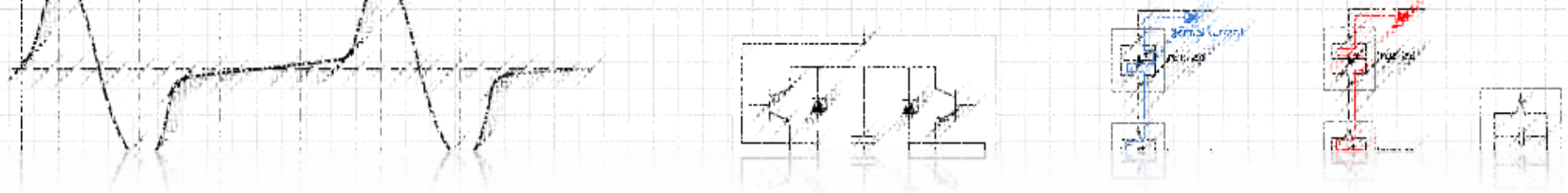

Energy Saving

an example of a test facility upgrade with pulsed magnets instead of DC magnets, saving 90% of energy consumption

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Contents

Special thanks to all Contributors: Jonathan COTTET (original presentation), Lau GATIGNON, Ilias EFTHYMIOPOULOS, Davide TOMMASINI, Dominique BODART, Gilles LE GODEC, Jean-Luc BLANC, Denis ARNOULT, Mauro NONIS, Serge DELEVAL, Rende STEERENBERG, Helfried BURCKHART, Bernard MULTON

