Engineering Department

Secondary Beams & Areas

The CERN Injector Complex and Beams for non-LHC Physics

Academic Training Lecture 18-06-2012

Lau Gatignon / EN-MEF

FIXED TARGET vs COLLIDERS

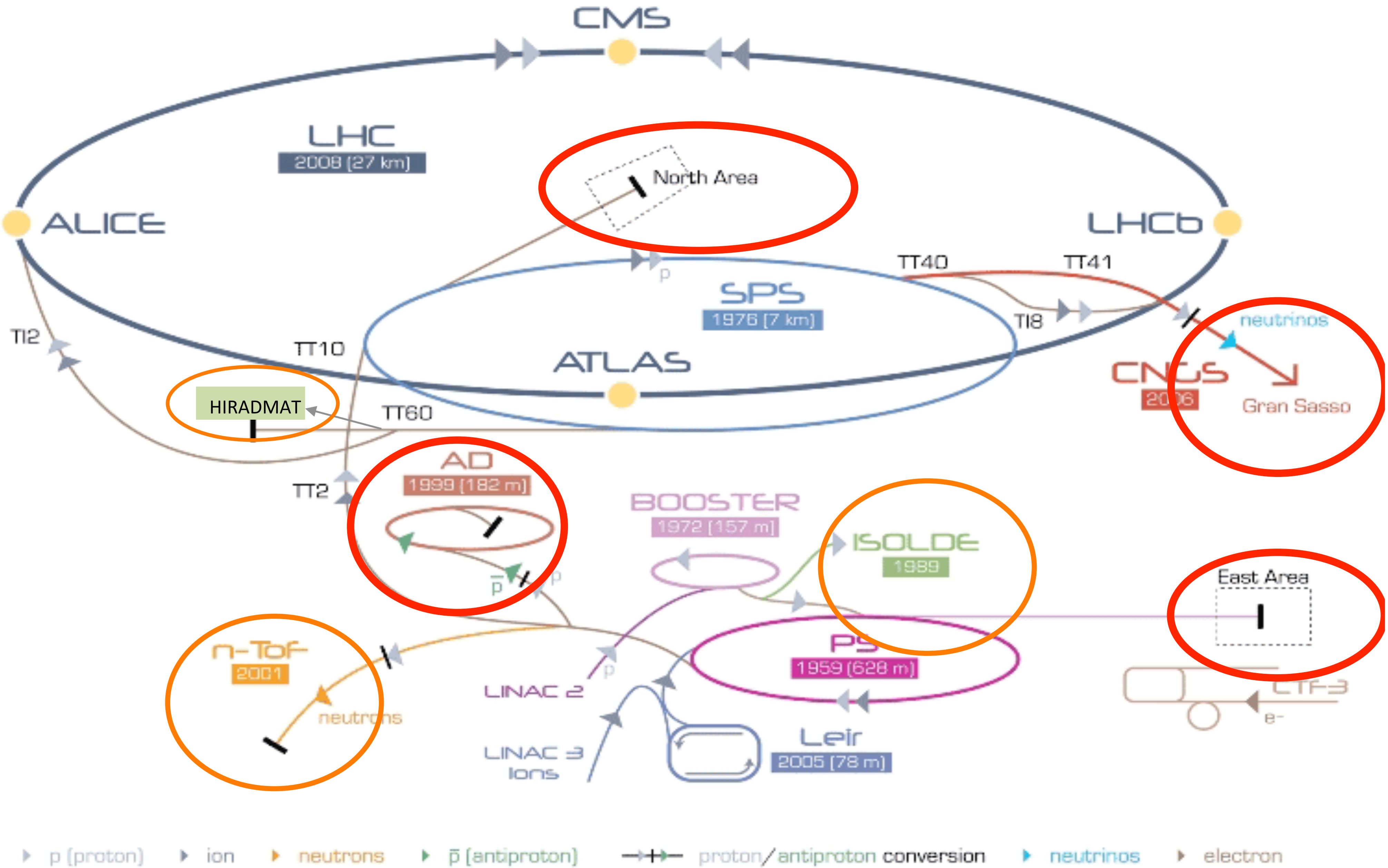
Fixed target physics is complementary to collider physics:

- The **maximum CM energy** in FT is much smaller: $s = 2\,M \cdot E_{beam}$, hence $E_{CM} \sim \sqrt{E_{beam}}$,
- But a collider is restricted to the particle types accelerated and stored in the collider, whereas fixed target beams allow control over a **wider range of particle types**
- A collider can only house a limited number of experiments, whereas a fixed target facility can house **many beam lines and experiments**.
- Collider detectors are closed and as compact as possible, therefore difficult to access, whereas fixed target experiments are normally long and open, **allowing easier access** to the individual detectors

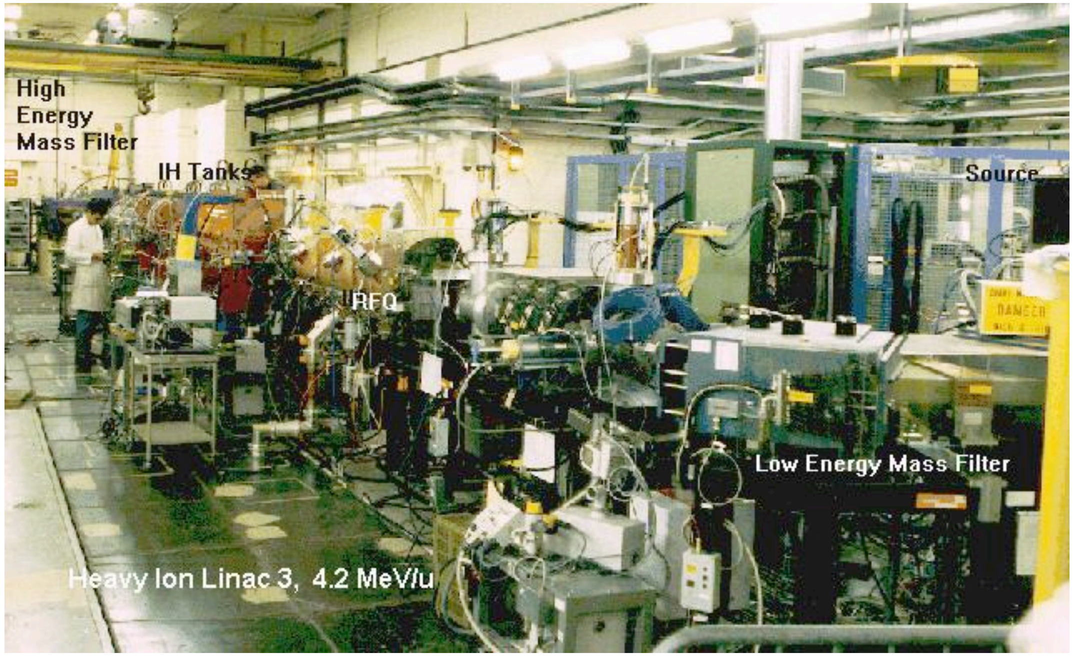
In general colliders are **discovery machines** giving access to new energy domains and thus to new and heavy particles.
Fixed target experiments are in many cases fine tuned for **specific measurements**, addressing e.g. very rare events or events with specific signatures, measuring specific values to great precision.

Both can give access to new and very interesting physics.

THE CERN ACCELERATOR COMPLEX WITH ITS EXPERIMENTAL AREAS



The LINACs: where it all starts…..



Linac2: the proton source

Built from 1973 to 1978

Total length: ~33 m + 80 m transfer line

50 MeV kinetic energy

~170 mA protons

Linac3: the heavy ions source

Commissioned in 1994

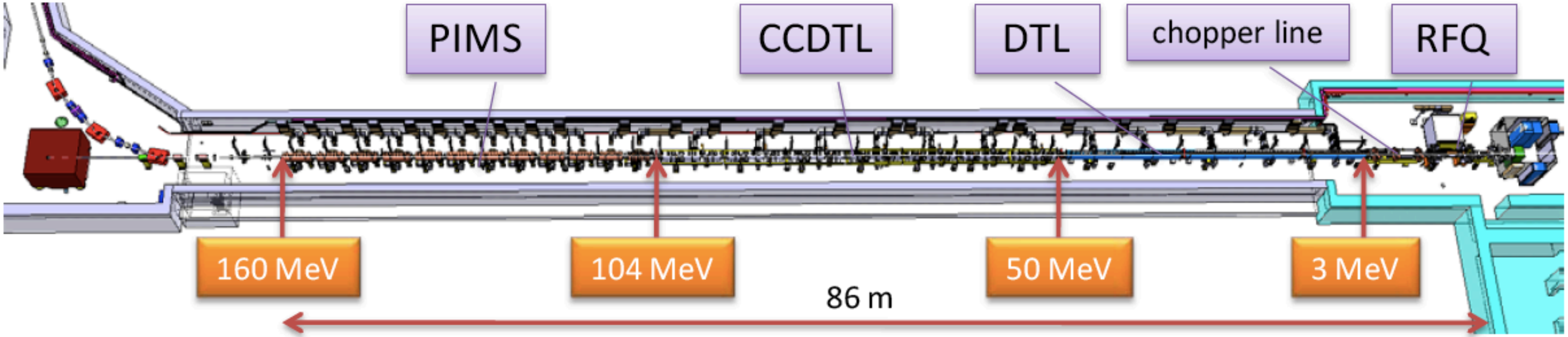
Total length: ~12 m + short transfer line

4.2 MeV/N

25 μA Pb^{54+}

Preparations under way for Ar and Xe beams

A new Linac is under construction: LINAC4



	energy	current	Pulse length (4rings)	Emittance (rms mm mrad)	
LINAC4	160MeV	40 mA	400μs	0.3	Chopped , H^-
LINAC2	50 MeV	160mA	100μs	1	

1. Lower emittance from the LINAC4, charge exchange injection allow for tailoring the emittance in the PSB
2. H- and chopping : lossless injection
3. Longer pulse , higher energy and lower current

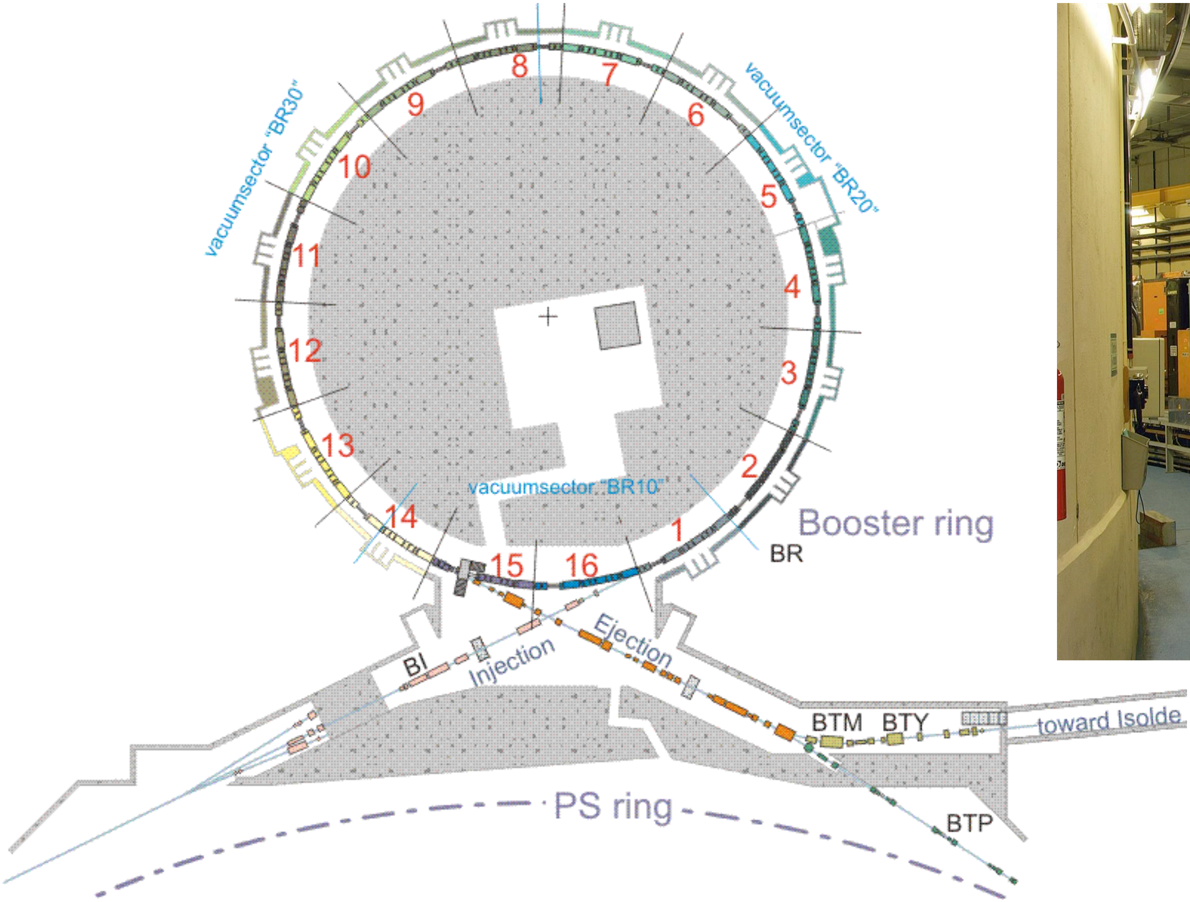
Ready for connection to PSB in 2015

The connection requires 8 months

Exact time tbd

Minor impact on FT beams

The PS Booster (PSB)



The PSB receives the beam from Linac2 and accelerates it to 1.4 GeV/c for ejection towards ISOLDE or into the PS.

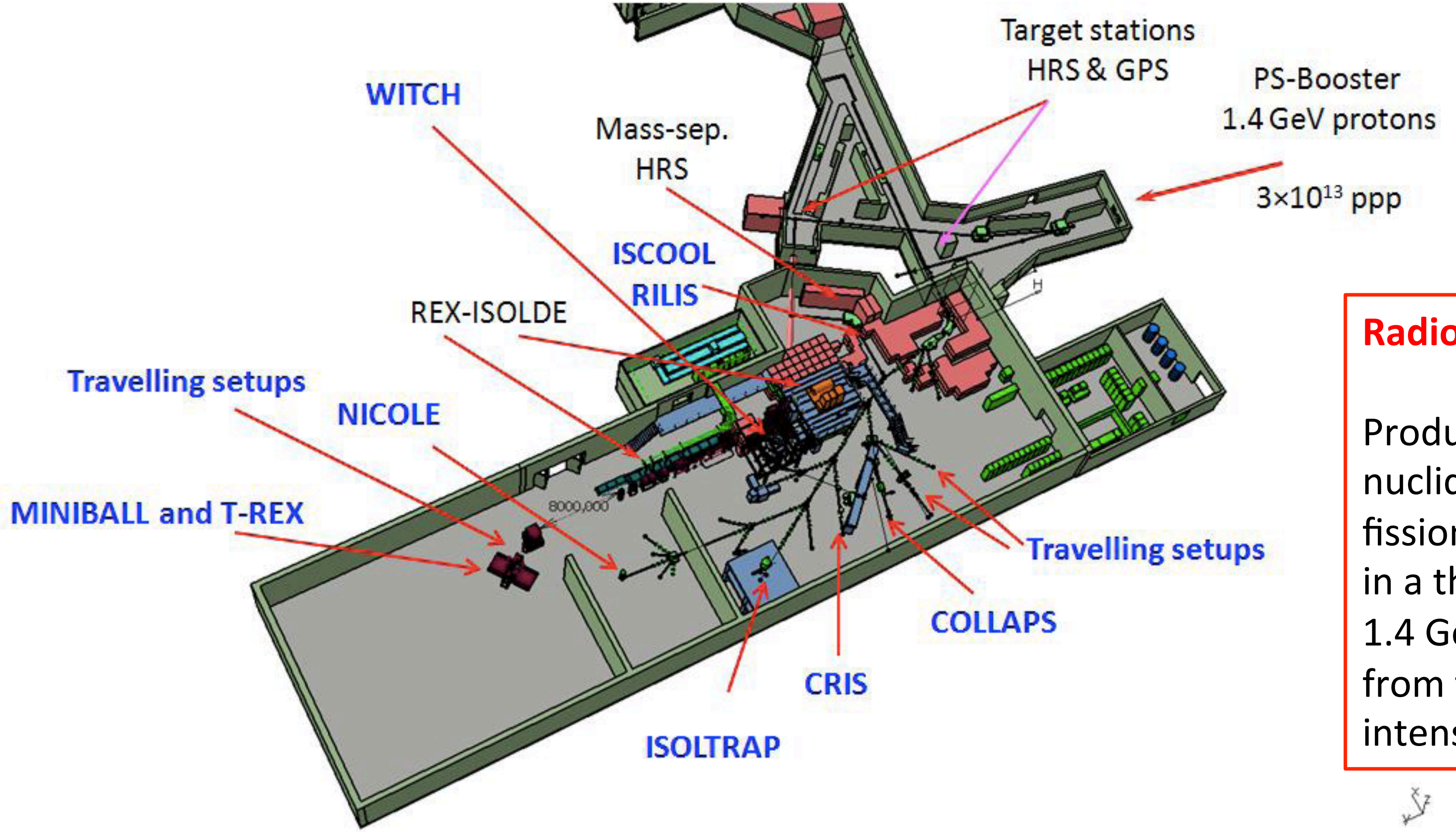
It consists of 4 parallel rings, which can be operated rather independently, e.g. 1 ring for the East Area and 1for nTOF.

