
100MeV/n Z/A=0.5

10 MeV/n Z/A=0.1

AGOR
Few numbers

Weight	320 T
Height	4 m
Diameter	4.4m
Magnetic field	4.05 - 1.75 T
RF	Amplitude 50 KV to 90 KV

33 Kms of supraconducting wires

250 l of liquid He (-269°c)

50 Millions Joules stored energy in SC oils

1 MW Installed power

400 T Attracting force on the poles (2/10 mm) at 4T

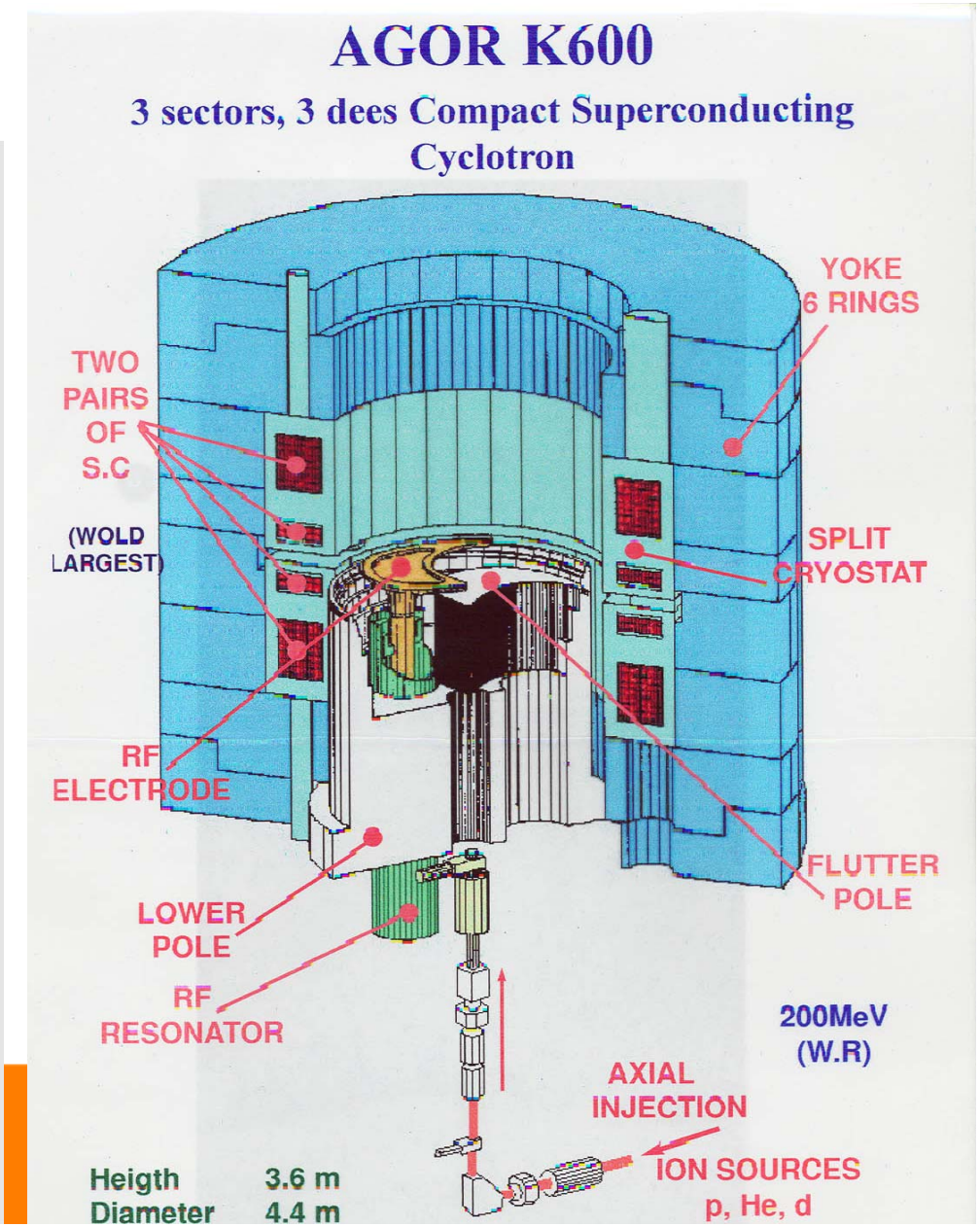
Protons beam at 200 MeV

$V = {}^1/_4\, C$

1.2 km

AGOR K600