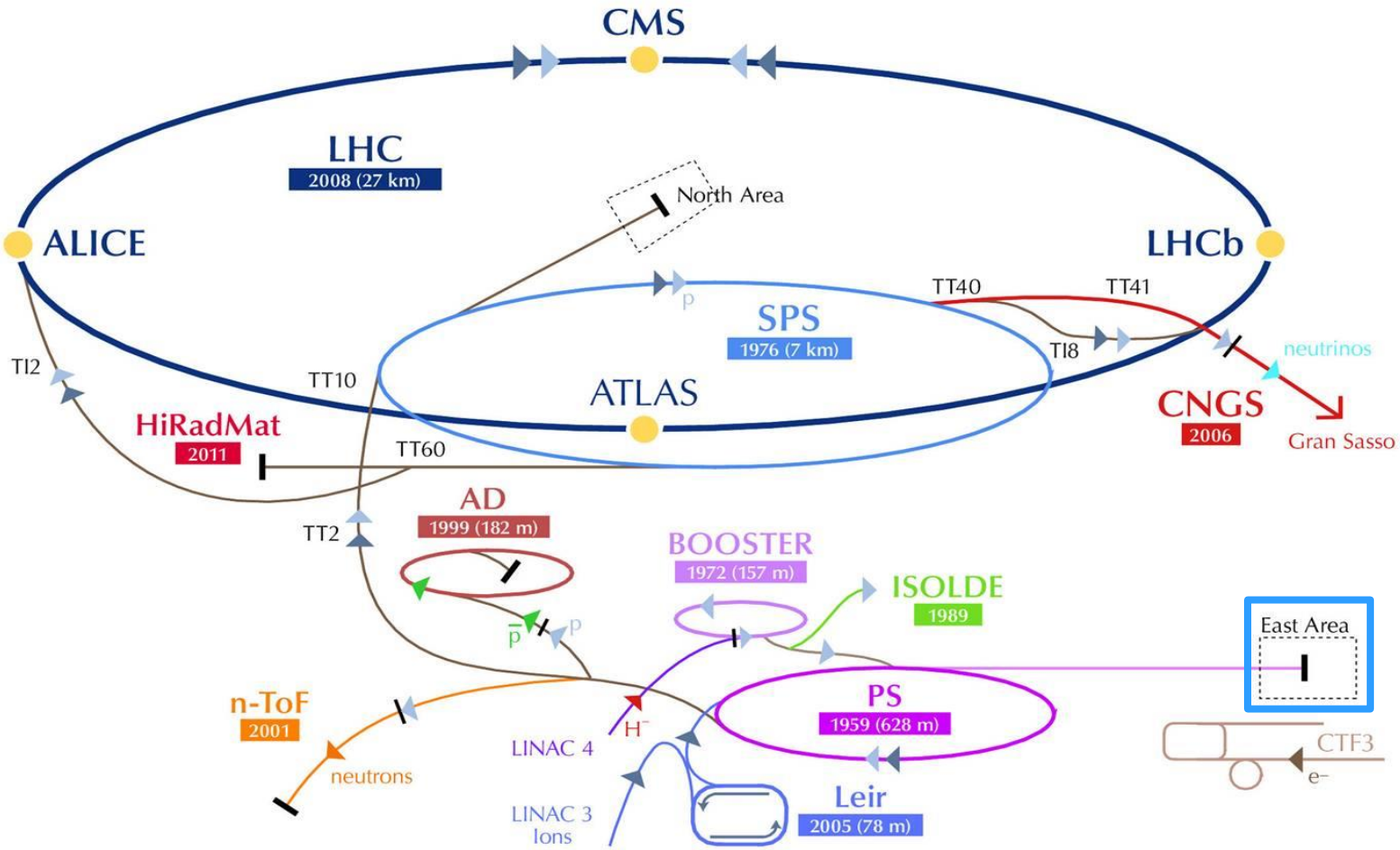
Introduction

- **Electricity at CERN**
  - Energy consumed in the year 2011: **1.2TWh**
  - An upwards Electricity price trend is foreseen
  - An increase of the consumption is expected

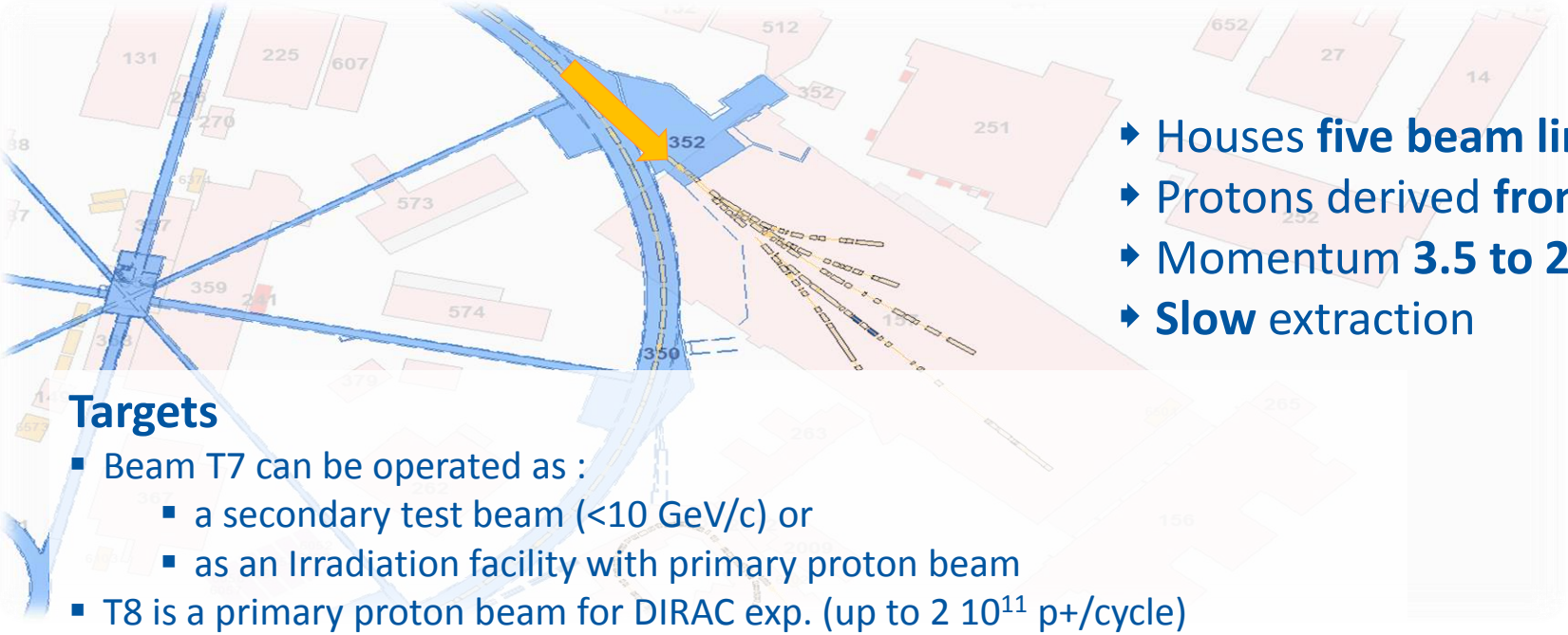
CERN Energy Coordinator: “Improve Energy Efficiency”