The PSB cycle is 1.2 seconds. The intensity spans 4 orders of magnitude, up to 3.2 10^{13}

The PS Booster was built in 1972,
Its circumference is ~157 meters (1/4 x PS).

An upgrade to 2 GeV/c is under study, as well as towards H^- injection from Linac4.

THE ISOLDE COMPLEX

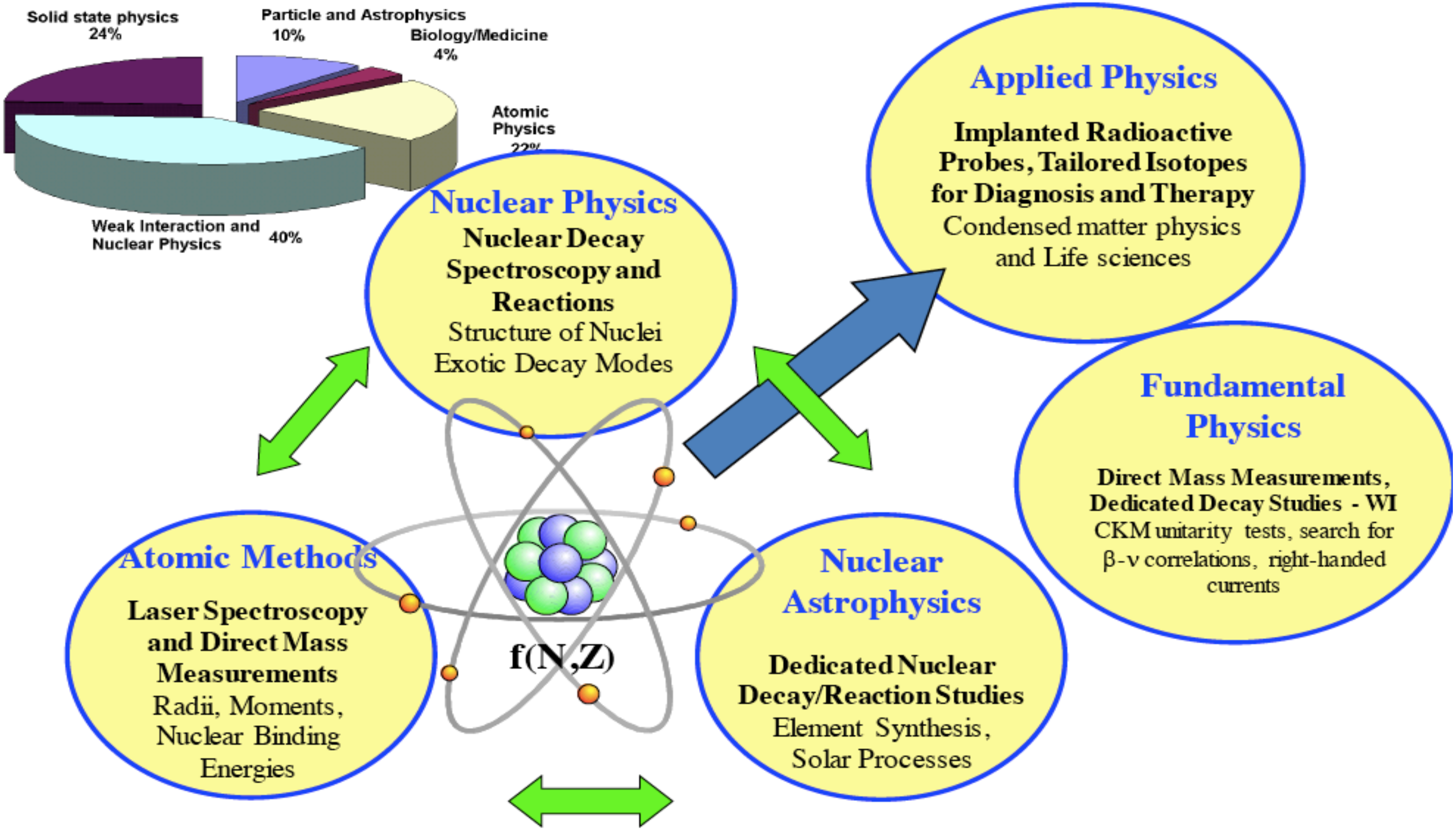


Radioactive Ion Beams

Produce radioactive nuclides via spallation, fission or fragmentation in a thick target via a 1.4 GeV/c proton beam from the PSB with an intensity up to 2 μA.

The HRS (High-Resolution Spectrometer) and General Purpose Spectrometer (GPS) are two isotope separators that deliver 60 keV mass separated radioactive ion beams. The GPS has one bending magnet and can extract three beams simultaneously. The HRS extracts one beam with two dipole magnets. Together they serve a large number of experimental installations.

Research with Radioactive Ion Beams

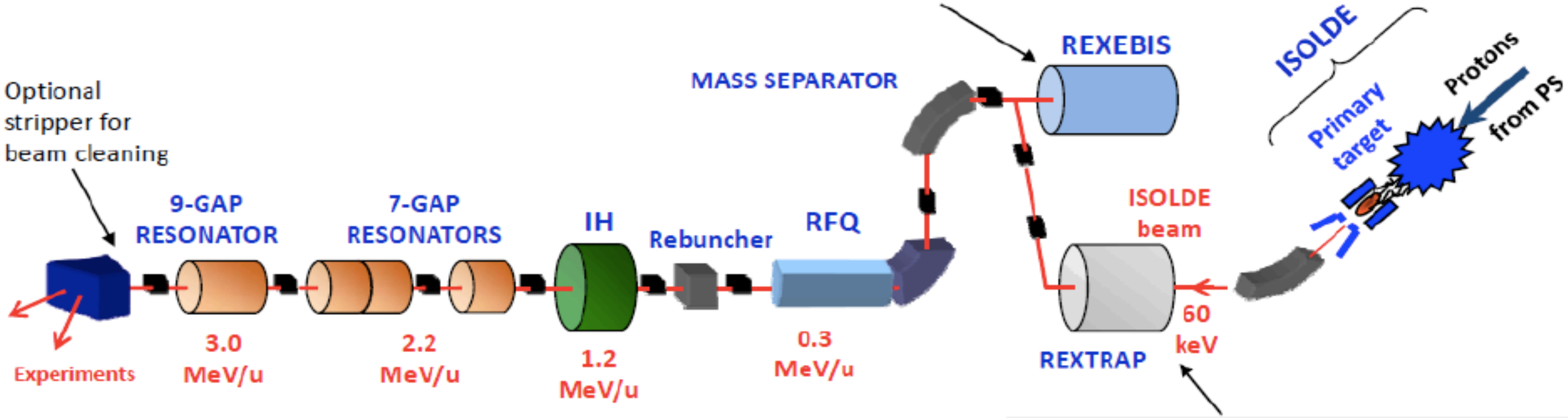


REX-ISOLDE layout

* Energy from 60 kV to few MeV/u
* Operational since Oct 2001
* Until now:
  >30 elements
  close to 100 isotopes

Electron beam ion source

* 1+ ions to n+
* Super conducting solenoid, 2 T
* Electron beam <0.4 A, 3-6 keV
* Breeding time 3 to >200 ms



Linac

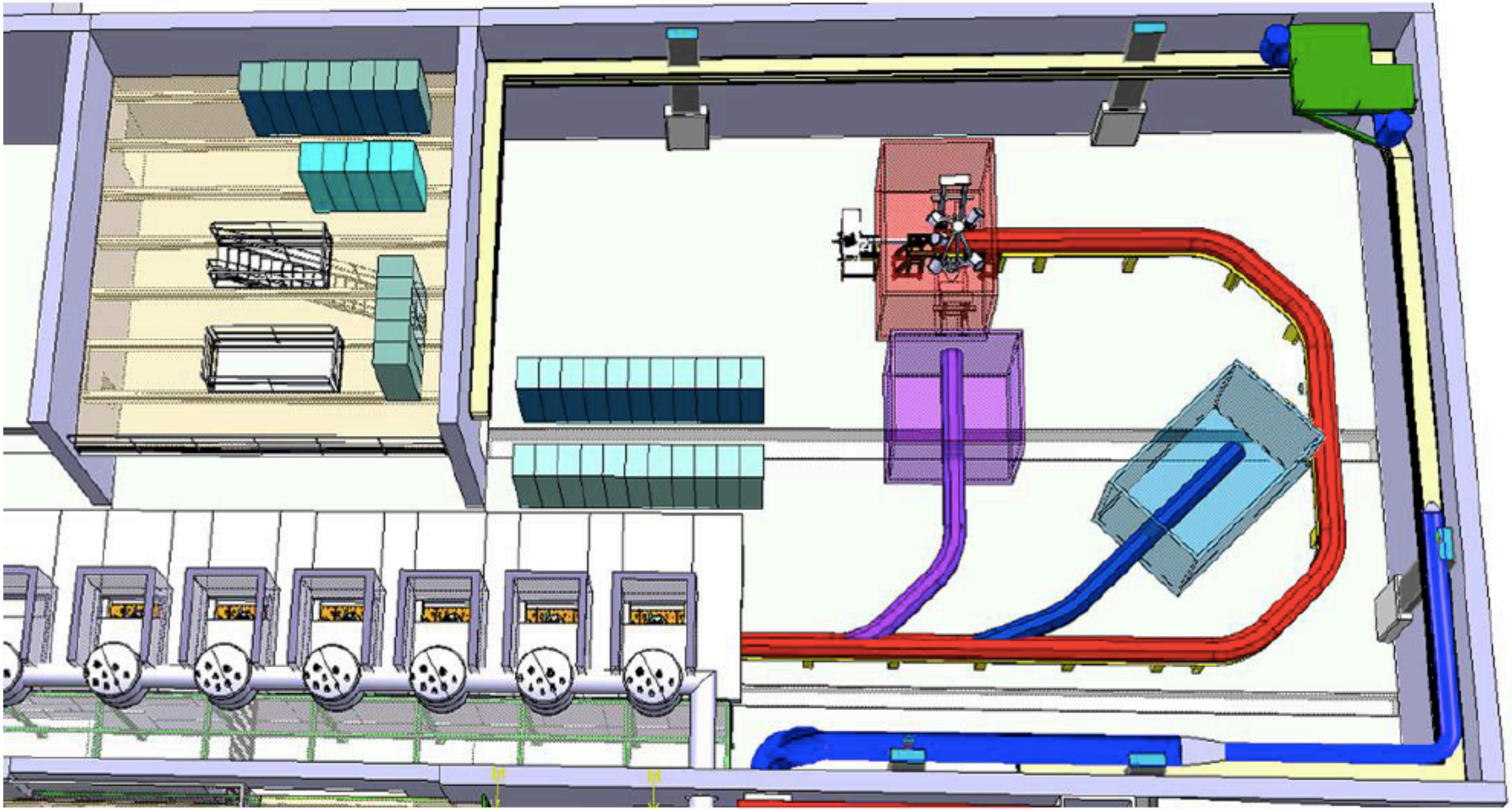
Type	normal conducting 6 accelerating cavities
Length	11 m
Freq.	101 MHz (202 MHz for the 9GP)
Duty cycle	1 ms 100Hz
Energy	300 keV/u, 1.2-3 MeV/u (variable)
A/q max.	4.5

Penning trap

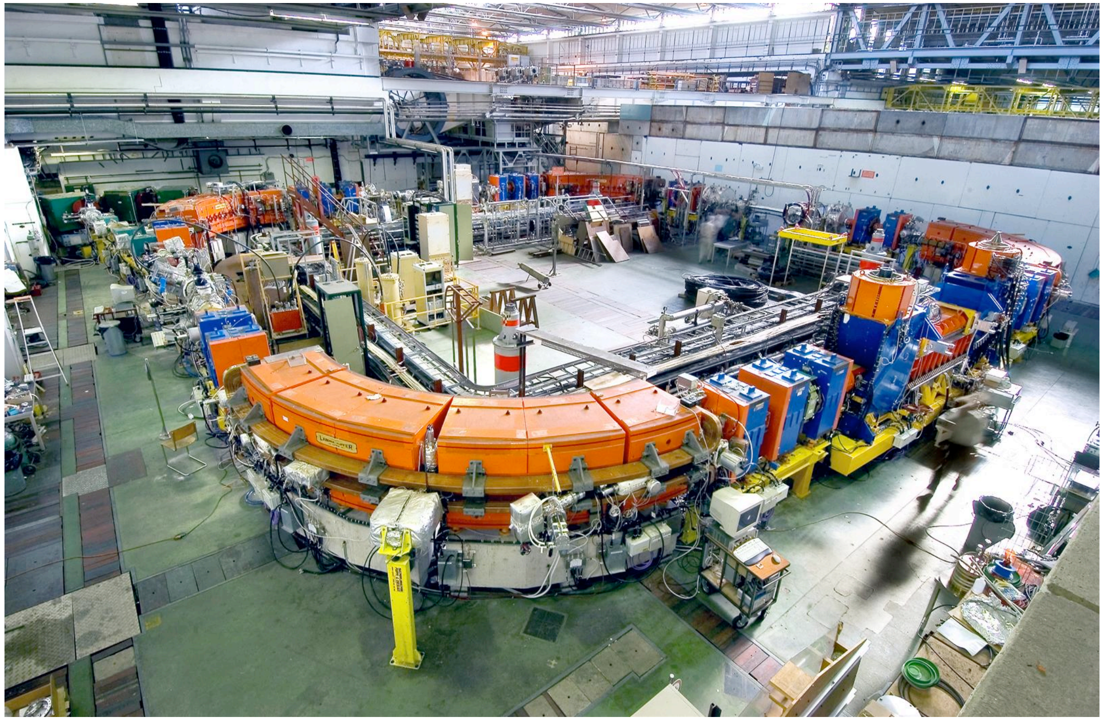
* Longitudinal accumulation and bunching
* Transverse phase space cooling
* 3 T solenoid field
  + quadratic electrostatic potential
  + RF cooling
* Buffer gas filled (5E-4 mbar)
* Cooling time ~20 ms

HIE-ISOLDE: A post-accelerator after REX-ISOLDE

Accelerate ions up to 10 MeV/u up to A/q = 4.5. First phase planned for 2015.



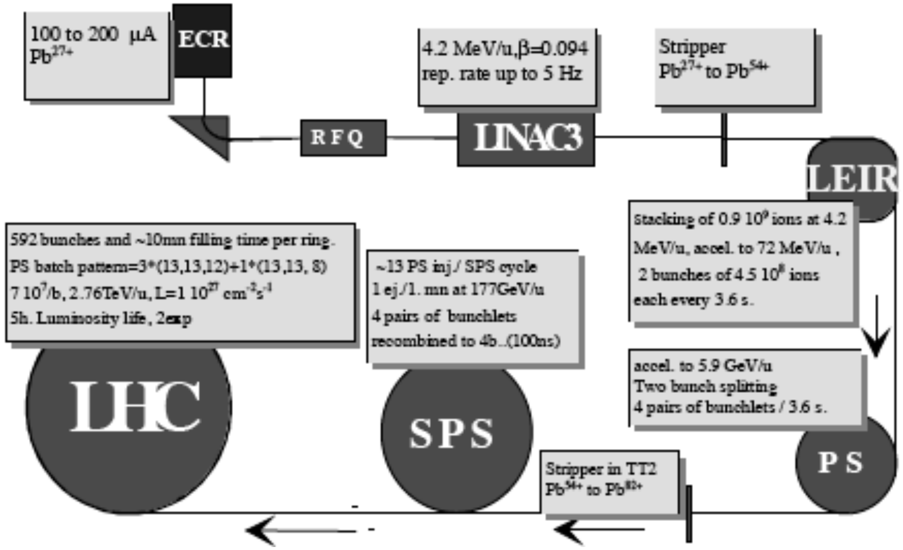
LEIR = Low-Energy Ion Ring



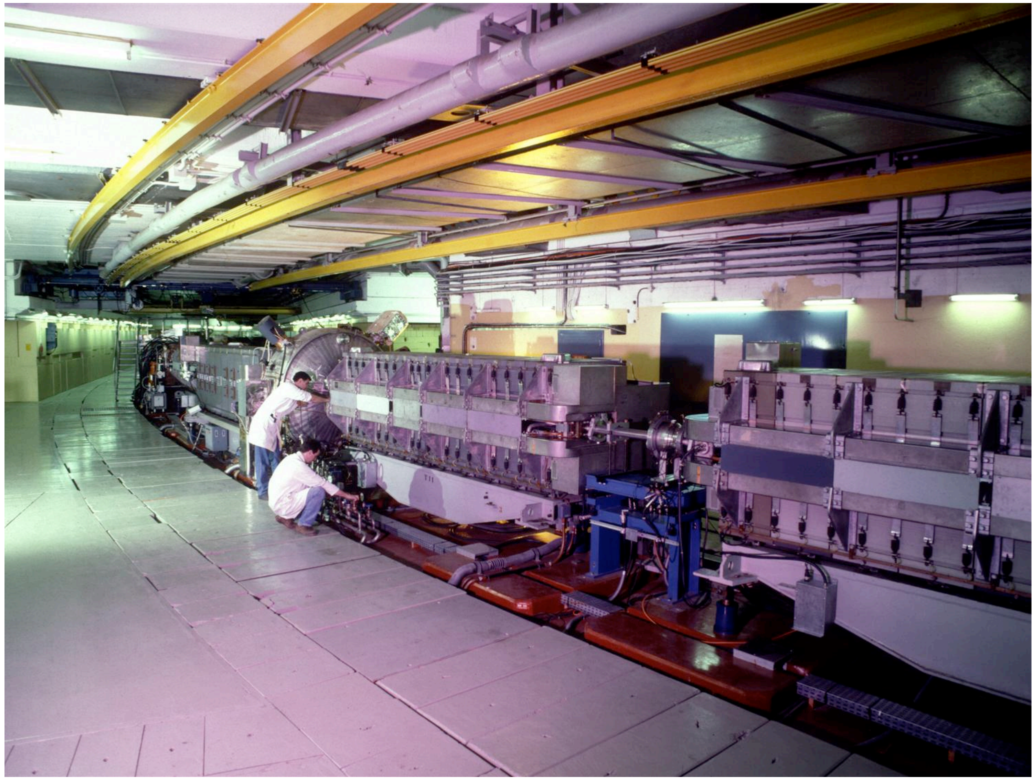
The LEIR ring accumulates ions from Linac3 for injection into the PS and from there via the SPS to the North Area or the LHC.
The ion beam is cooled with strong electron cooling in order to reach the high density needed for LHC ion operation. LEIR also plays a central role in providing the ion beams for the North Area ion physics program.