3 sectors, 3 dees Compact Superconducting Cyclotron



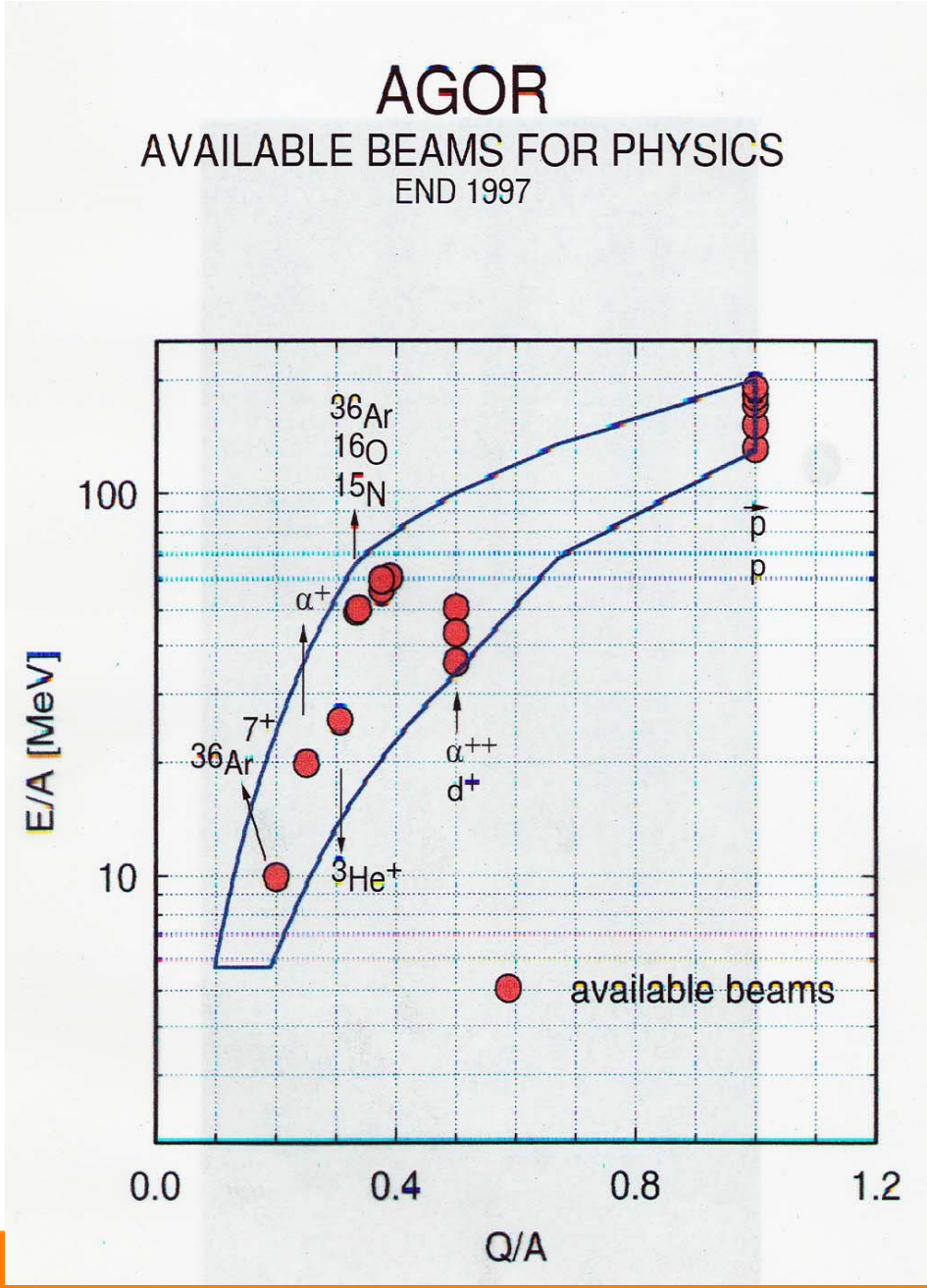
Some features of the project

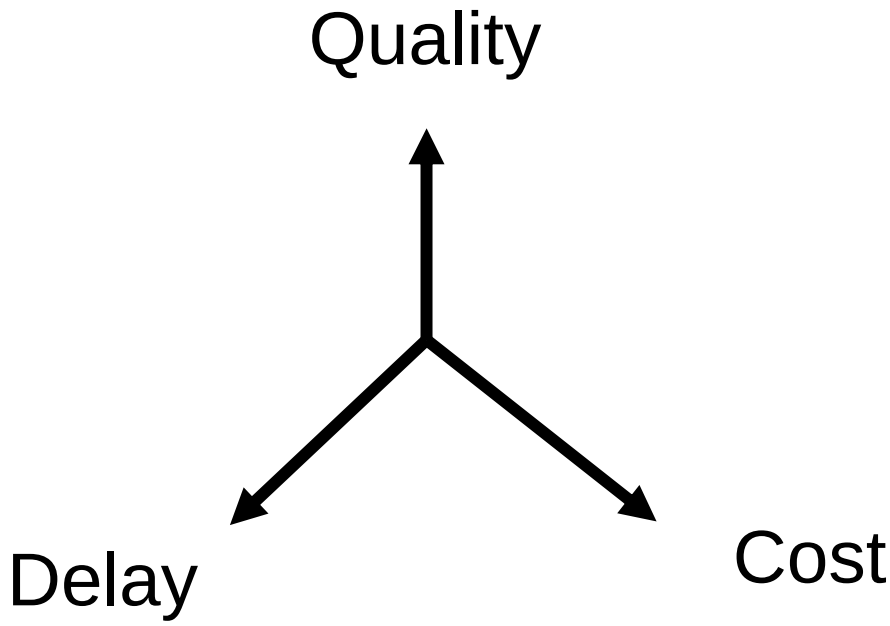
1. Expected results in terms of range of particles

2. Cyclotron built at Orsay and re-installed at KVI

3. Small leak in the cryostat

4. New concept: coils + vacuum systems (Heat pipes)





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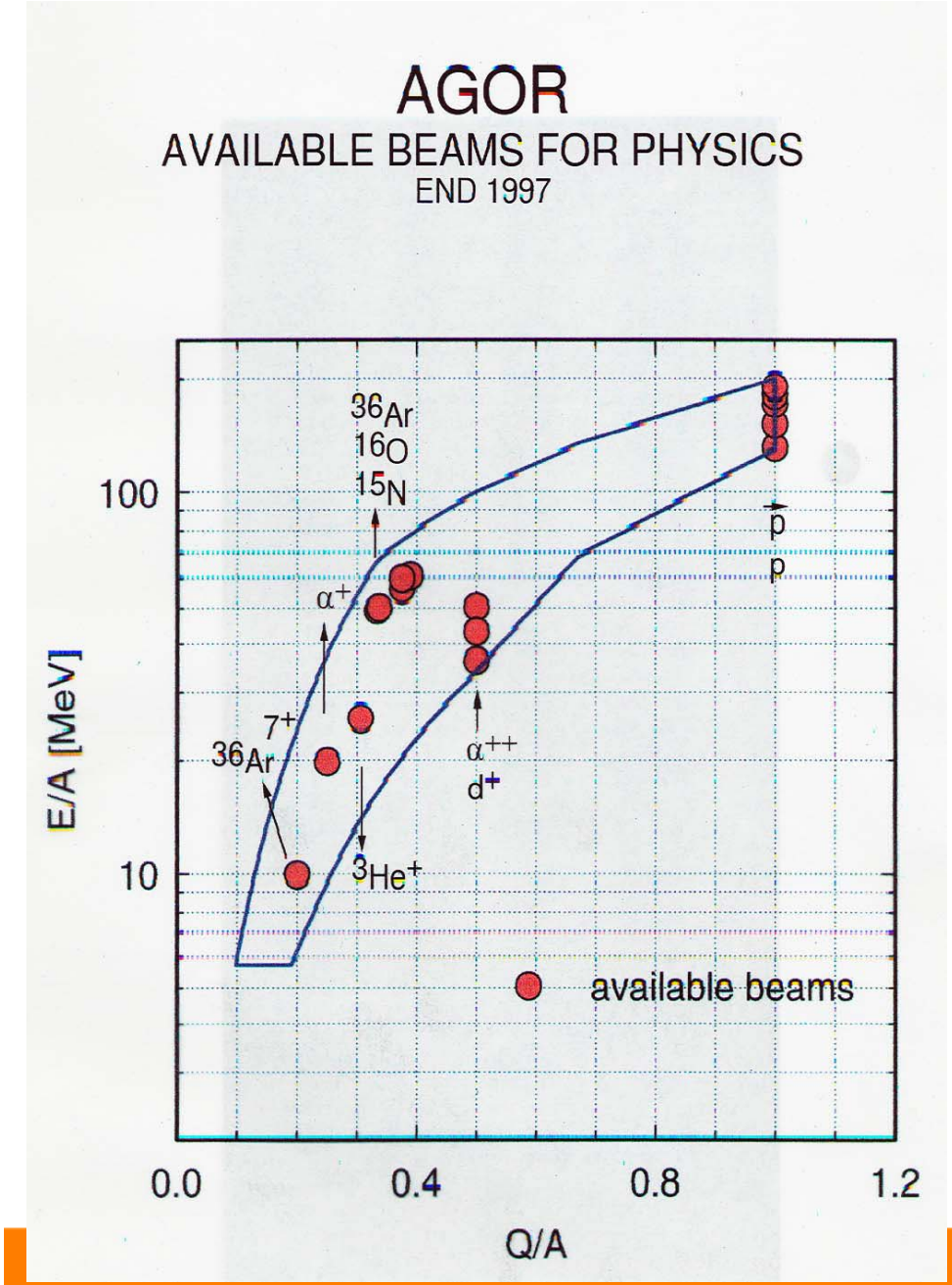