- **East Experimental Area: a good candidate**
  - Old installation - consolidation programme foreseen in 2018
  - Evaluation of energy balance of the PS EAST area on-going
  - Use it as a model for other projects!

The East Experimental Area



The East Experimental Area

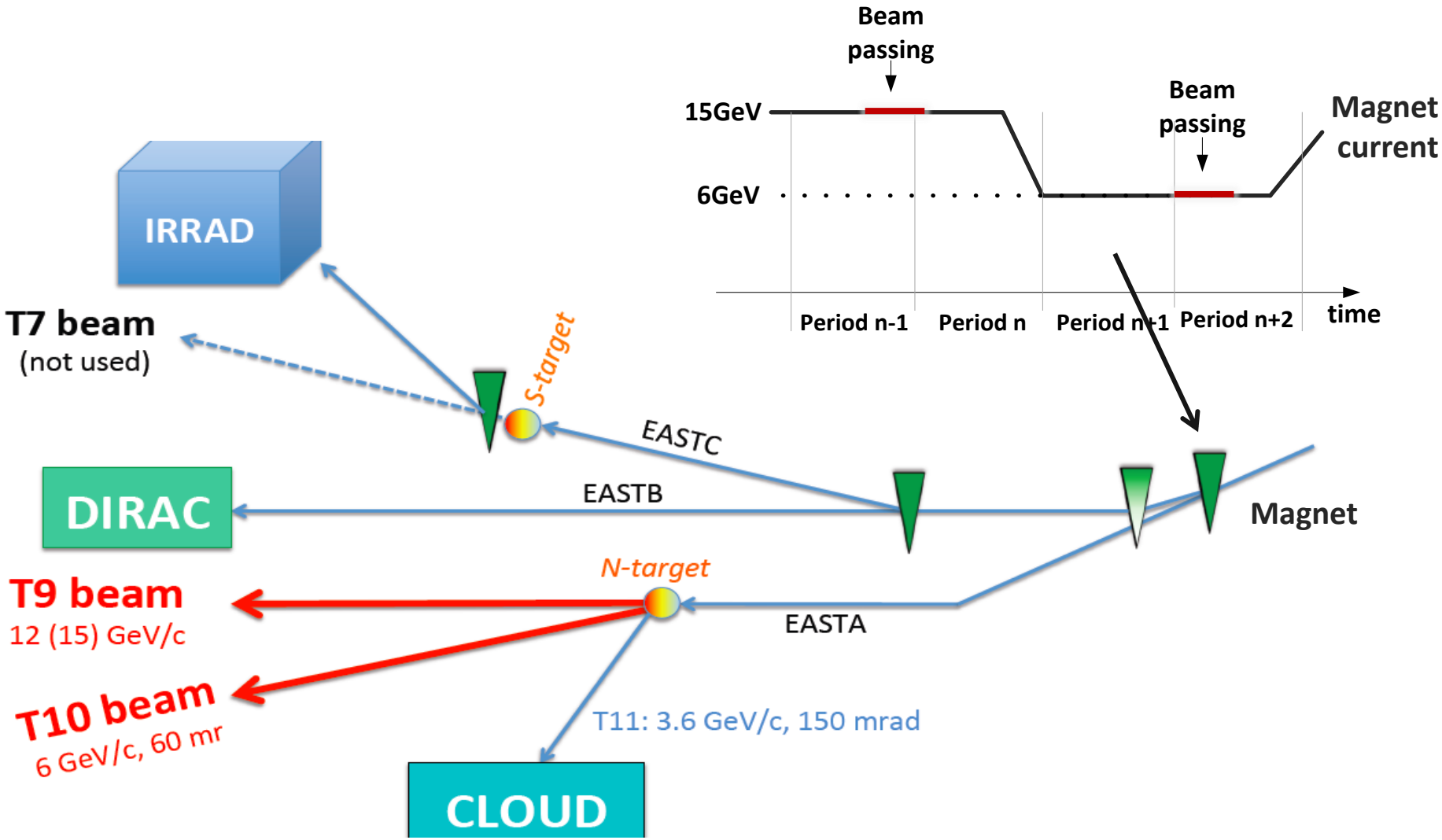


- Houses **five beam lines**
- Protons derived **from the PS**
- Momentum **3.5 to 24GeV/c**
- **Slow** extraction