The LEIR machine uses a multi-turn injection from Linac3, normally Pb^{54+}, but lighter isotopes are possible (e.g. Ar and Xe). They are accelerated to 72 MeV/u, then further accelerated by the PS and fully stripped before being sent to the SPS.

The LEIR circumference is about 80 m.



THE PROTON SYNCHROTRON (PS)



The Proton Synchrotron is the oldest machine at CERN, commissioned in 1959 (!) ,but it is still functioning well and even well beyond its initial specifications!

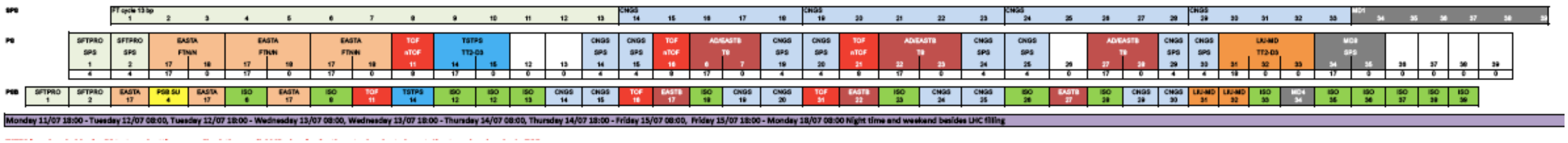
The PS is still vital for almost all beams at CERN and its versatility and flexibility is truly impressive.

Contrary to the SPS, the PS has no separate quadrupoles, but it has shaped pole faces and special coils in the main magnet units to provide the focusing. In total there are 100 main magnets and as many straight sections with special function equipment

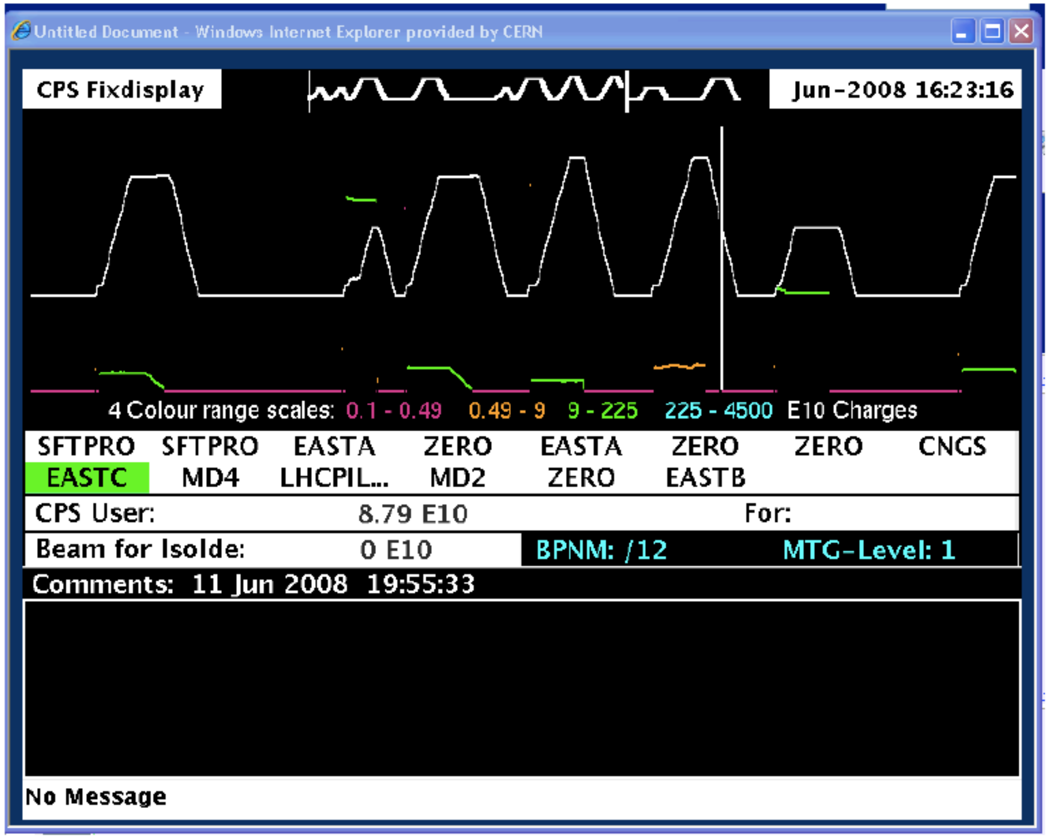
The PS has a circumference of ~628 meters and is capable to accelerate protons up to 26 GeV/c.

It operates in a cyclic mode with a basic period of 1.2 seconds. The PS super-cycle is driven by the SPS, which has recently operated with a repetitive cycle of about 45.6 seconds. Within that time the PS must serve all users, including the SPS North Area, CNGS, the LHC, the AD, the East Area, nTOF and machine studies. The proton intensities per cycle vary from 10^{11} ppp for DIRAC to 2-3 10^{13} ppp for CNGS.

EXAMPLE OF A PS SUPER-CYCLE



Or e.g. :
(part of s.c.)



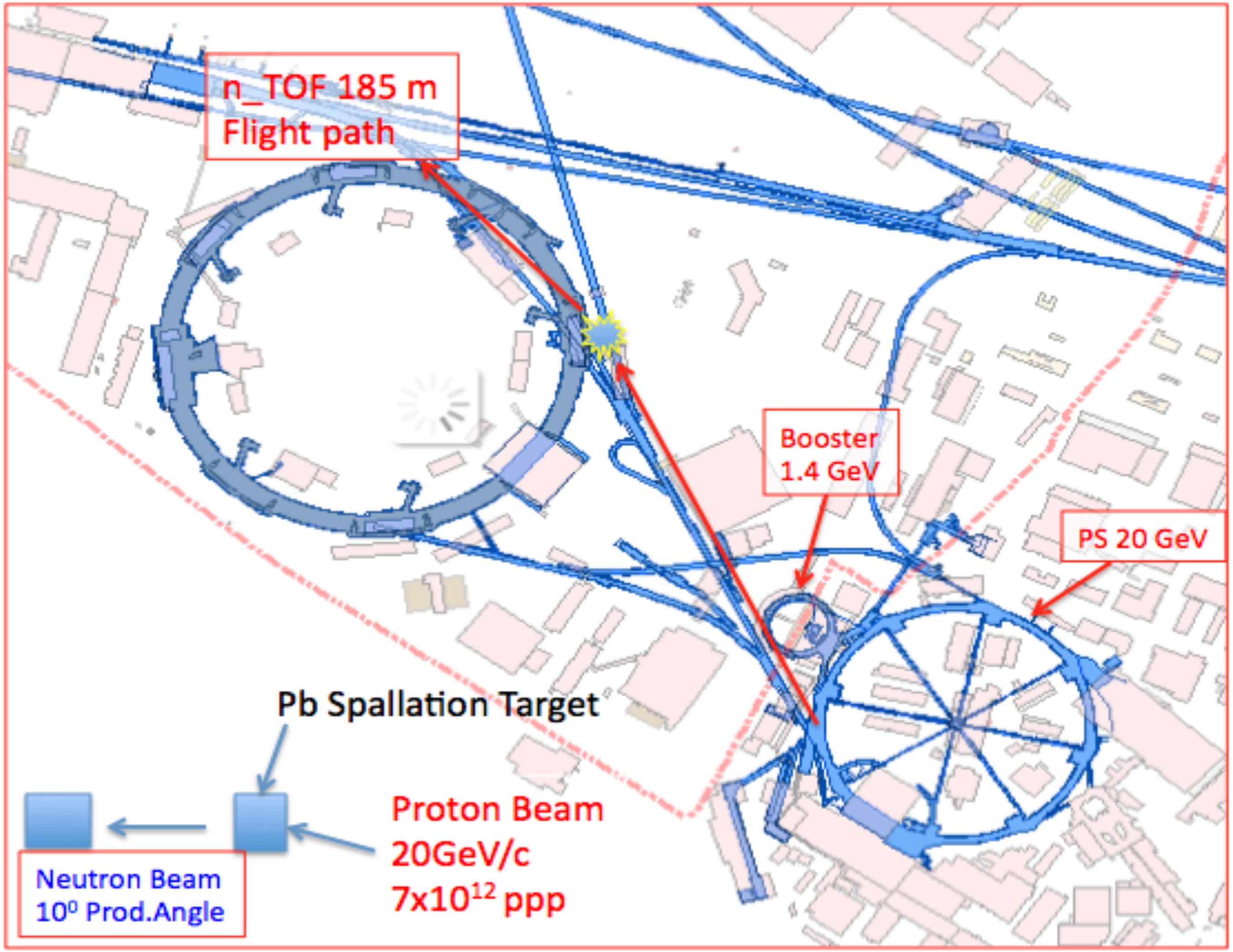
The super-cycle can now be re-programmed ‘on the fly’

SOME TYPICAL PS CYCLES

User	Momentum	Flat top	Intensity	Duration	Comments
SFTPRO	14 GeV/c	–	Up to 3 10^{13}	1.2 s	Need 2 to fill SPS *)
CNGS	14 GeV/c	–	Up to 3 10^{13}	1.2 s	Need 2 to fill SPS *)
LHC	26 GeV/c	–	1.4 10^{11}/bunch	1.2 s	
EASTA	24 GeV/c	0.4 s	2-3 10^{11}	2.4 s	For test beams T9+T10 + CLOUD
EASTB	24 GeV/c	0.4 s	1.2 10^{11}	2.4 s	For DIRAC experiment
EASTC	24 GeV/c	0.4 s	Up to 5 10^{11}	2.4 s	For Radiation facility
TOF	20 GeV/c	–	8 10^{12}	1.2 s	
AD		–	1.5 10^{13}	1.2 s	Only once per ~90 seconds
MD					Variable parameters

*) The SPS circumference is 11 times the PS one. Need 1/11th of SPS for kicker switching and 5 turns of the PS to fill one half. The so-called CT extraction takes 5 turns.

nTOF: THE NEUTRON TIME OF FLIGHT FACILITY

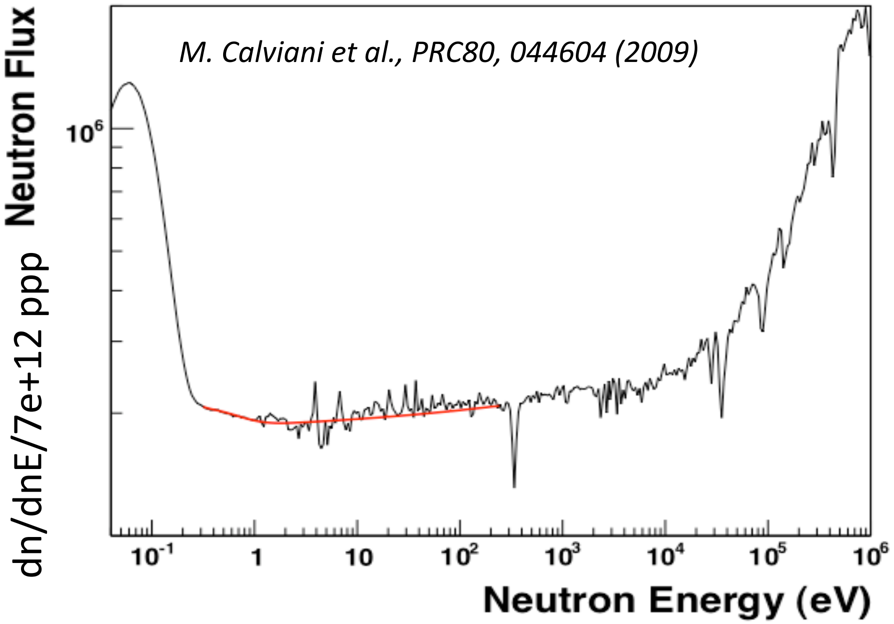


Neutrons are generated by a **pulsed** beam of 20 GeV/c protons (6 ns RMS), hitting a lead spallation target.

Each pulse provides up to 8 10^{12} protons (~25 kJ), i.e. 6-20 kW on average.
Every proton yields ~300 n.
The neutrons span an energy range from the **meV** to the **GeV** region.

The neutrons are collimated and guided through an evacuated pipe of 185 m length to the experimental area, where the neutrons impinge on a sample.
A number of detectors allow to detect the reaction products.

The n_TOF facility



Main features of the n_TOF:

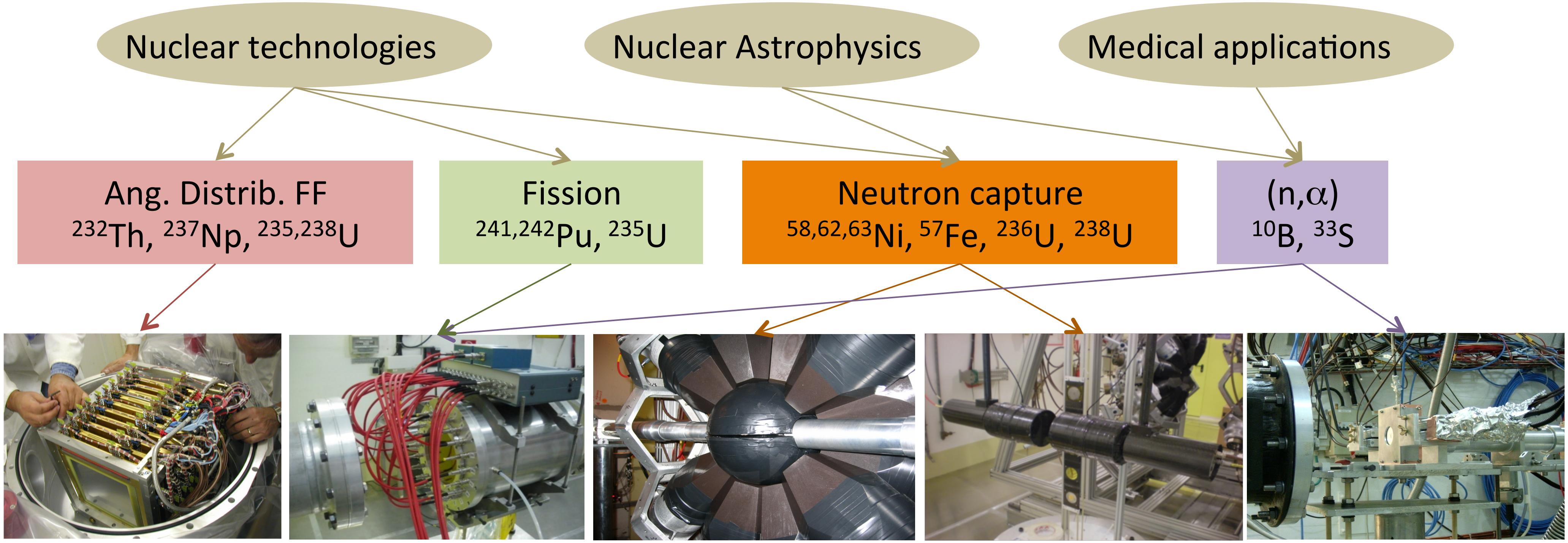
- Proton **intensity** *$8x10^{12}$ p/pulse*
- Proton beam **momentum** *20 GeV/c*
- Proton **pulse width** *6 ns (rms)*
- high **instantaneous n flux** *10^5 n/cm^2/pulse*
- wide energy **spectrum** *25 meV$<E_n<$1GeV*
- low **repetition** rate *< 0.8 Hz*
- good energy **resolution** *$\Delta E/E = 10^{-4}$*

Neutron beam + state-of-the-art detectors and acquisition systems make n_TOF UNIQUE for:

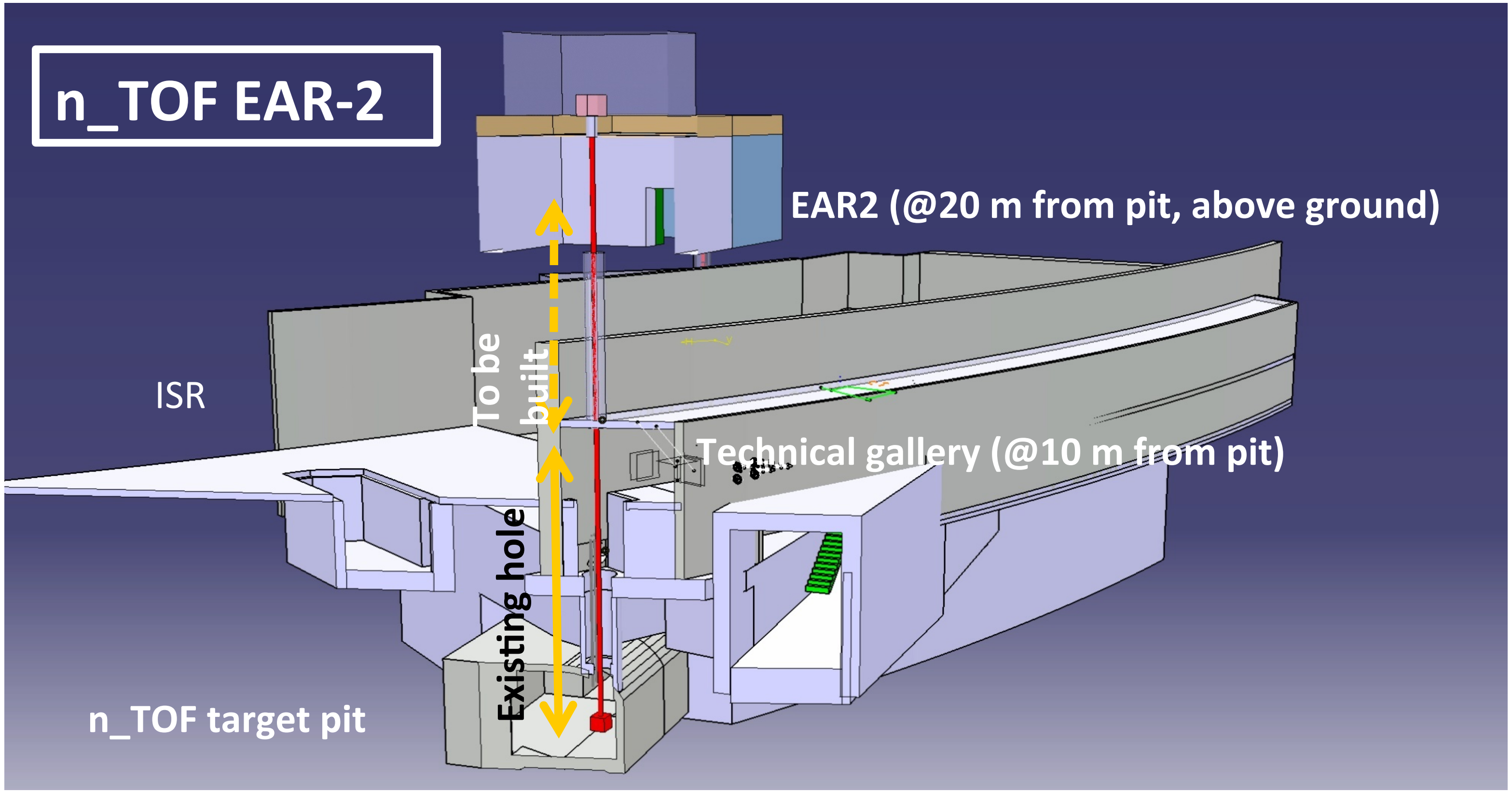
- measuring **radioactive isotopes**, in particular **actinides**
- identifying and studying **resonances** (at energies higher than before)
- extending **energy range** for fission (up to 1 GeV !).

nTOF PHYSICS MOTIVATIONS

range from nuclear technology (ADS, nuclear transmutation, etc) via basic nuclear physics to nuclear astrophysics and medical applications.



nTOF EAR2 : AN UPGRADE OF THE EXISTING FACILITY

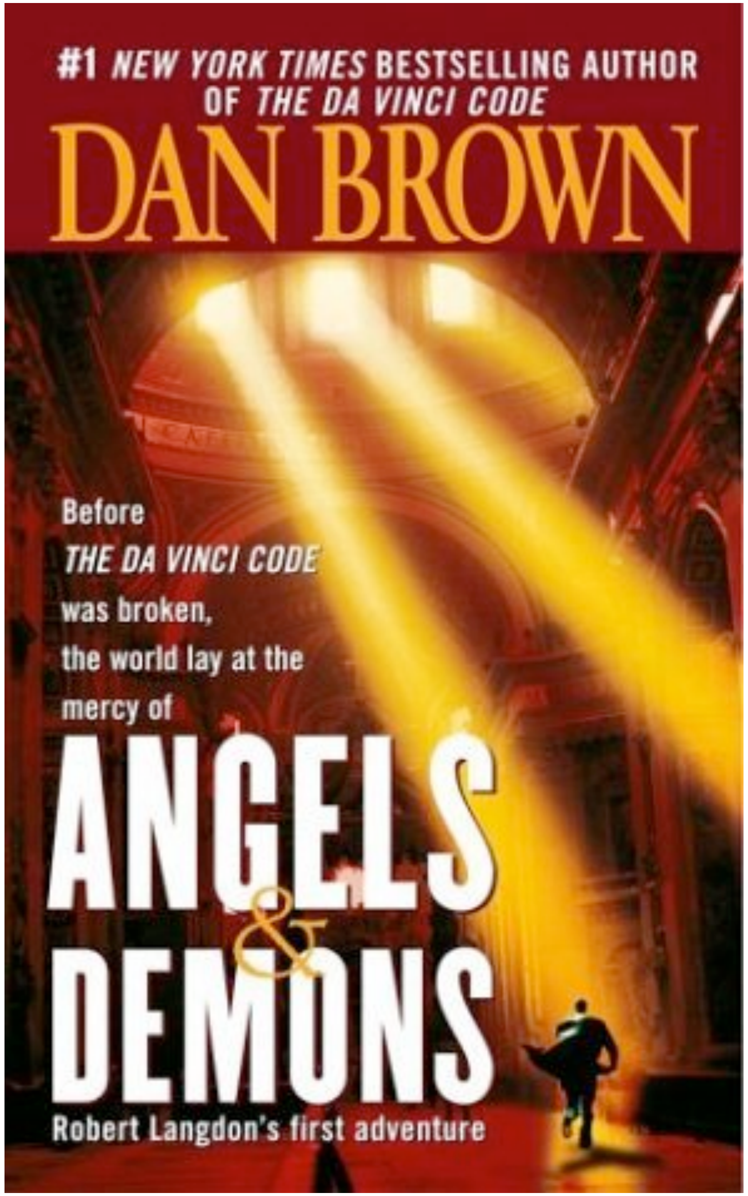


Main advantages of EAR-2 wrt. EAR-1

- Neutron fluence increase in a factor 18-25 w.r.t. EAR-1.
- Strong reduction of the g-flash because of vertical flight path (EAR-1 is placed forwards wrt. p beam) .
- Complete neutron beam width reduced by a factor of 10: increase S/B ratio for radioactive samples.

Together, these improvements will result in more accurate and faster cross-section measurements, and open the door to new physics cases at even higher neutron energies.

The Antiproton Decelerator (AD)



Antiprotons are produced from pulses of $1.5\ 10^{13}$ protons at 26 GeV/c on a Iridium production target, followed by a magnetic horn.

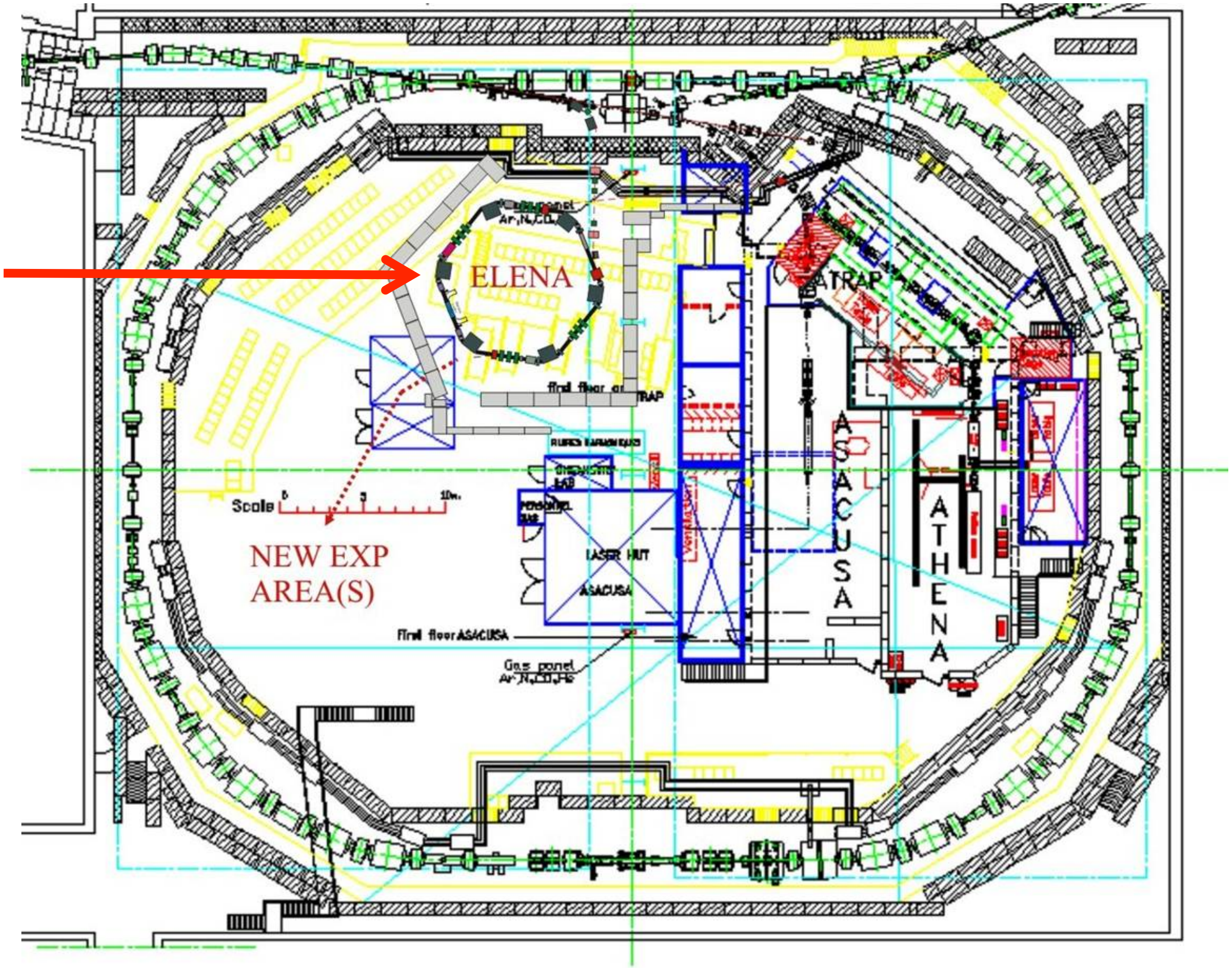
The antiprotons are collected at 3.57 GeV/c. Bunch rotation allows to decrease the $\Delta p/p$ from ±3% to ±0.75%. Before deceleration, further reduction of the $\Delta p/p$ as well as further reduction of transverse emittance is achieved by stochastic cooling.
The antiprotons are then decelerated to 100 MeV/c. During this deceleration, the beam is again cooled several times with stochastic and electron cooling to counteract adiabatic blow-up during the energy decrease.

The beam is fast extracted and then sent to the experiments ALPHA, ATRAP, ASACUSA, AD4/ACE and AEGIS. The pbar intensity is about $4\ 10^{7}$ per pulse.

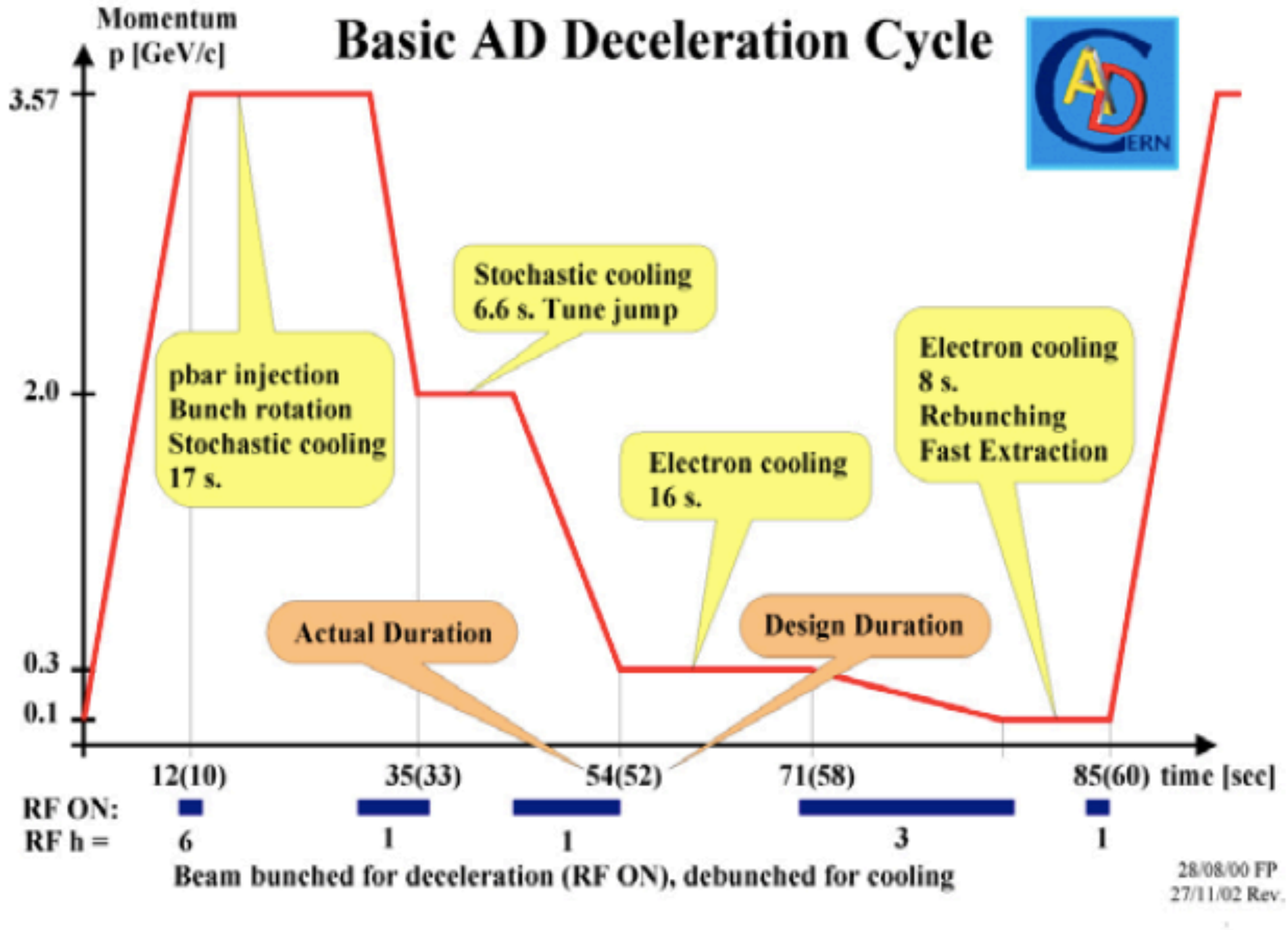
The (magnificent!) physics at the AD experiments will be explained by J.Hangst later this week.