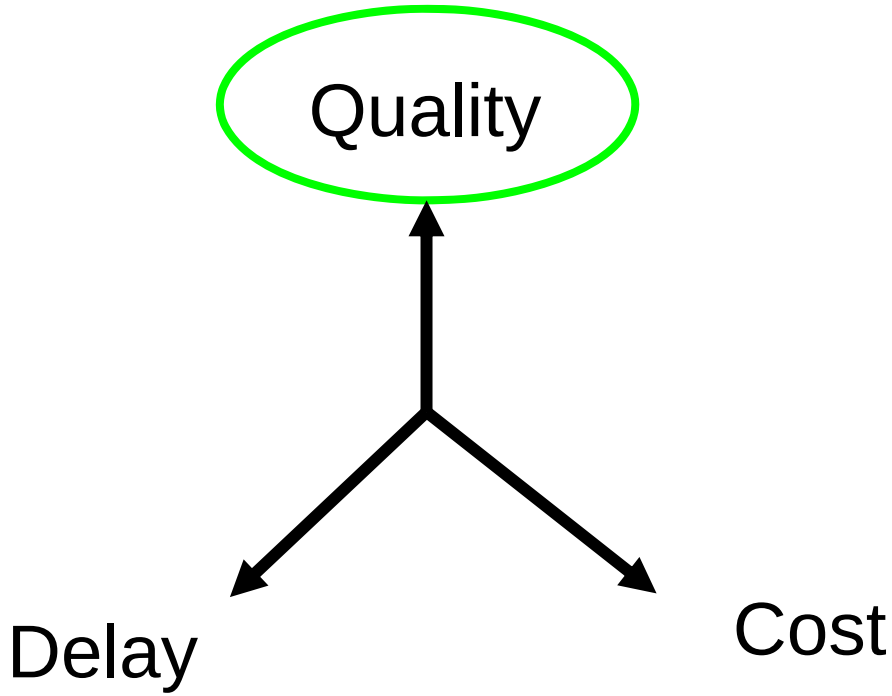

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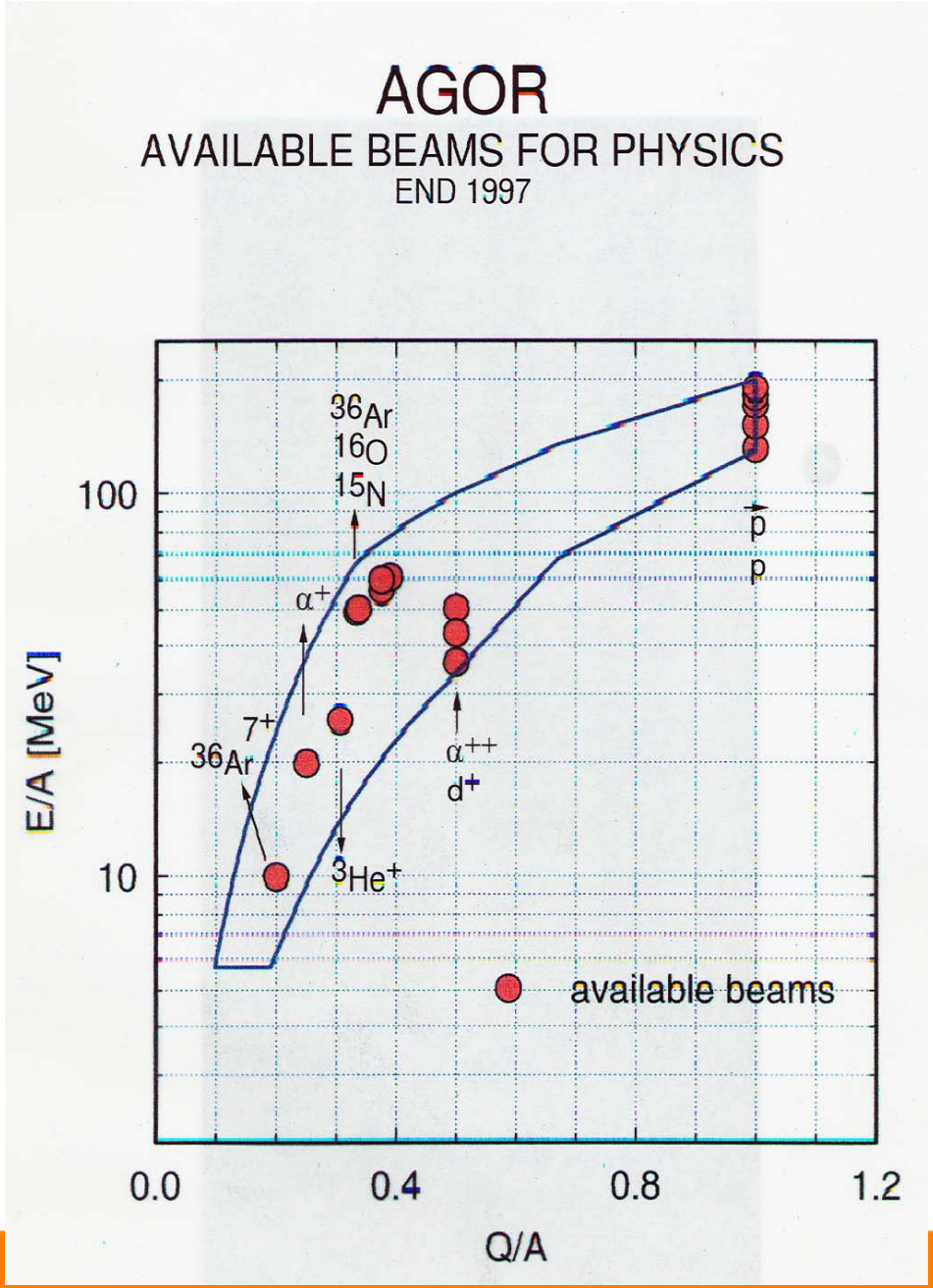