Targets

- Beam T7 can be operated as :
  - a secondary test beam (<10 GeV/c) or
  - as an Irradiation facility with primary proton beam
- T8 is a primary proton beam for DIRAC exp. (up to 2 10^{11} p+/cycle)
- T9 is secondary test beam (<15 GeV/c at 0 mrad production angle)
- T10 secondary test beam (<7 GeV/c at 60mrad production angle)
- T11 can be used as
  - test beam (<3.6 GeV/c at 210 mrad) or
  - as a very large spot (almost 2x2 m2) hadron beam (CLOUD experiment)

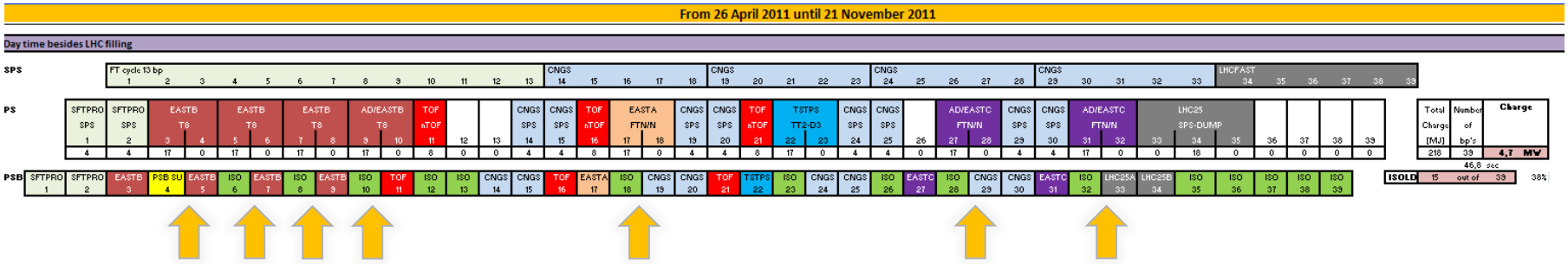
East Area Beam Lines



Duty cycle of East Area installations

A typical Super-cycle at CERN
46.8s (39 cycles of 1.2s)

Zone	Time in PS Supercycle
EASTA	4301 h
EASTB	4044 h
EASTC	3274 h



- Number of "EAST" area cycles: 7
- Beam takes 400ms to 700ms to pass through the beam line
- Particles in East Area beam lines: **3.5s** over **46.8s** of the super-cycle!
- "duty cycle" is only **7.5 %**

East Area
Energy and Water Consumption

Energy Consumption

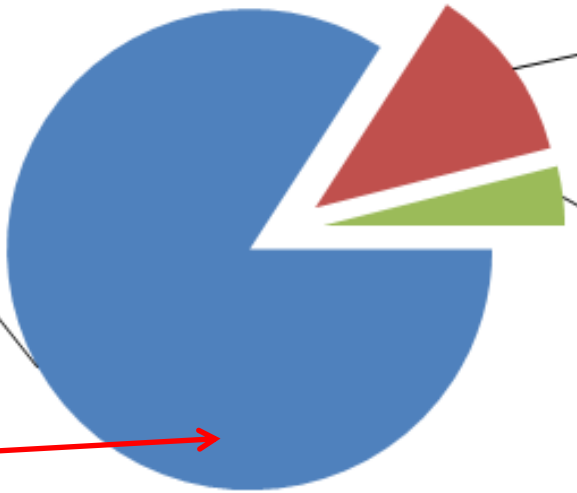
- **The East Area consumes 15GWh per year after**
- **PS (55GWh/year) and the Booster (25GWh/year)**