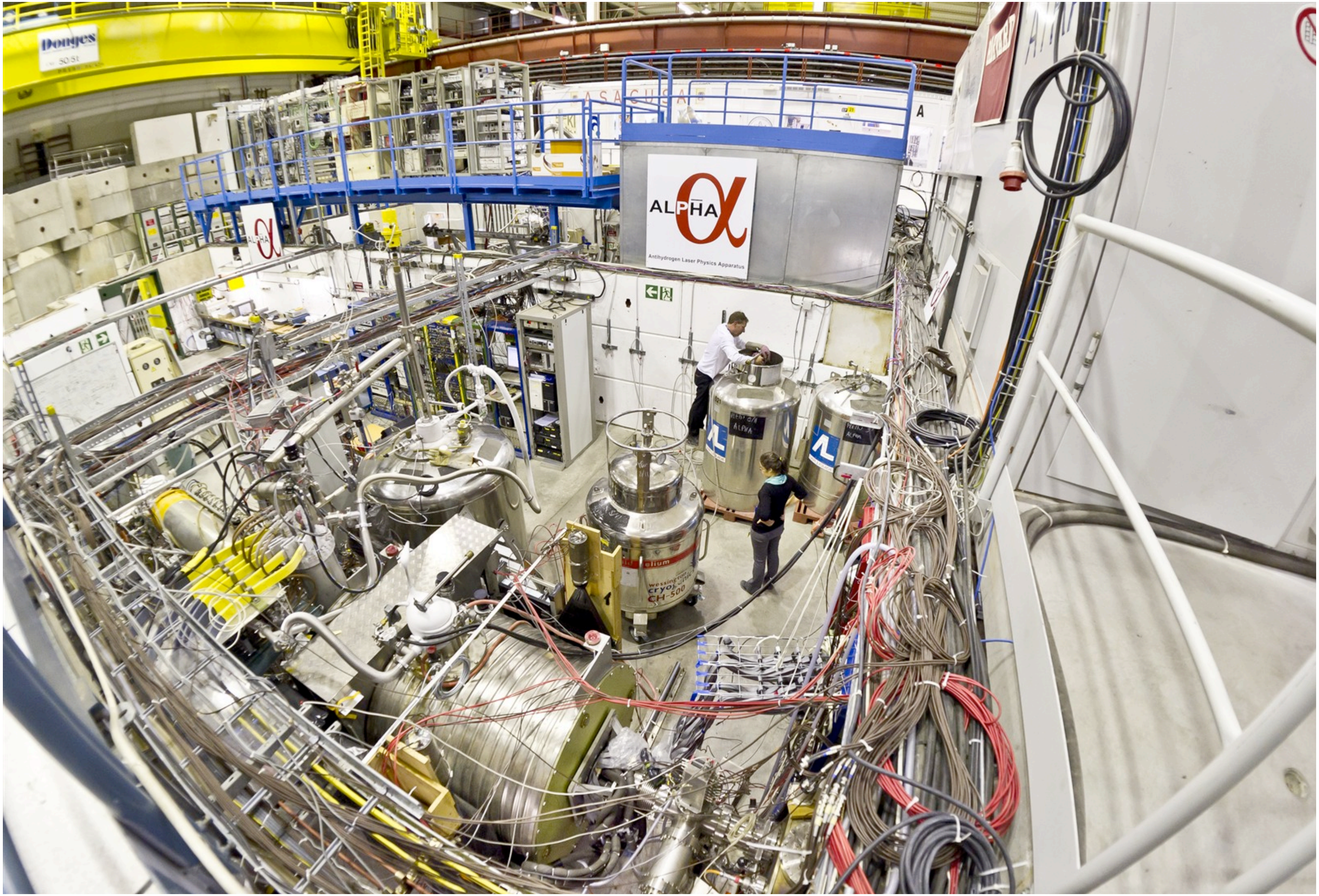
The AD machine

For 2017

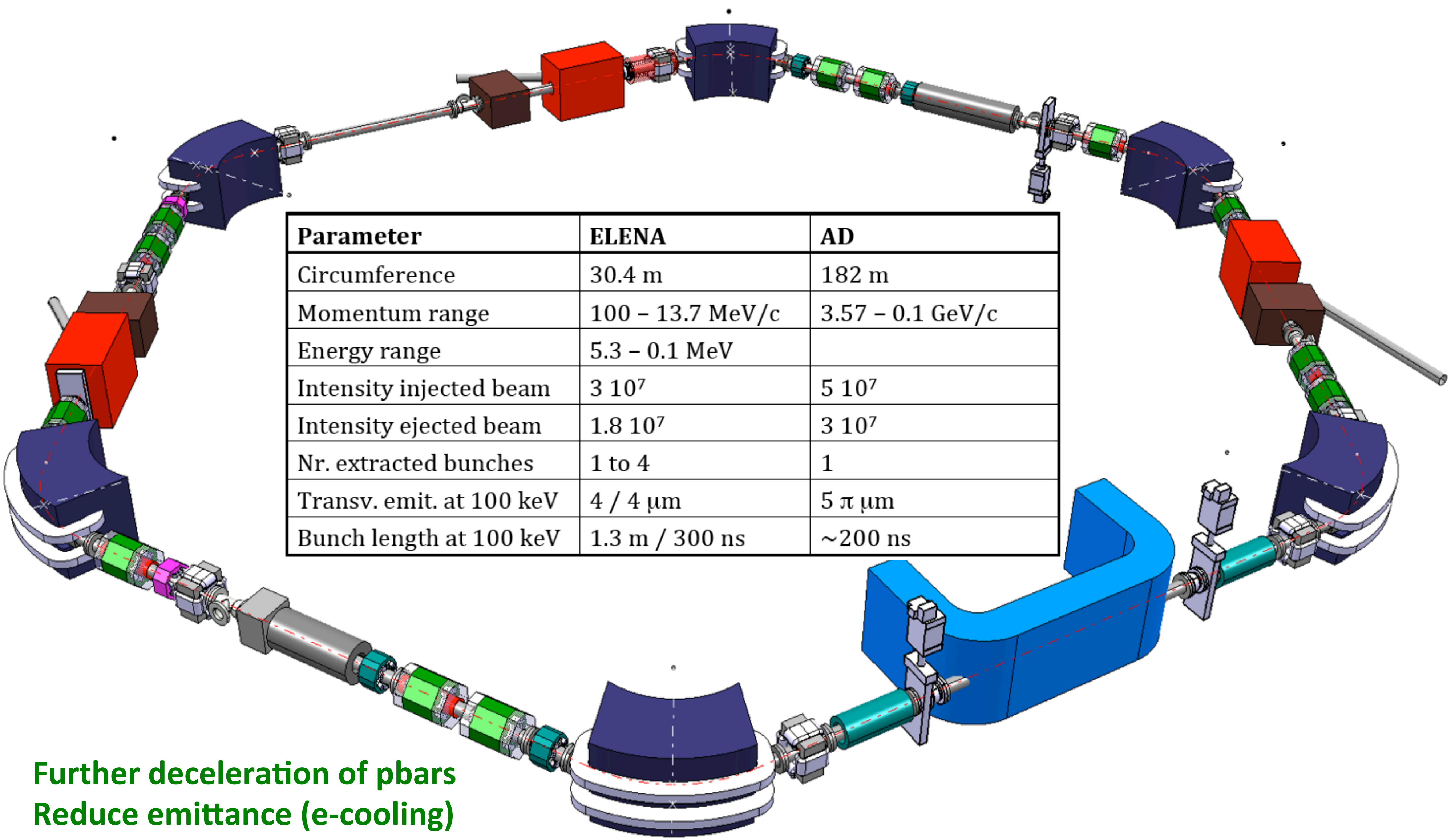


Some AD pictures


Momentum
p [GeV/c]
Basic AD Deceleration Cycle
3.57
2.0
0.3
0.1
pbar injection
Bunch rotation
Stochastic cooling
17 s.
Stochastic cooling
6.6 s. Tune jump
Electron cooling
16 s.
Electron cooling
8 s.
Rebunching
Fast Extraction
Actual Duration
Design Duration
12(10)
35(33)
54(52)
71(58)
85(60) time [sec]
RF ON:
RF h =
6
1
1
3
1
Beam bunched for deceleration (RF ON), debunched for cooling
28/08/00 FP
27/11/02 Rev.


Donges
ALPHA
Antihydrogen Laser Physics Apparatus
CH-500

ELENA (for 2017)



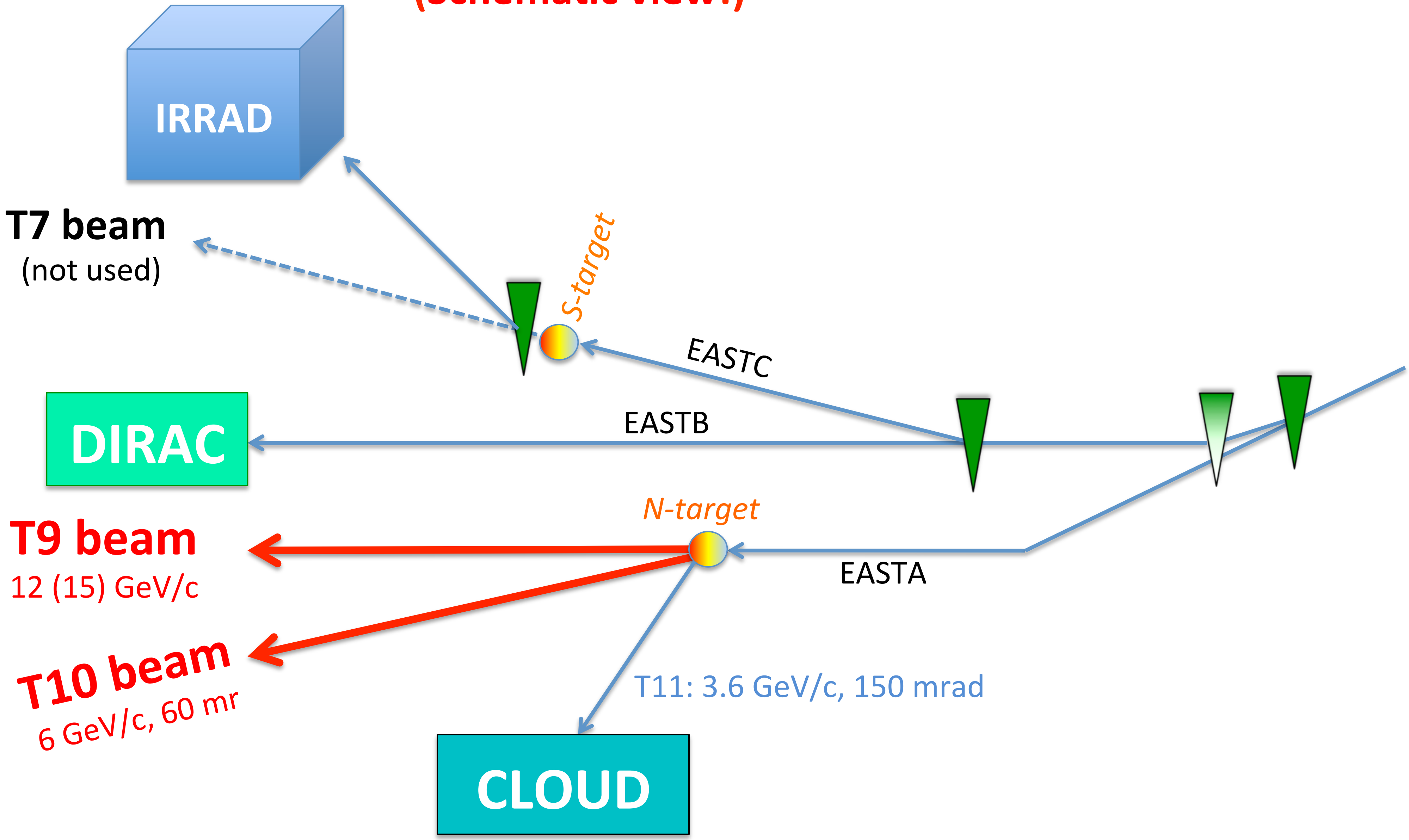
Parameter	ELENA	AD
Circumference	30.4 m	182 m
Momentum range	100 – 13.7 MeV/c	3.57 – 0.1 GeV/c
Energy range	5.3 – 0.1 MeV	
Intensity injected beam	$3\ 10^7$	$5\ 10^7$
Intensity ejected beam	$1.8\ 10^7$	$3\ 10^7$
Nr. extracted bunches	1 to 4	1
Transv. emit. at 100 keV	4 / 4 μm	5 π μm
Bunch length at 100 keV	1.3 m / 300 ns	~200 ns

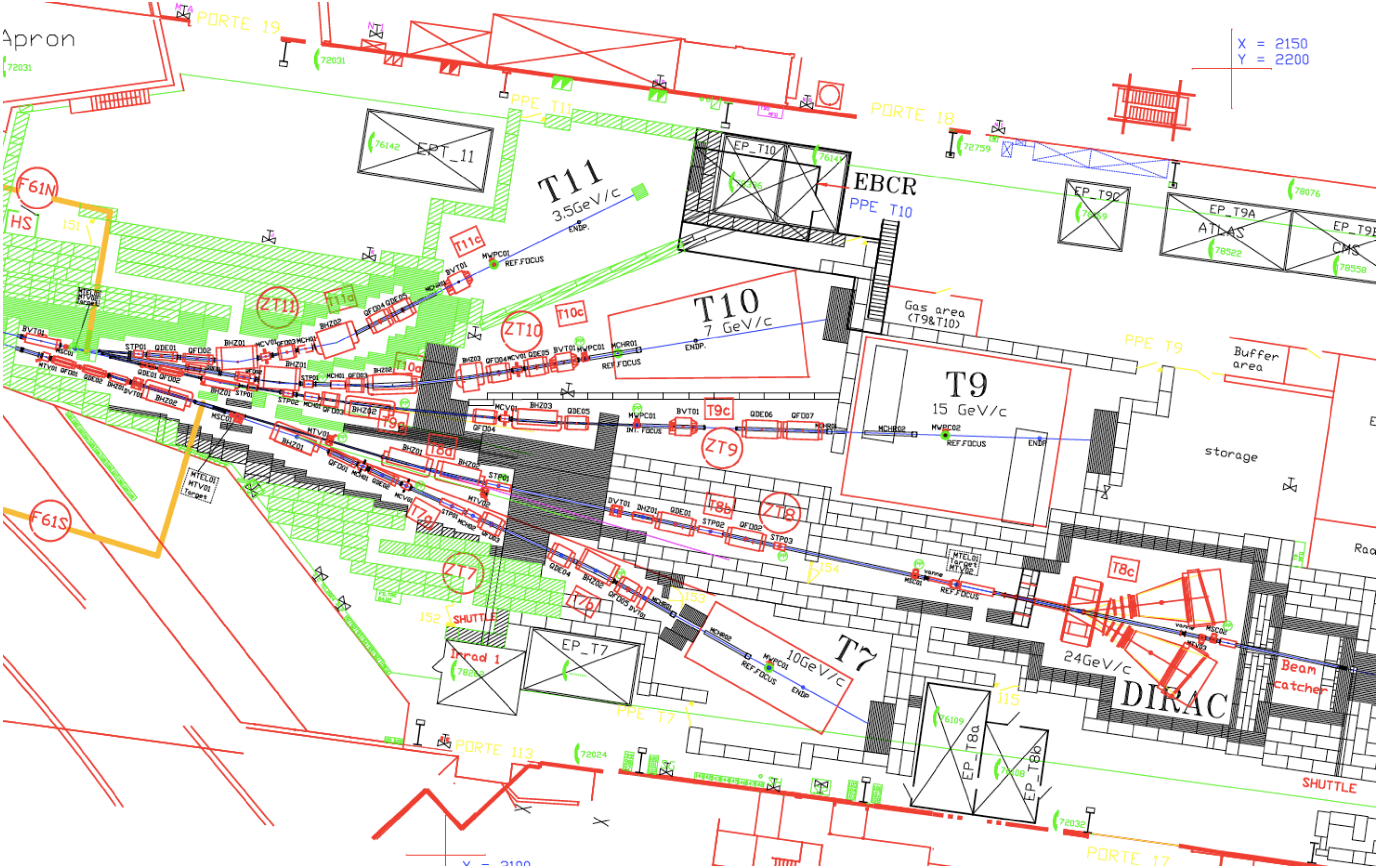
- **Further deceleration of pbars**
- **Reduce emittance (e-cooling)**
- **Gain ~100x in intensity for most experiments**

The East Area(PS)

The East Area Beams

(Schematic view!)