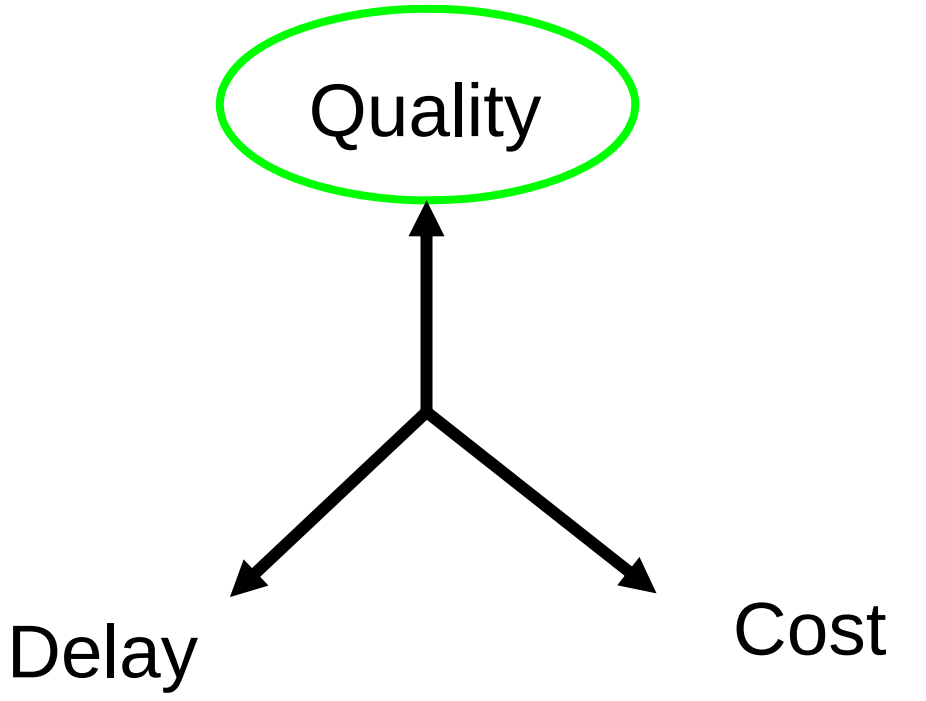

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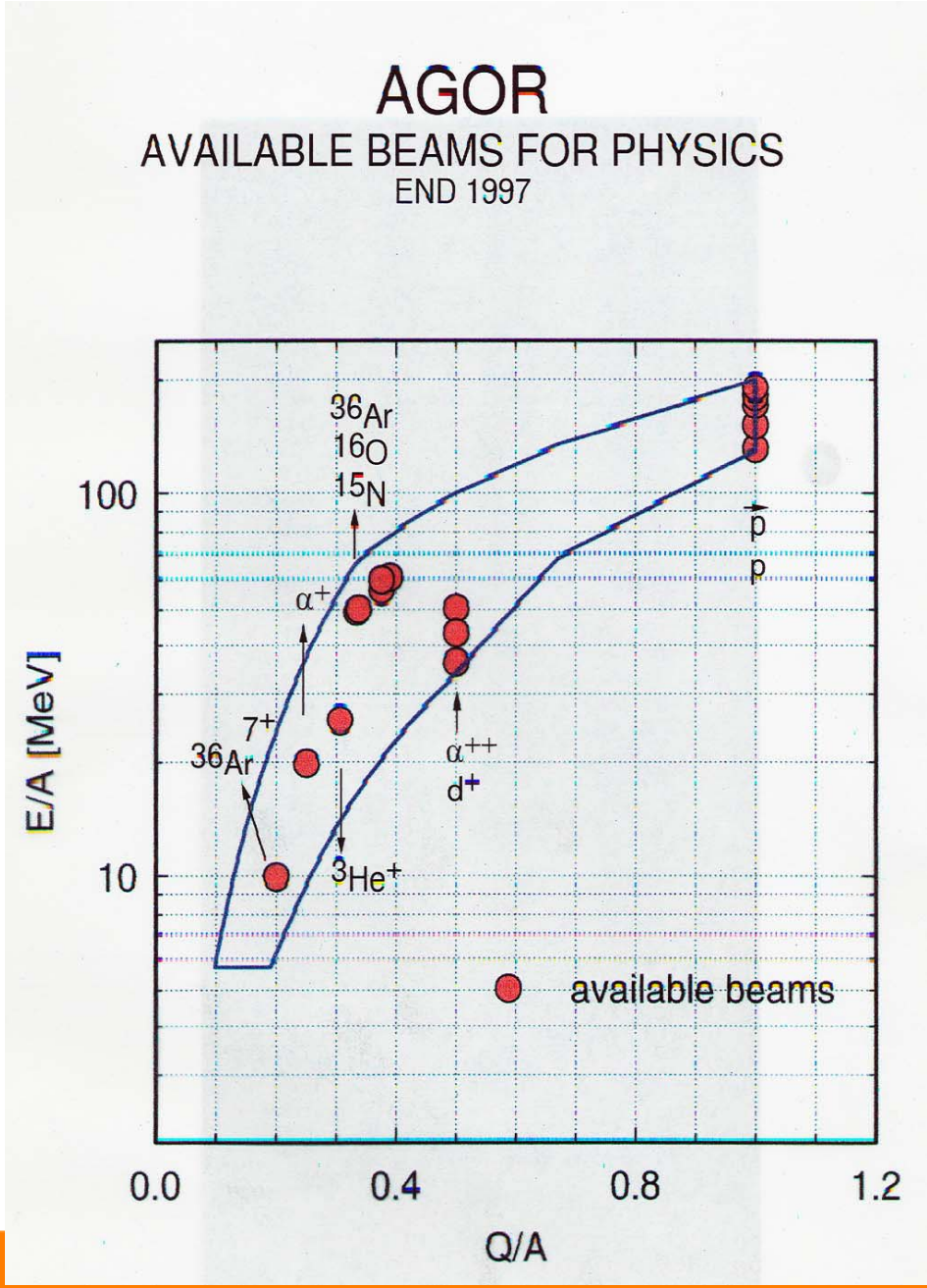

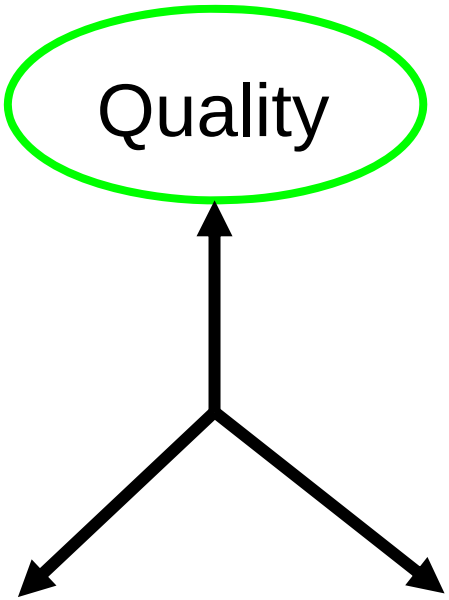

Delay
1991->1994

Cost
Limit /year

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Some features of the project

1.Expected results in terms of range of particles
OK for results – 3 years of delay

2. Cyclotron built at Orsay and re-installed at KVI

3. Small leak in the cryostat

4. New concept: coils + vacuum systems (Heat pipes)

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4. New concept: coils + vacuum systems (Heat pipes)
OK : good management of R&D on innovation

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3. some paradoxes about reliability (for accelerators)

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Some paradoxes about reliability

In order to obtain the maximal reliability, this thematic must be considered by all.