The East Area consumes energy continuously whereas it is used only during 7.5% of the PS Supercycle time

- Electricity consumption appears in the form of:
  - Magnet thermal power losses
  - Water and Air Cooling pumps
- But also indirect consumption of resources:
  - Water supply to compensate for evaporation in cooling towers
  - De-ionised Water and other cooling fluids

Energy Consumption: detail

2011 Electricity consumption of the East Area (in MWh)



84%
TOTAL power supply for magnets before converters
13 071

12%
Water cooling electrical supply
1 853

4%
Air cooling electrical supply (estimated)
618

Equipment	Energy in MWh
T8 Spectrometer	6 360
T7 Spectrometer	*NA*
Building 251	5 386
SMH 57 AND 61	22
Building 263	1 303

10

Key loads

- **Identified loads where potential savings can be gained**
- **Calculated cost of energy loss and cost of cooling**
- **Examine alternative, energy saving magnet operation**

EAST AREA ENERGY CONSUMPTION in 2011		
	Energy in GWh	Price in kCHF
Electrical energy	8.0	406
Total cooling fluid		75
TOTAL energy cost		**480 kCHF**

East Area Consolidation Programme

East Area Consolidation Project

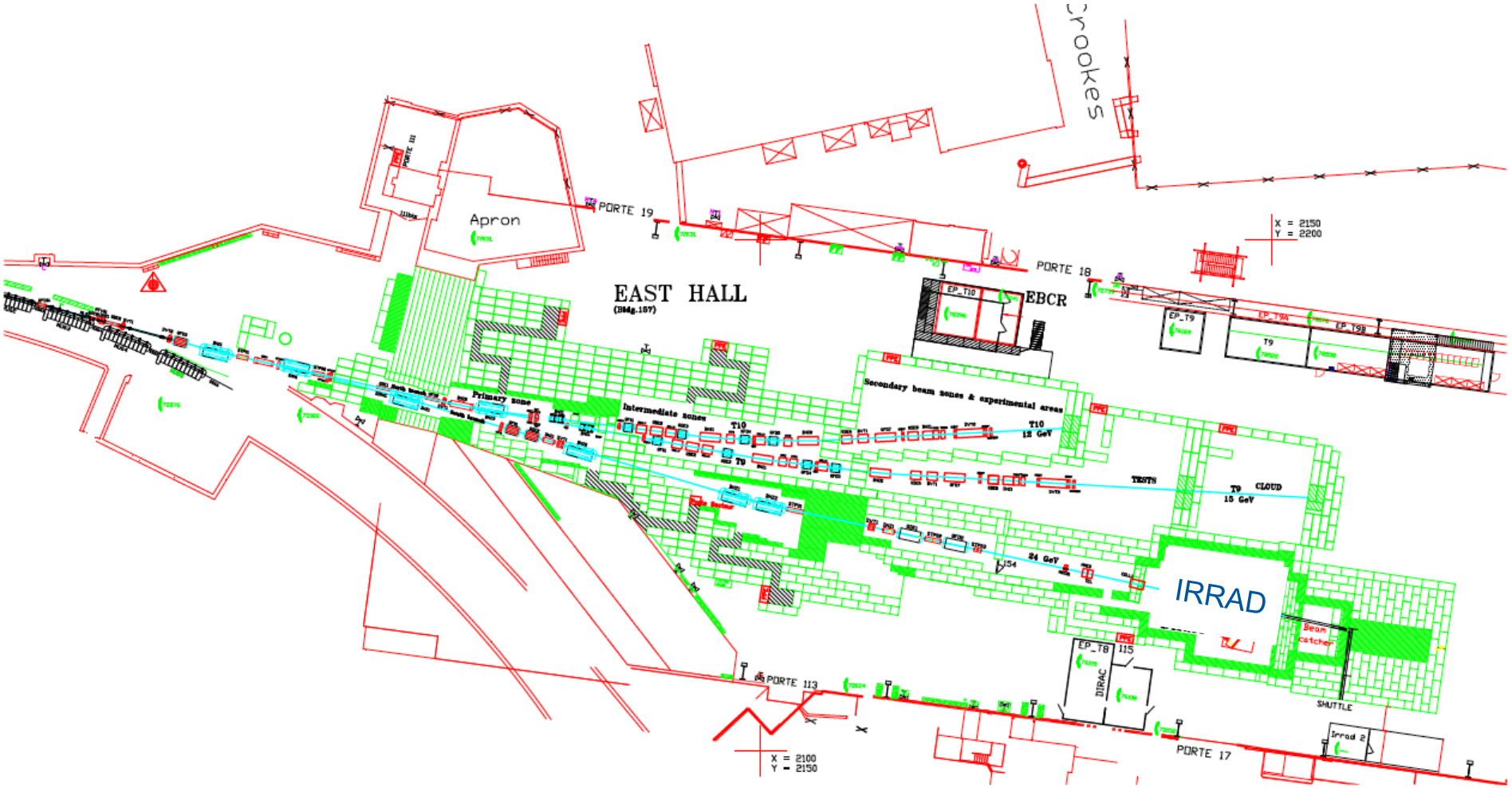
A consolidation programme includes:

- A thorough maintenance/renovation of the infrastructure
- A redesign, manufacture and installation or restoration of key equipment (magnets, power converters, power network).

Facilities in East Area after the consolidation:

- T8: Irradiation facilities for protons and “mixed field”
- T9: Test beam facility and CLOUD experiment
- T10: Test beam facility mainly for the ALICE collaboration

East Area new layout



Future Energy Consumption

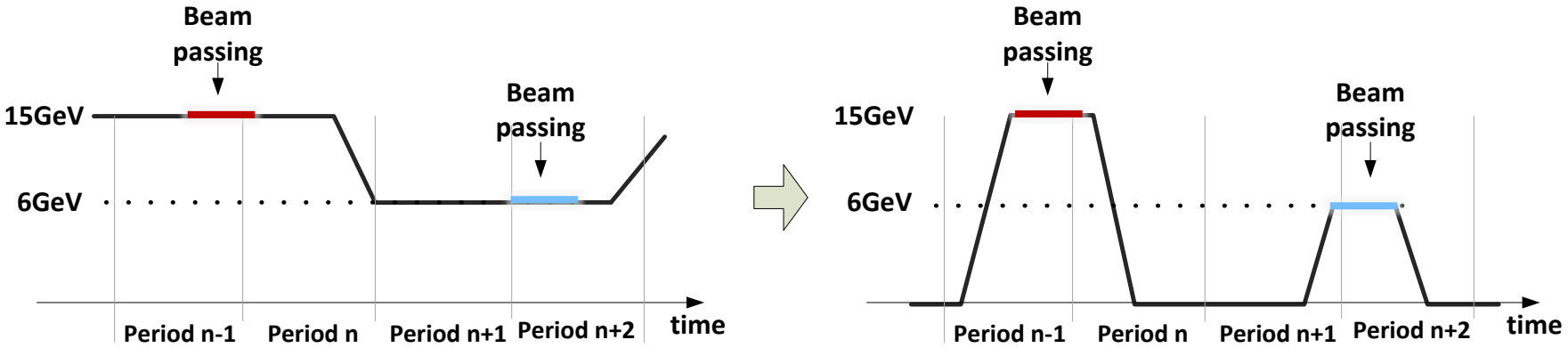
- **Assuming future operation in continuous mode**
  - The total energy cost will rise by more than 25%
  - The cooling fluid (mainly water) costs will rise by 25%
- **Despite fewer users the operating cost is higher**

	Future (3 beam lines)		Present (5 beam lines)	
	Energy in GWh	Price in kCHF	Energy in GWh	Price in kCHF
Electrical energy	10.9	**552**	9.0	**406**
Total cooling fluid		**102**		**75**
TOTAL energy cost		**653 kCHF**		**480 kCHF**