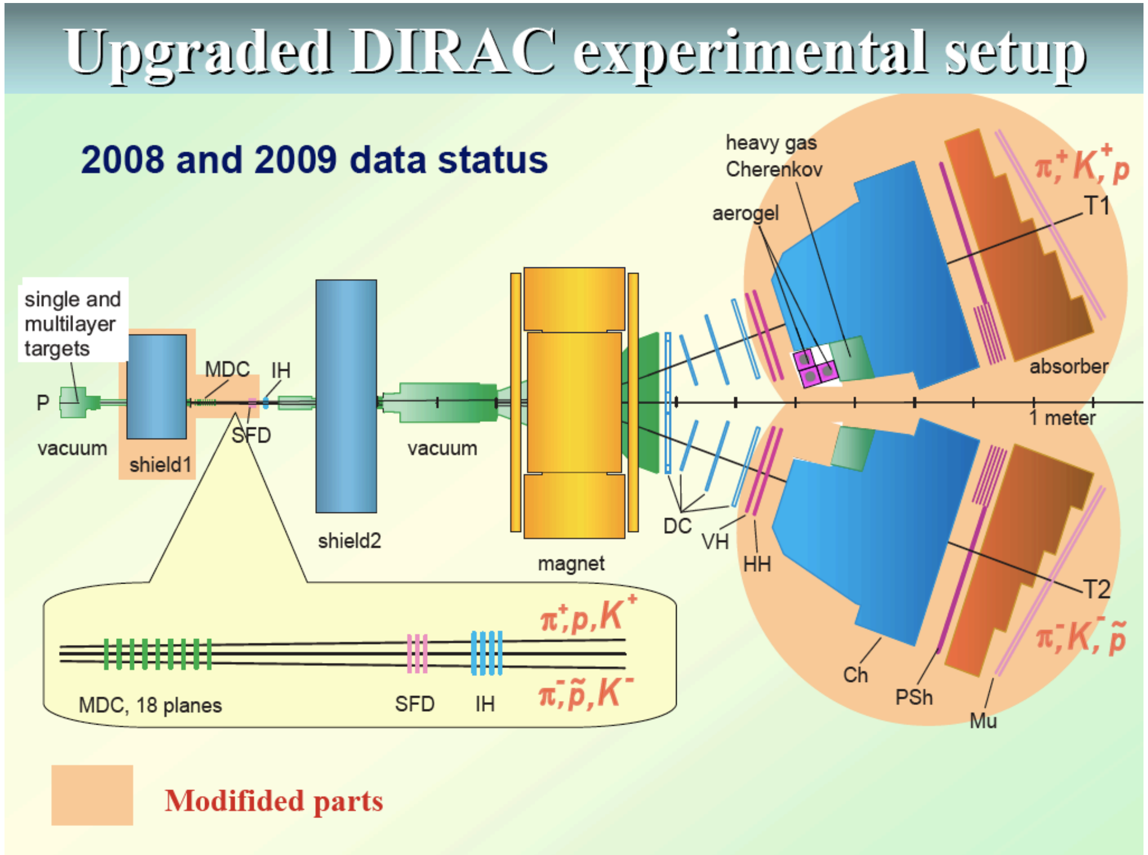
Apron
PORTE 19
PORTE 18
PORTE 17
PORTE 113
X = 2150
Y = 2200
EPT_11
T11
3.5GeV/c
EP_T10
EBCR
PPE T10
PPE T11
EP_T9C
EP_T9A
ATLAS
CMS
F61N
F61S
HS
T10
7 GeV/c
Gas area (T9&T10)
PPE T9
Buffer area
T9
15 GeV/c
storage
ZT11
ZT10
ZT9
ZT8
ZT7
T11c
T11a
T10c
T10a
T9c
T9a
T8a
T8b
T8c
T7a
T7b
SHUTTLE
Irrad 1
EP_T7
PPE T7
T7
10GeV/c
24GeV/c
DIRAC
Beam catcher
EP_T8a
EP_T8b

THE T8 BEAM LINE

The T8 beam line serves the DIRAC experiment (⟶ G.Mallot lecture).

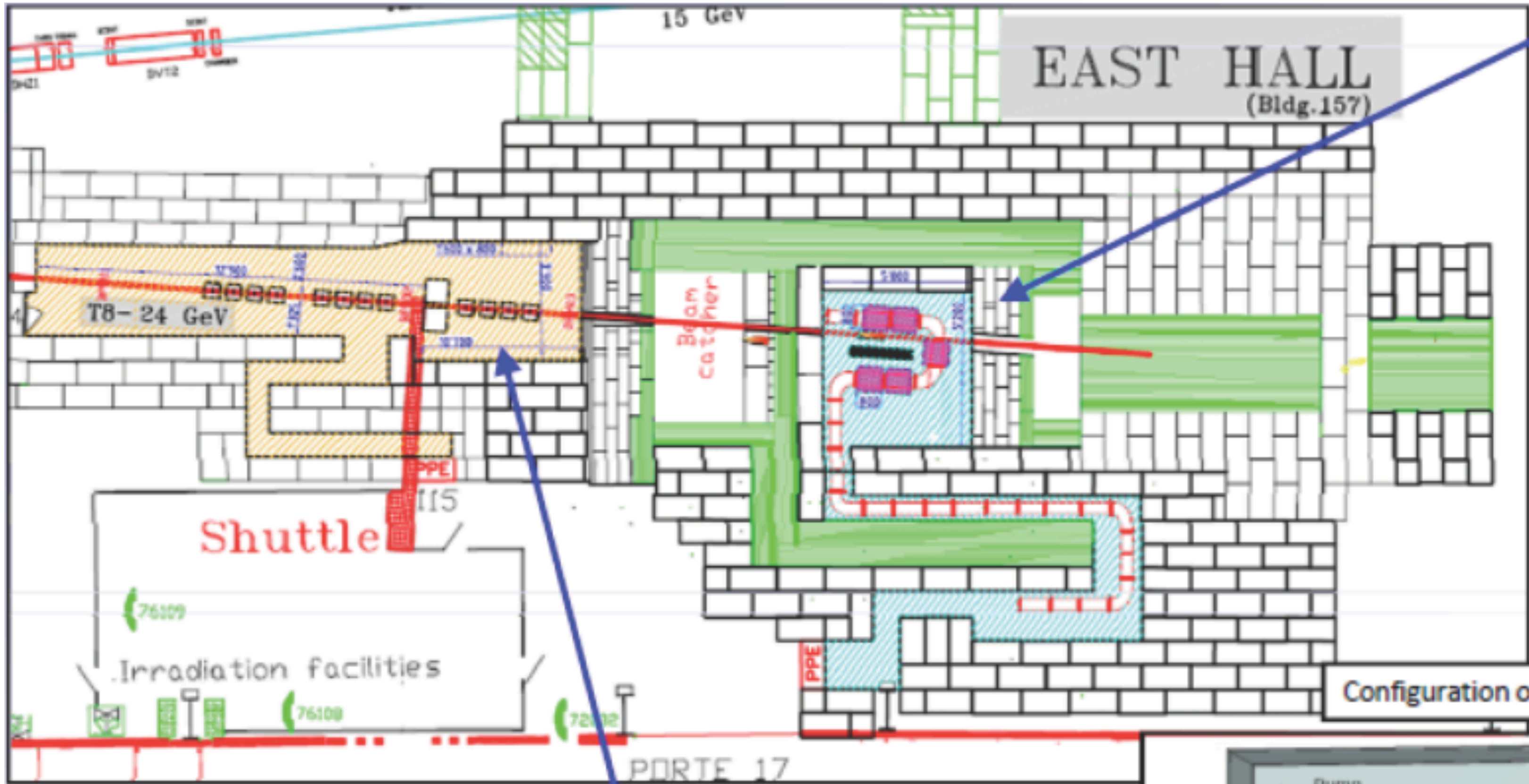
It is a **primary proton beam** of 24 GeV/c slowly extracted over a flat top of 400 or even up to 600 msec.
For a 45.6 sec super-cycle up to five EASTB (T8) cycles can be scheduled, depending on the requirements of the overall program.
The T8 intensity is normally in the range 1-5 10^{11} ppp typically 1.1 10^{11} for DIRAC).

The beam is de-bunched.
The spot size at DIRAC is ~5 mm RMS.



It is foreseen to dismount DIRAC in 2013 and to move the IRRADiation facility into the T8 line.
The required beam characteristics are the same, apart from the higher beam fluxes (up to ~5 10^{11} ppp).
The new facility will include a **proton irradiation** facility plus a **mixed field** facility.
The existing IRRADiation facilities on the T7 side and behind DIRAC will be dismantled.

THE PROPOSED IRRADIATION FACILITY (by R2E + AIDA)

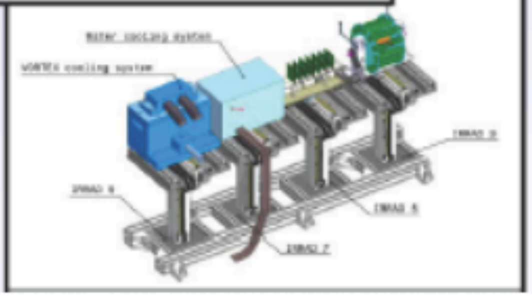


Mixed Field Facility

multiple user communities:
LHC machine
LHC Experiments,
Dosimetry (RP),
MC benchmarking

rail system on floor for heavy material, shuttle system or small rail system on ceiling (?)

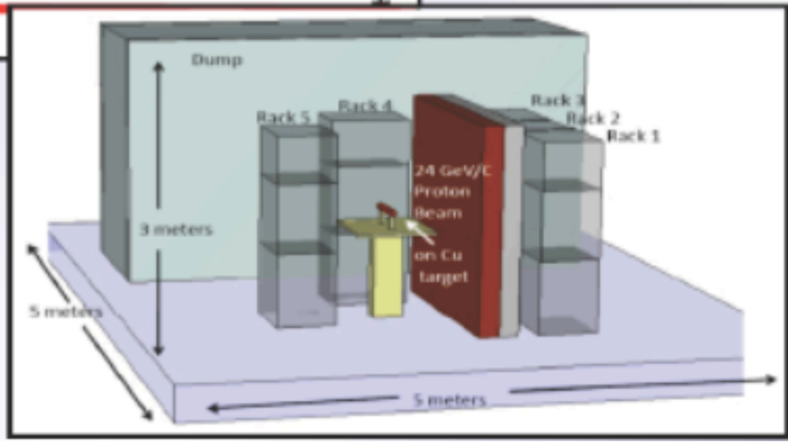
Layout IRRAD Tables System

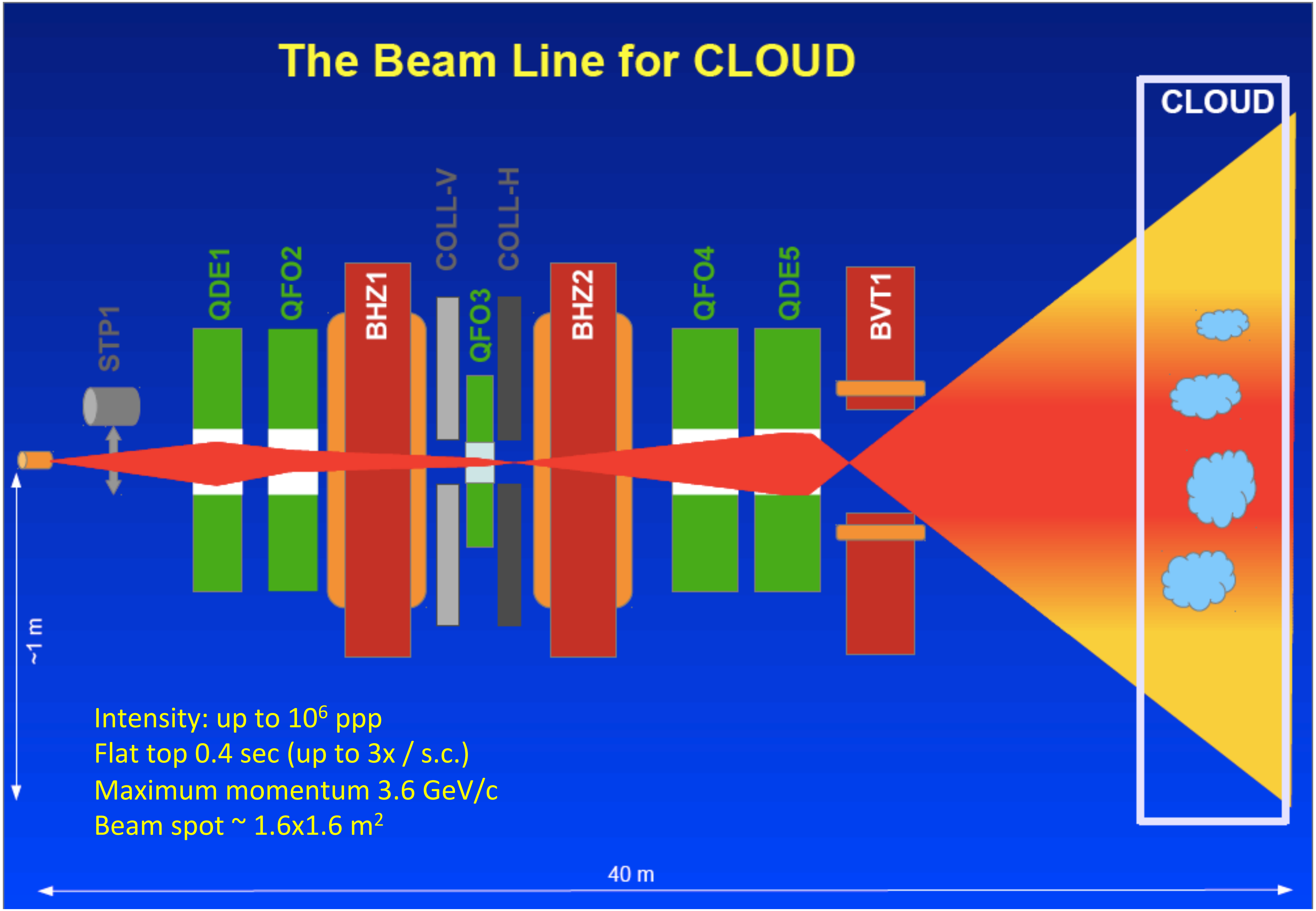


Proton Facility

- main user community:
  LHC Experiments
- Irradiation tables
- Cold boxes
- Shuttle system

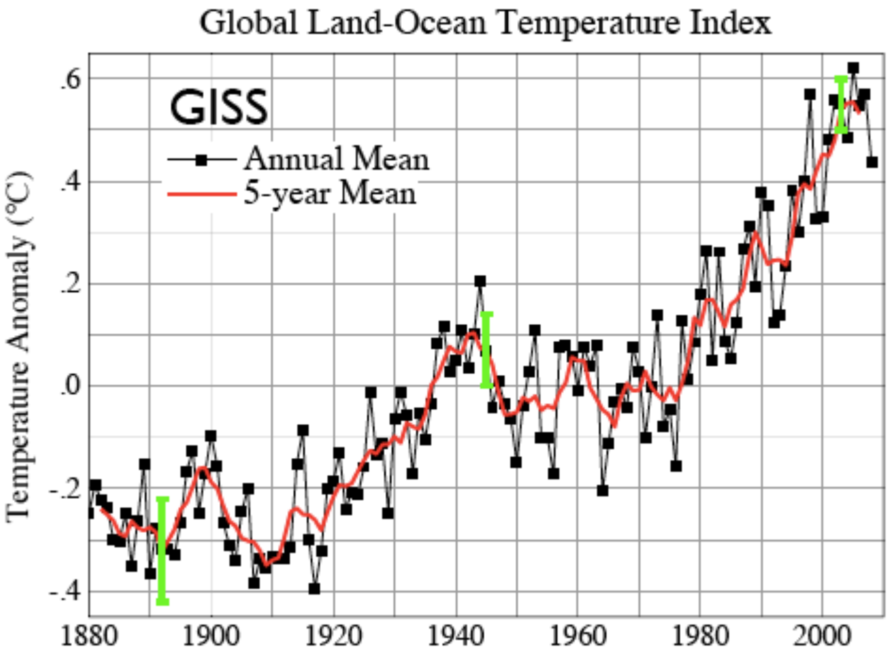
Configuration of Mixed Field Area

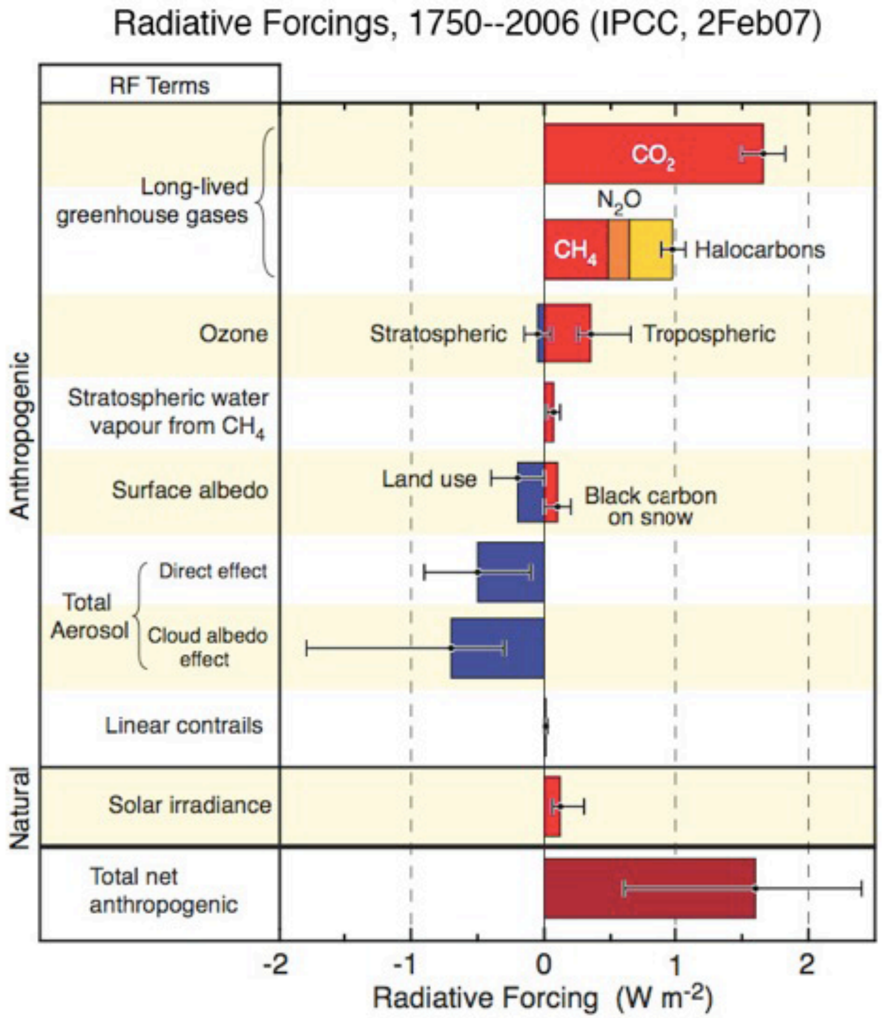



The Beam Line for CLOUD
CLOUD
STP1
QDE1
QFO2
BHZ1
COLL-V
QFO3
COLL-H
BHZ2
QFO4
QDE5
BVT1
~1 m
Intensity: up to 10⁶ ppp
Flat top 0.4 sec (up to 3x / s.c.)
Maximum momentum 3.6 GeV/c
Beam spot ~ 1.6x1.6 m²
40 m

THE CLOUD EXPERIMENT IN THE T11 BEAM

Climate forcings (IPCC 2007)





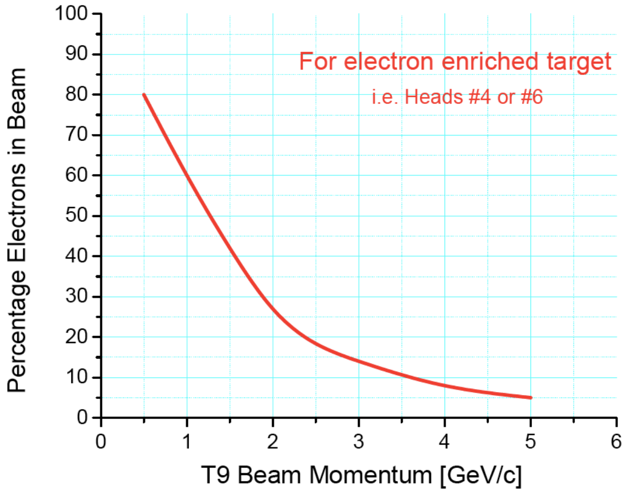
- 0.7°C rise since 1900 (not uniform)
- IPCC findings:
  - Total anthropogenic 1.6 W/m² (≅ 1 candle per 25 m²)
  - Negligible natural (solar) contribution: 0.12 W/m²
  - Clouds poorly understood

3

East Area Test Beams

The T9 and T10 beam lines are **mixed beams**.
Their maximum flux is 10^6 per EASTA cycle.
Both beams are served from a common target, together also with the T11 beam for CLOUD.
The flat top is 0.4 seconds.
The number of EASTA cycles is defined by the physics coordinator, depending on the overall schedule, but is normally 1 per super-cycle.
When CLOUD runs up to 3.