A permanent and rational approach will permit to reach the expected results.

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Some paradoxes about reliability

In order to obtain the ~~maximal~~ reliability, this thematic must be considered by all.

A **nal approach will** **xpected results.**

The maximal reliability
is an utopia

To be defined, means necessaries, associated costs…

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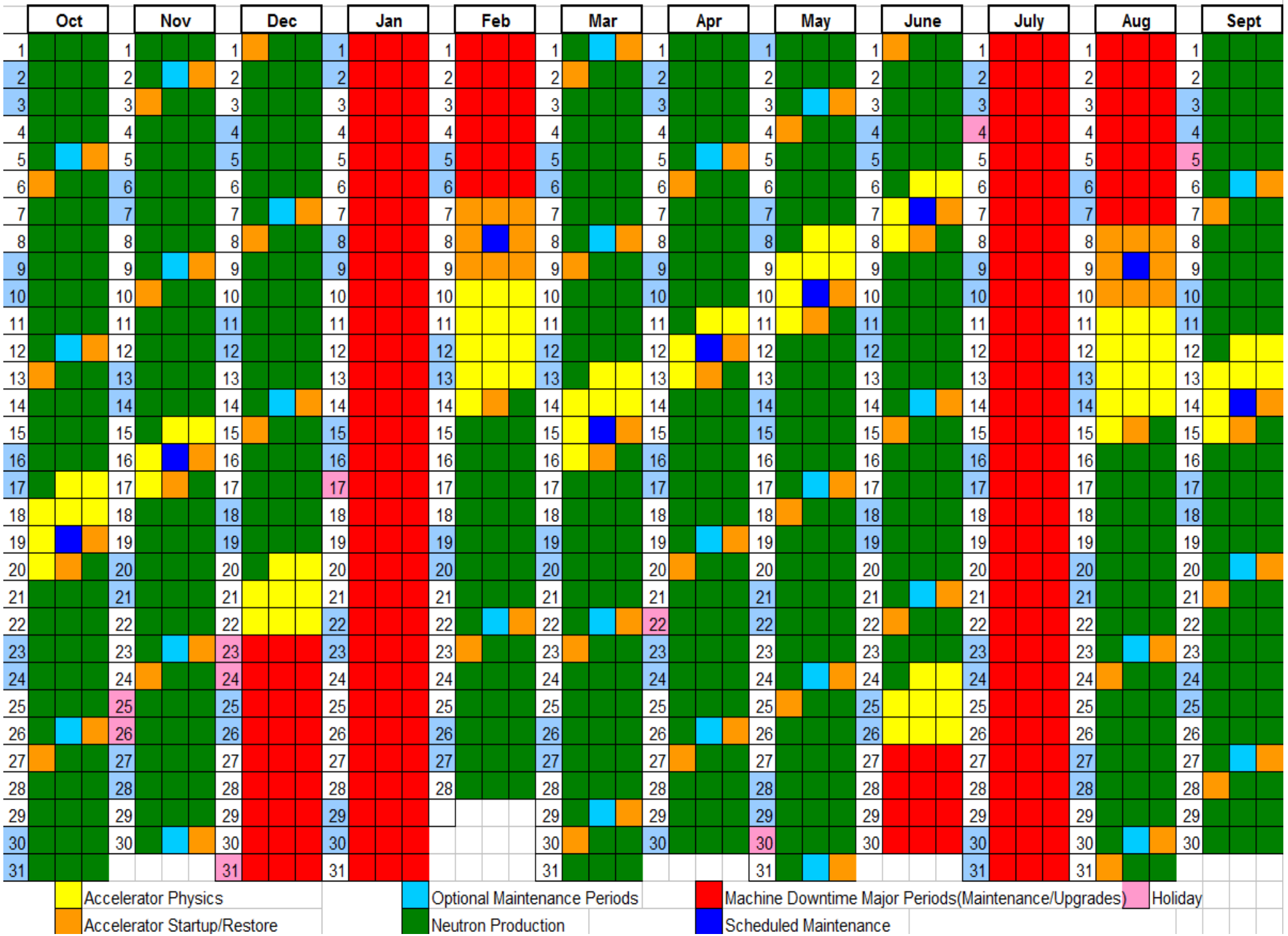
Run Schedule for FY 2011



Some paradoxes about reliability

In order to obtain the ~~maximal~~ reliability, this thematic must be considered by ~~all~~.

A permanent and rational approach will ed results.

Who is responsible of what ?
Are the guilties the payers ?

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Some paradoxes about reliability

In order to obtain the ~~maximal~~ reliability, this thematic must be considered by ~~all~~.

A ~~permanent~~ and rational approach will permit to reach the expected results.

Access difficult during operations
No mobilisation if all run well

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Some paradoxes about reliability

In order to obtain the ~~maximal~~ reliability, this

Durable effects obtained on long-term
Budget often discussed during crisis

~~all~~.

A ~~permanent~~ and ~~rational~~ approach will permit to reach the expected results.

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Some paradoxes about reliability

In order to obtain the ~~maximal~~ reliability, this thematic must be considered by ~~all~~.

A ~~permanent~~ and ~~rational~~ approach will permit to reach the ~~expected~~ results.

Reliability is measured a posteriori

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Some paradoxes about reliability

In order to obtain the ~~maximal~~ reliability, this thematic must be considered by ~~all~~.

A ~~permanent~~ and ~~rational~~ approach will permit to reach the ~~expected~~ results.