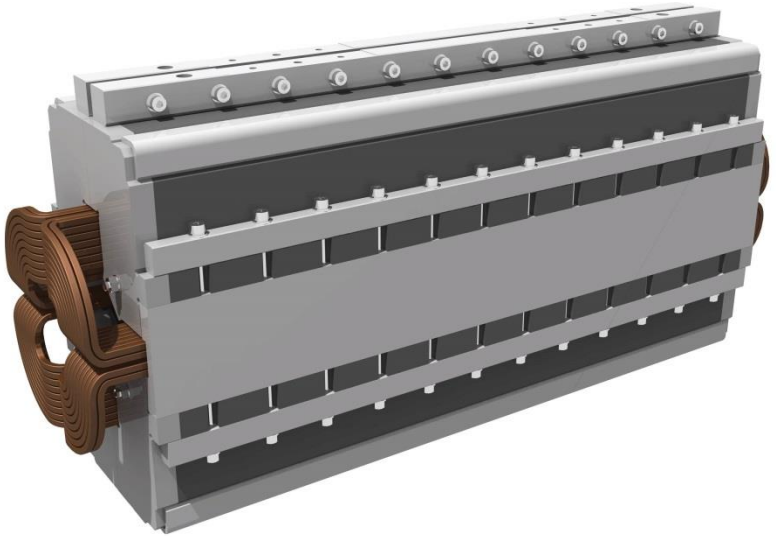
- Unless operation changes to “pulsed mode”…

Pulsed operating mode: Magnet current is reduced to zero when no beam is present in its vacuum chamber (as opposed to the continuous operating mode)

Pulsed (or cycling) operation



- **Pulsed operation requires a di/dt through the magnet**
  - 23/55 magnets do not support cycling due to a solid steel yoke
  - Eddy currents would heat up the yoke material



Magnet refurbishment cost

Solution Elaborated by the Magnet Groups at CERN

- **replacement all the solid steel yokes by new laminated yokes while keeping the present coils**

Type	Estimated Price magnet (kCHF)	Number of magnets	Total cost per family (kCHF)
MDX	20	6	120
M100	70	2	140
M200	100	5	500
Q100	50	5	250
Q200	70	4	280
Q74	40	1	40
Total		**23**	**1.3 MCHF**

- Total magnet refurbishment cost is 1.3MCHF
- Considerable cost – could it be finance by energy saving?

Pulsed Operation: consumption

FUTURE OPERATION (HYPOTHESIS)			
Zone	**number of cycle per Supercycle**	**duration in 2011 (in hr)**	**duty cycle**
Total - East	**6**	**4301**	**15%**
EASTA	**2**	**4301**	**5%**
EASTA on T9	1	4301	2.5%
EASTA on T10	1	4301	2.5%
EASTB	**4**	**4044**	**10%**

CALCULATION RESULTS: ENERGY-WATER CONSUMPTION				
	Pulsed Mode		**Continuous Mode**	
	Energy in MWh	**Price in kCHF**	**Energy in MWh**	**Price in kCHF**
Total magnet electrical consumption	557	28.3	9 128	464
Water cooling electrical consumption	79	4.0	1 294	66
Air cooling electrical consumption	26	1.3	431	22
Total electricity consumption	**662**	**33.7**	**10 853**	**551.8**
Total cooling fluid cost		**6.2**		**101.5**
TOTAL energy cost		**40 kCHF** ●		**653 kCHF** ●

Pulsed Operation: Impact

- **Pulsed operation will raise the project costs:**
  - Magnet consolidation of solid steel yokes: 1.3MCHF
  - Power Converter replacement costs will increase by: 1.5MCHF
    - ⇨ Power converter consolidation was already scheduled
  - Electrical distribution costs will be lower
    - ⇨ 2x2MVA transformers are sufficient to power the EAST Area (currently 8 transformers)

- **BUT pulsed operation will result in recurring savings:**
  - 10GWh/year
  - 600kCHF/year
- **…and a much smaller carbon**  **from the East Experimental Area**

AND pay back of the project costs will occur in 5 years

Conclusions

- **Energy Audits, a useful tool for identifying potential for saving**
- **The PS East Area is a prime candidate**
  - Continuously energised BUT used <4% of physics operations time
  - DC powering of magnets ➧ unnecessary cooling requirements
- **Pulsing the magnets drastically reduces consumption**
  - Energy requirement from 11GWh to 0.6GWh per year
  - Saving of 600kCHF per year
- **Great example of a self-funded project**
  - Extra cost of approximately 3MCHF but,
  - Short investment depreciation time - approximately **5 years**
- **East Area is a model for other projects (e.g. North area)**

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