Each beam line is equipped with 1 (T10) or 2 (T9) threshold Cerenkov counters, a scintillator and a Delay wire chamber.



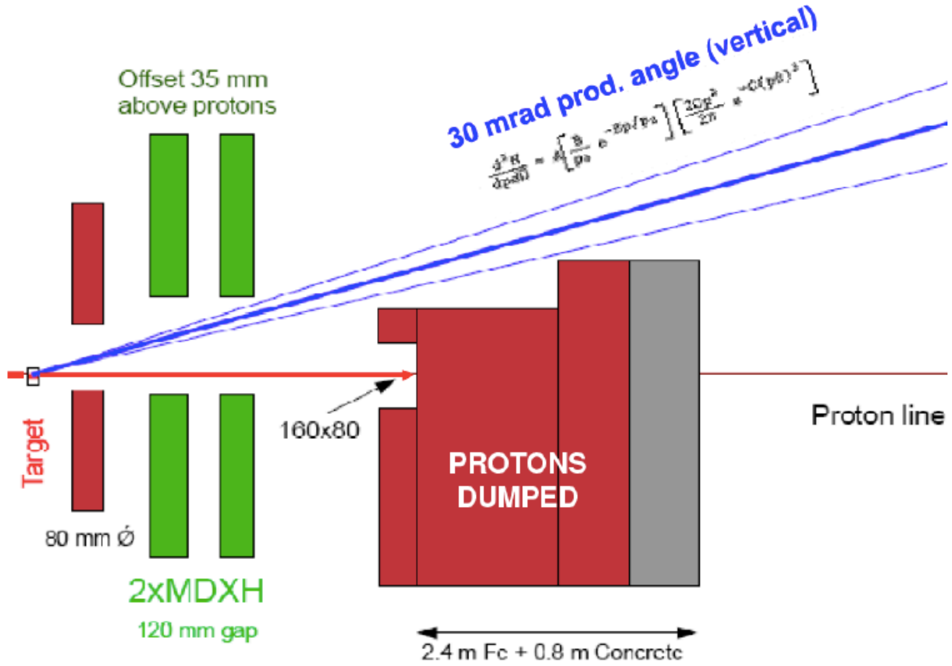
Parameter	T9	T10
Maximum momentum (GeV/c)	12	6
Production angle (mrad)	0	61.6
Beam length to ref. focus (m)	55.8	34.9
Beam height above floor (m)	2.50	2.505
Ang.acceptance Horiz (mrad) Vertic (mrad)	±4.8 ±5.8	±5.4 ±13.9
Acc. Solid angle (μsterad)	87	224
Theor. momentum resol. (%)	0.24	0.24
Max. momentum band (%)	±10	±8
Magnification at ref. focus	1.0, 1.2	0.8, 0.6
Protons on North target	~2.5 10^{11}	
Max. flux (depending on p, Q)	10^6	10^6

THE PROPOSED EAST AREA UPGRADE

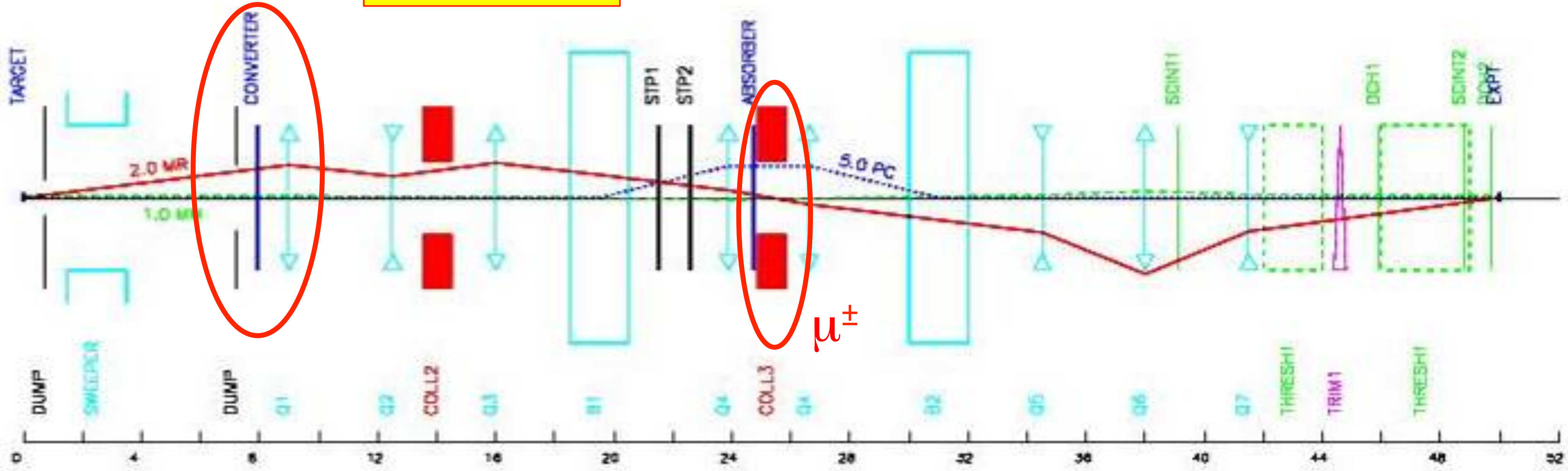
An upgrade and consolidation program has been proposed for the East Area.
A first phase is foreseen in this year's MTP and includes as a first phase the upgrade of the IRRADiation facilities and some preparation works. Most of the upgrade, if approved, will happen in/after LS2.

The main parts of the new layout include:

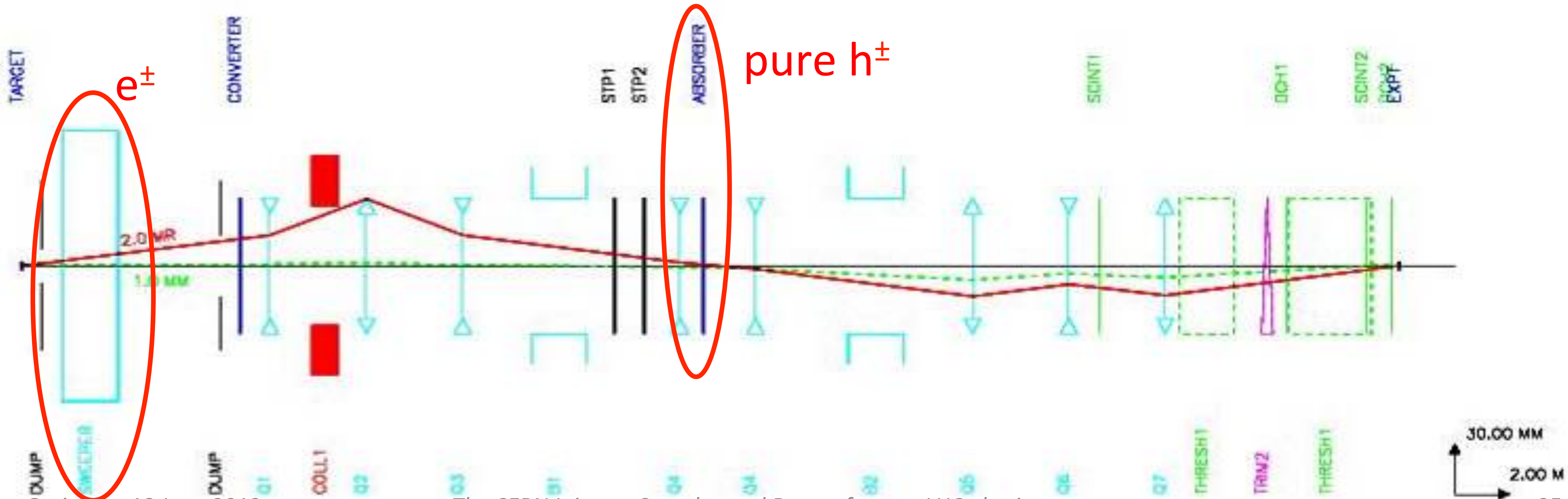
- Suppress the old T7+IRRAD branch
- **Move IRRAD to T8 beam line**
- Increase **top momentum** of T9 to 15 GeV/c and T10 to 12 GeV/c (overlap with SPS beams)
- Implement control over particle type: e / h / μ
- Study option to preserve T11, if not realistic move CLOUD to downstream end of T9
- Use fewer types of **magnets** (with spares) which are reliable and maintainable
- **Improve RP aspects** of zone: stop protons soon after production target, ventilation, ...
- Improve **access to beam line elements**
- Improve **infrastructure** in general



CONCEPT:



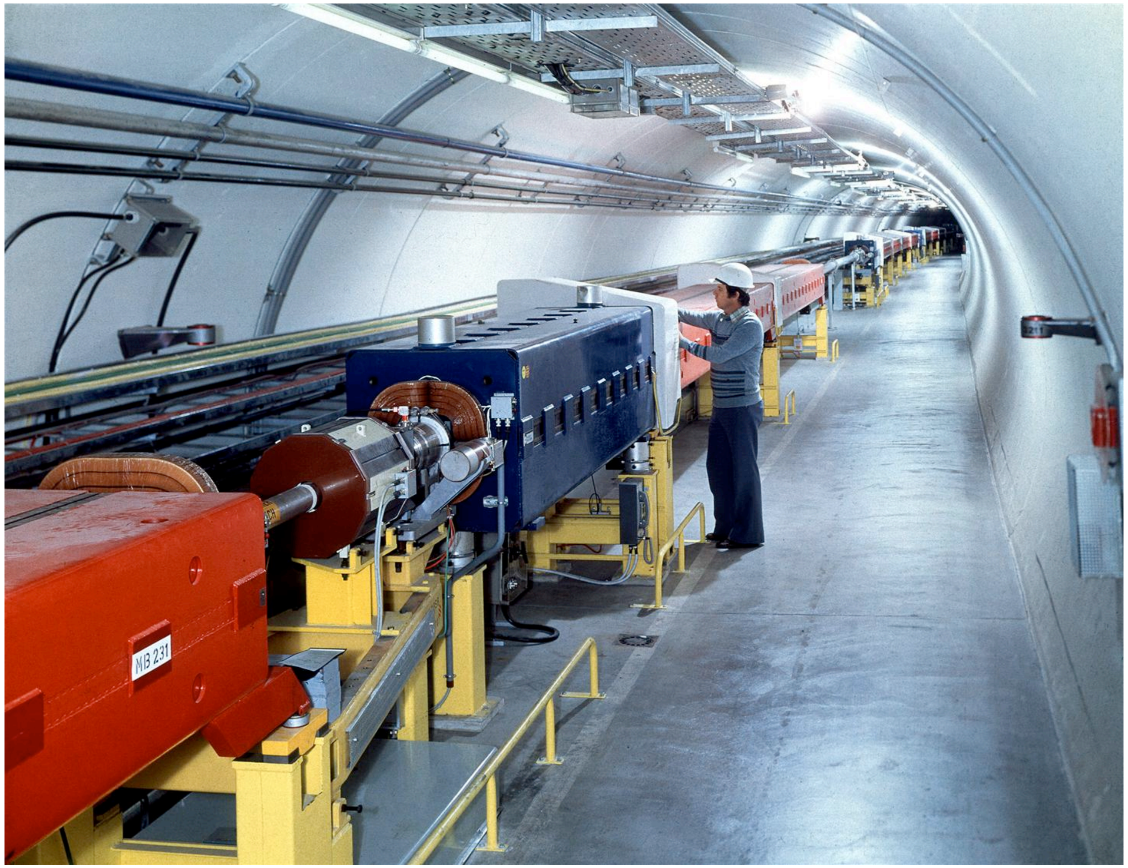
GENERIC NEW EAST AREA TEST BEAM OPTICS



THE SUPER PROTON SYNCHROTRON (SPS)

The Super Proton Synchrotron is the last accelerator in the injector chain before the LHC.
Its commissioning started in 1976, but the North Experimental Area started only in 1978.
Originally designed for fixed target proton operation at 300 GeV/c, it has operated up to 450 GeV/c for fixed target physics (and LHC filling), but also as a prestigious p-pbar collider (270 GeV/c) and as injector for LEP. It has also served the heavy ion physics programs with various ion species, up to Pb.

The circumference of the SPS is 11 times the PS: about 6.9 km (t_{rev} = 23 μsec).
The PS fills one half of the SPS in a 5-turn extraction, the second half 1.2 seconds later.
One eleventh of the machine is reserved for switching the injection kicker on and off.
The protons are injected at 14 GeV/c and (nowadays) accelerated to 400 GeV/c.
At the end of acceleration Δp is maximised, the RF switched off (→debunching!) and the beam slowly extracted over a 9.6 s flat top to the North Area.
Alternatively the beam can be extracted in two shots of ~10 μsec each (separated by 50 msec) to the CNGS target.

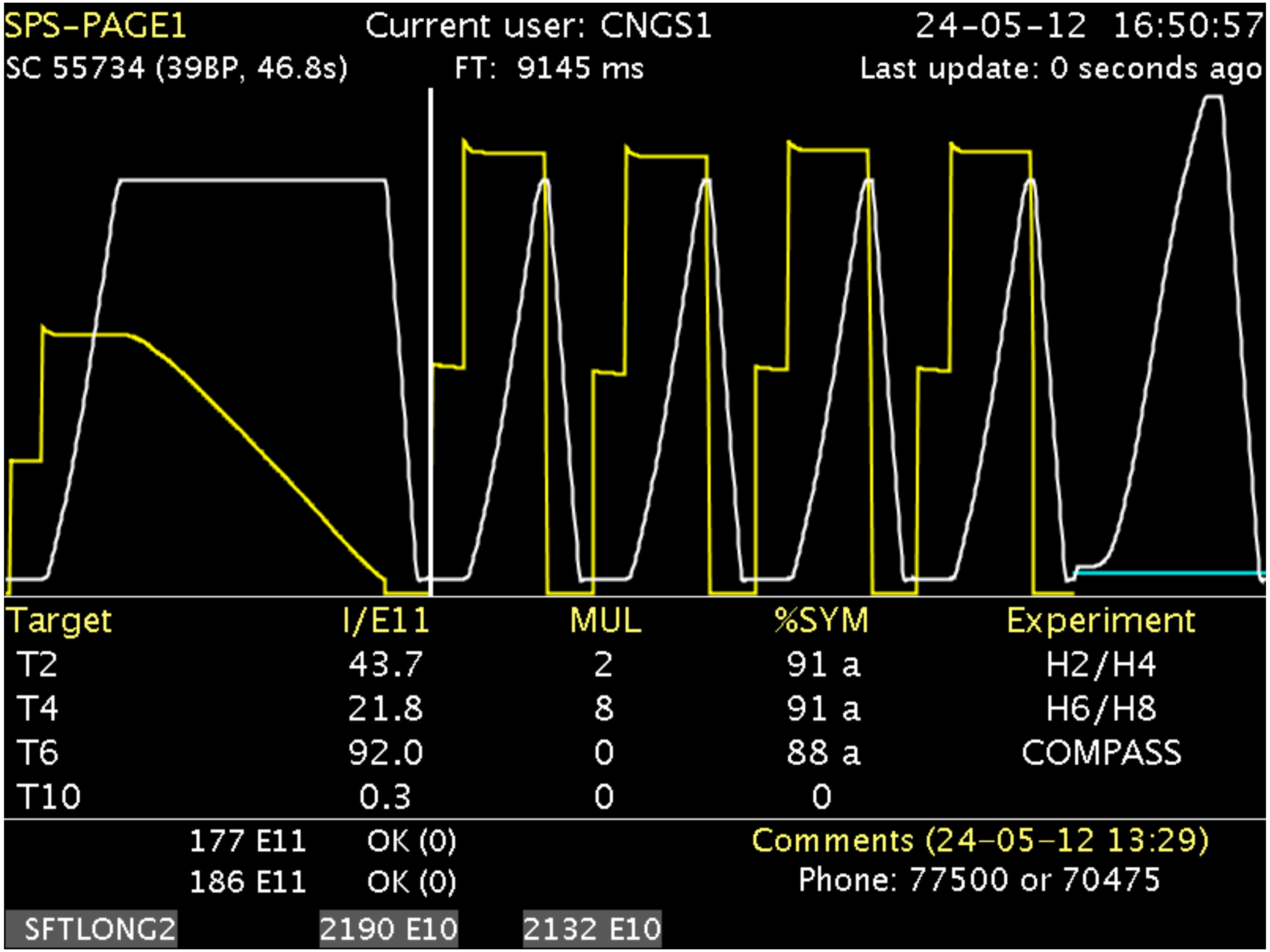


The SPS has gradually been transformed into a **multi-cycling machine**.
The super-cycle can be re-programmed (almost) on the fly.
The addition of CNGS and LHC filling cycles had lead to very long super-cycles:

The white curve indicates the current in the main SPS dipoles. The yellow curve indicates the proton intensity in the ring. The blue curve is the same for lower beam intensities where a larger gain factor is used.