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Salutations

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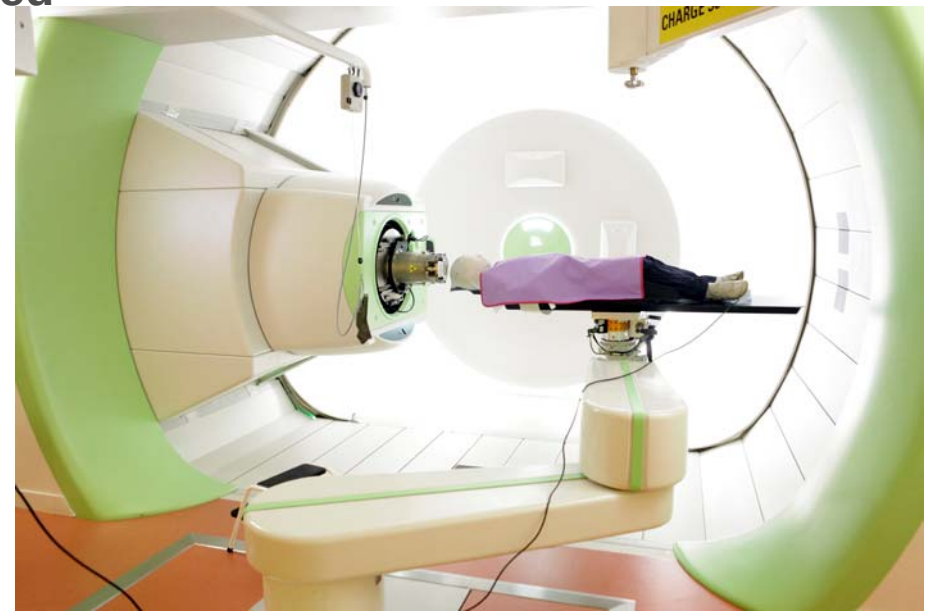
Nouveau Centre de Protonthérapie

From 1st treatment: july 2010

To now: May 2012

545 days of treatment

Only **3 days OFF** with patients cancelled due to cyclotron process



Thanks to:

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IBA: G. Chau, JB Ruaud, B. Van Lierde, C. Pierret, S. Nacivet, N. Brixko, +LLN: P. Pellerin, J. Belmans, P. Caillau, P Verbruggen, …

IPNO, GANIL, PSI,…

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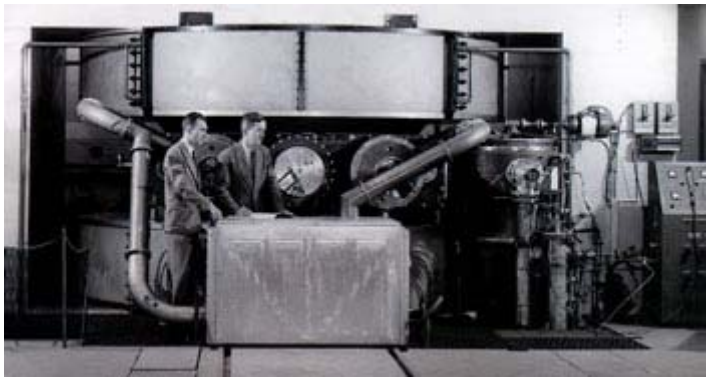
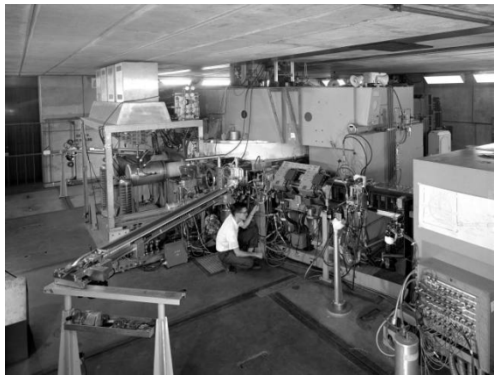
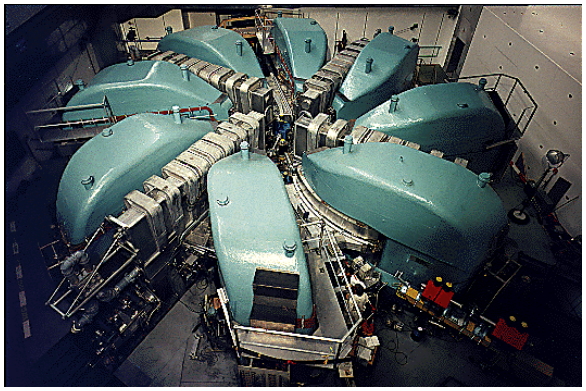
Synchro-cyclotron - HCL
Harvard (1949-2003)



Cyclotron 88 inch - LBL
Berkeley (1961 - …)



Cyclotron PSI (590 MeV)- CH
designed for 100 µA (1974)
an now at 2,2 mA (2012)



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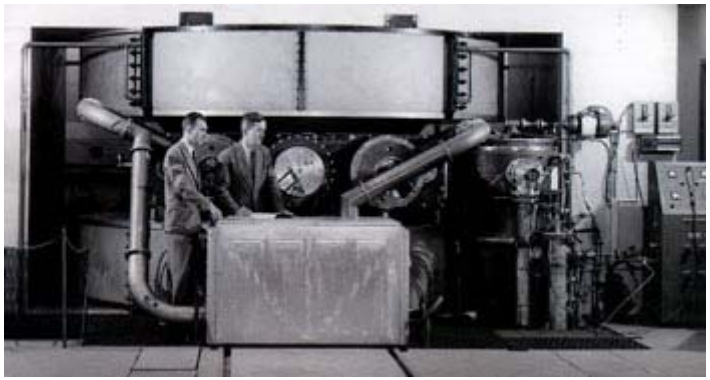

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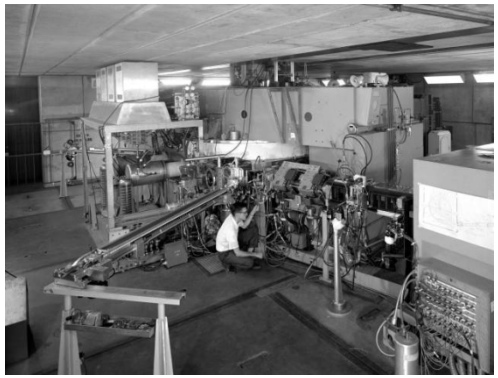

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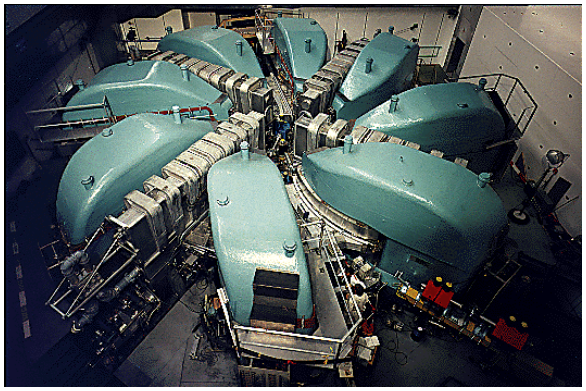

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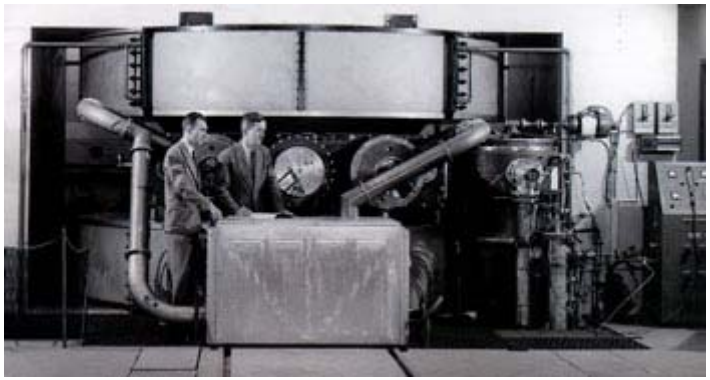

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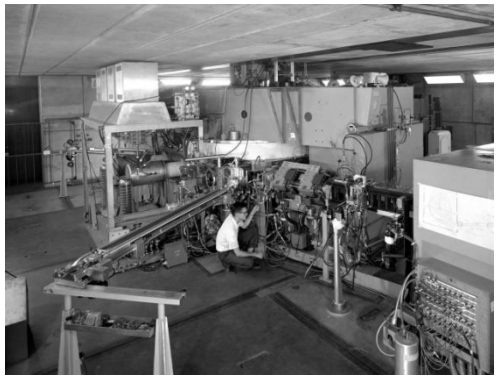

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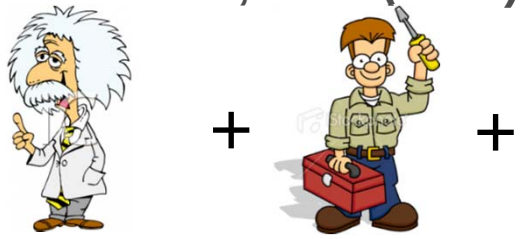

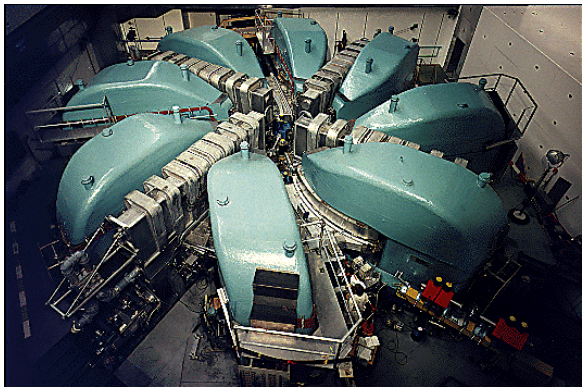

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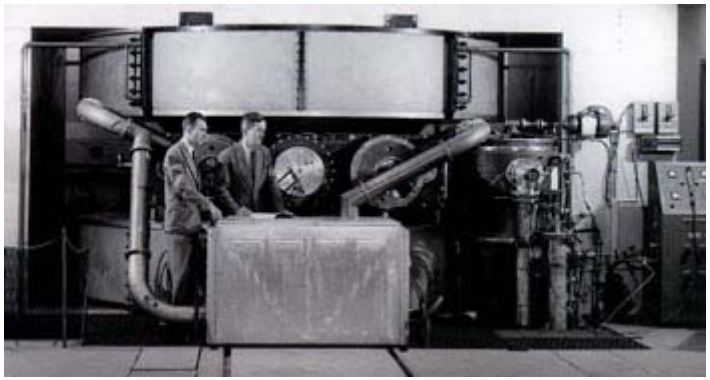

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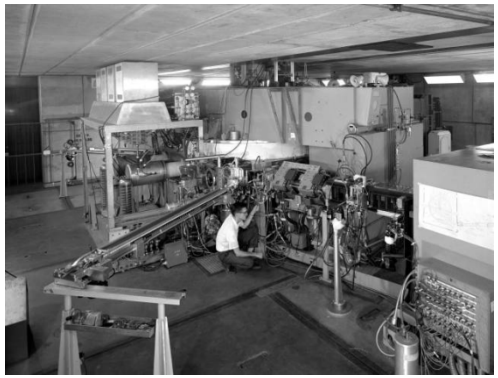

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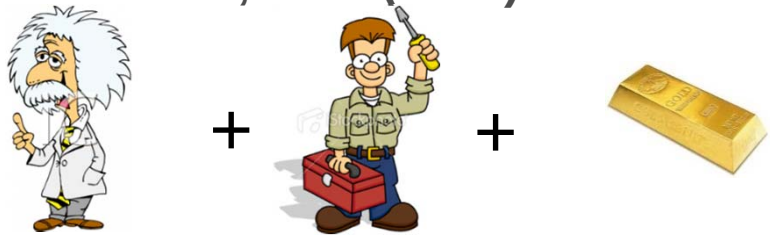

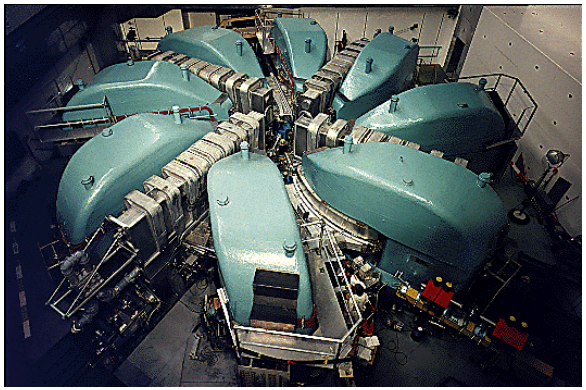

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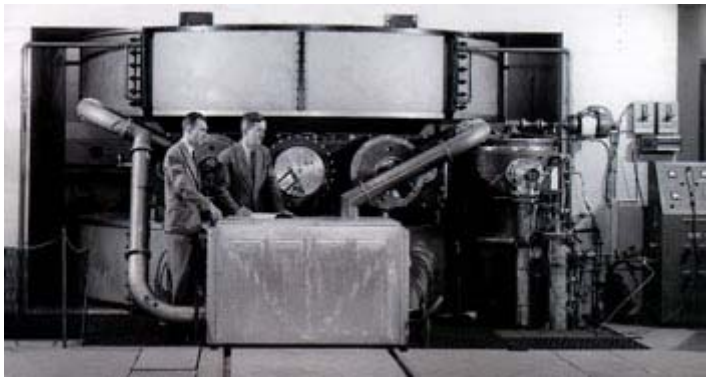

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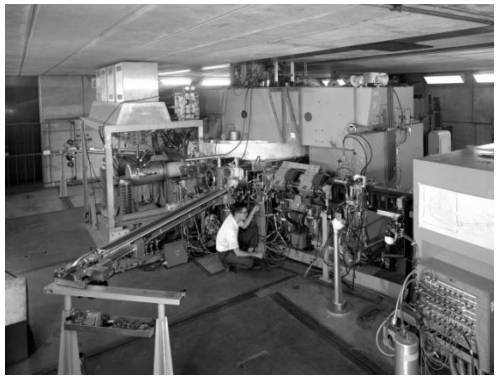

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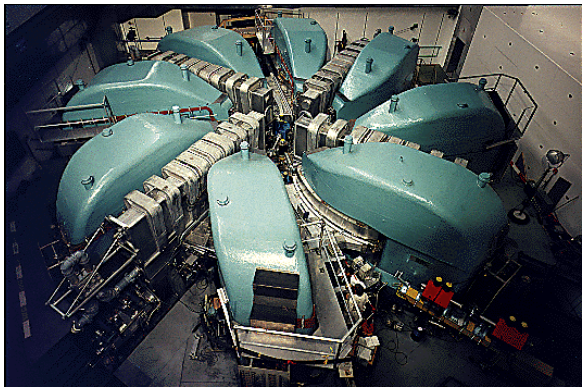

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Summary

Reliability and accelerators

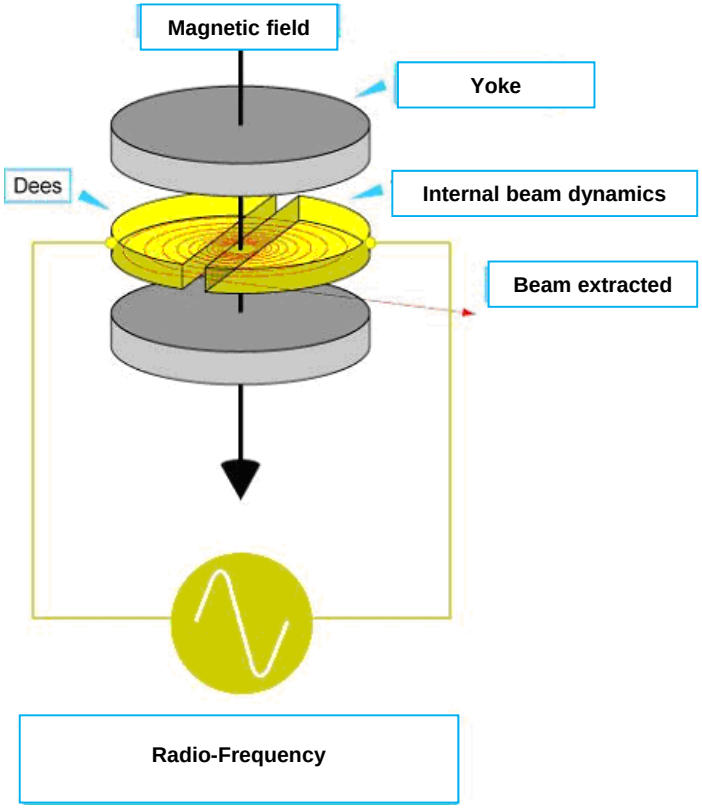
- **Concepts**: principles to increase reliability, risk to consider

- **Definition** : Importance to agree on (what, how, mode, constraints/freedoms, …)

- **Maintenance**: % determinist (mechanical, cooling, …) % based on monitoring (systems + organisations)

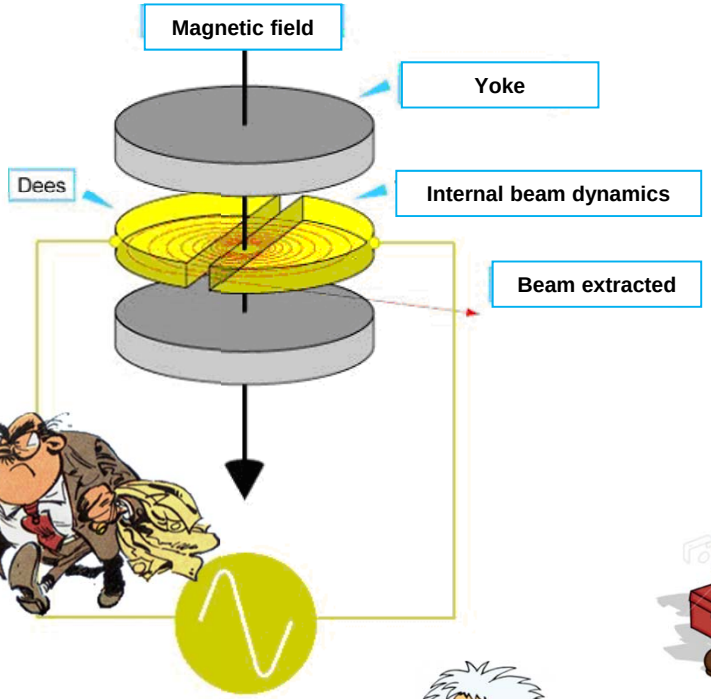
- **Responsabilities**: to etablish and clarifiy (systems, organization, Quality assurance, test, …)

- **Information**: how to get as soon as possible (other experiences, test, …), how to keep during the life of accelerator.



Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance

Building



Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance

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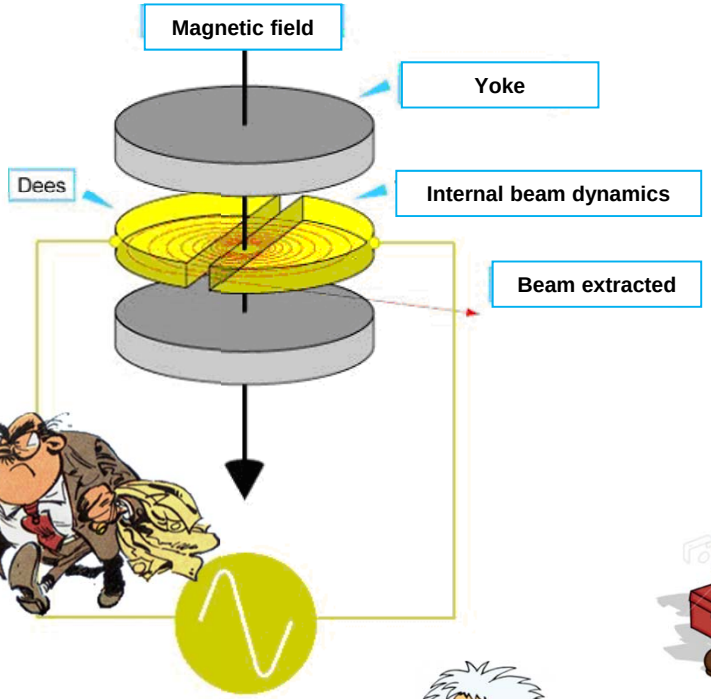
Building



Concepts Pre-studies	detailed studies	Construction Installation-Test	Operation & maintenance

THANK YOU !

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