The maximum intensity per SPS cycle that can be extracted to the North Area or to CNGS is of the order of **4 10^{13} ppp**. This corresponds to a total energy of 2.5 MJ !

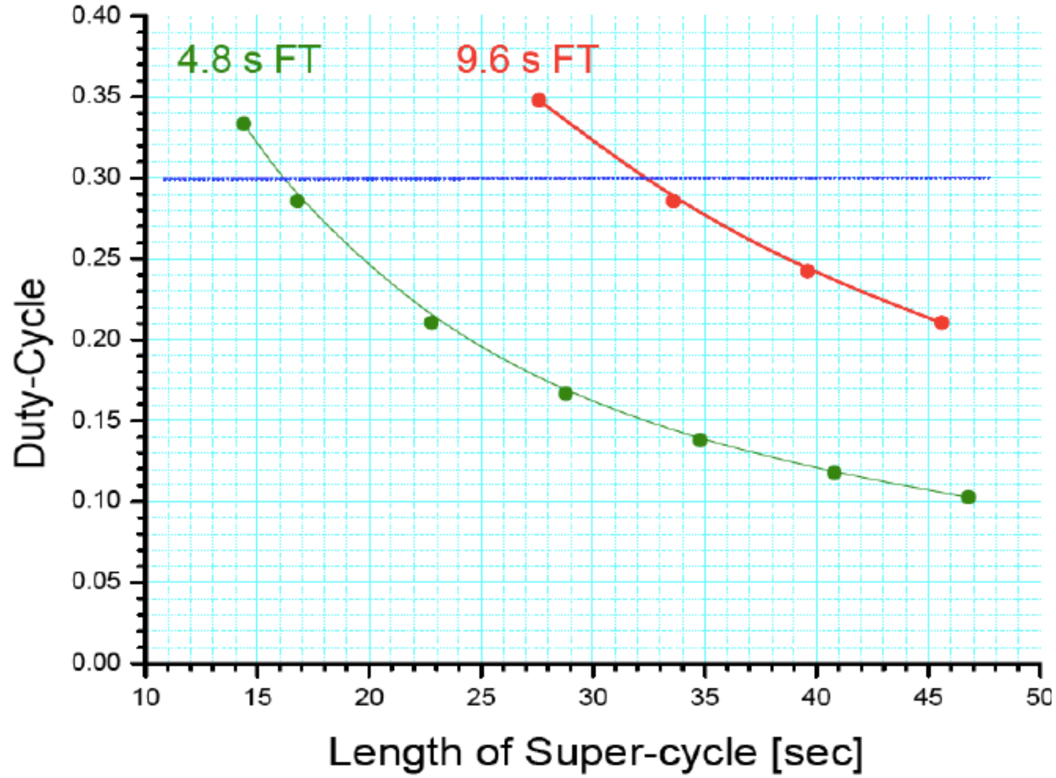
The beam to the NA is split into 3 branches, serving 3 primary targets.



SHORT VS LONG FLAT TOP

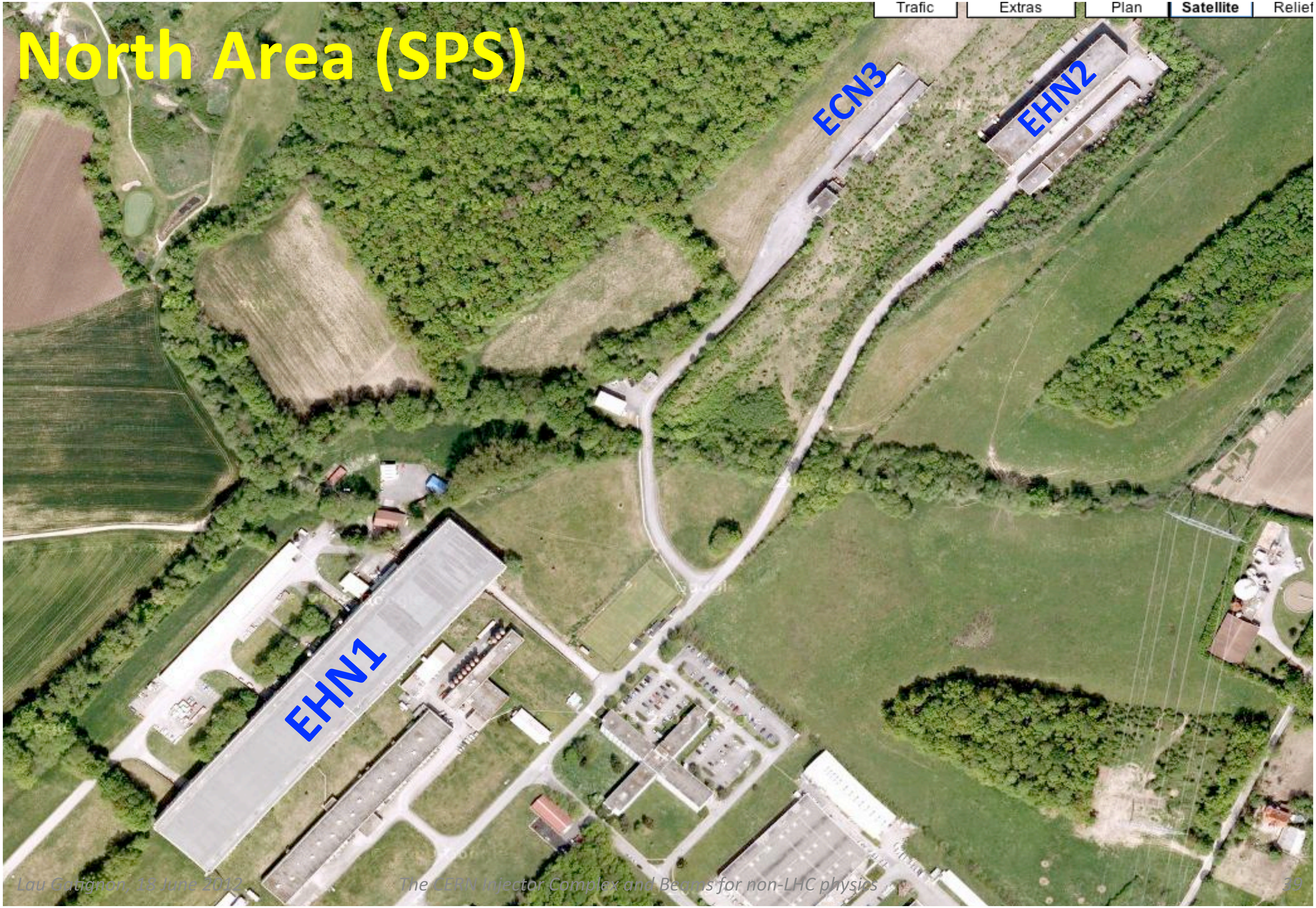
For most experiments the statistics depends on integrated "time on flat top", hence on the **duty cycle.**
Up to 2007, the duty cycle was ~30%, e.g. 4.8 sec FT per 14.4 or 16.8 sec.

The addition of CNGS cycles in the super-cycle would have lead to a reduction of duty-cycle for the fixed target program in the North Area.
The introduction of a longer flat top has mitigated the effect to a large extent



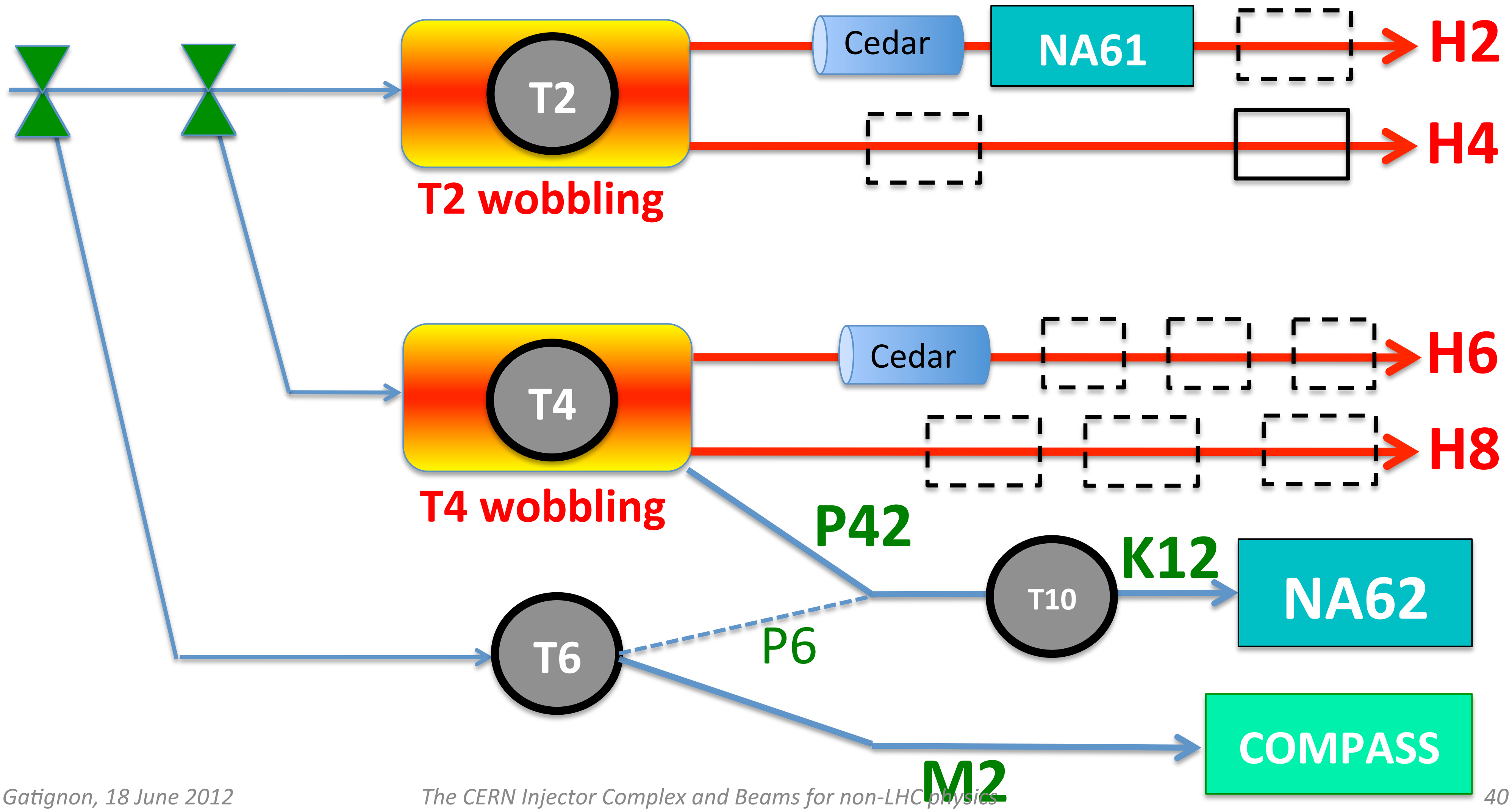
Period	P [GeV/c]	F-T [s]	S.C. [s]	Comment
Up to 1999	450	2.4	14.4	FT limited by heating
2000 - 2007	**400**	3.2 - **4.8**	14.4 – 16.8	To have better duty cycle
2008-now	400	9.6	~ 45.6	CNGS (+LHC filling)
After LS1	400	**Yet to be defined**		E.g. depending on CNGS future

North Area (SPS)



NORTH AREA BEAM LINES

(Schematic view!)



THE EHN1 HALL

THE BEAM LINES IN EHN1

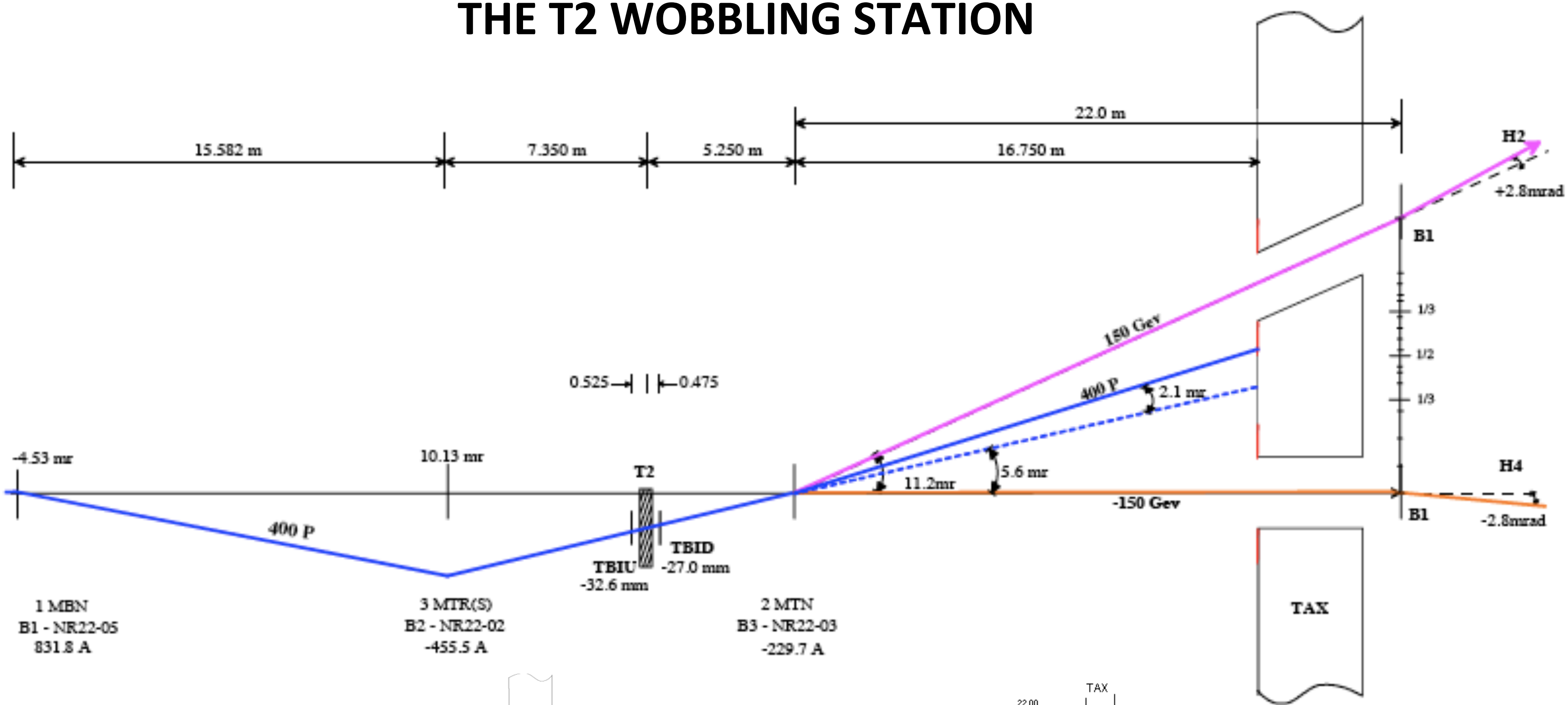
Beam	Momentum	Particle types	#Zones	Expts	Comments
H2	≤ 400 GeV/c	p,e, h, μ, ions*)	2	NA61*)	One zone reserved for NA61.
H4	≤ 450 GeV/c	p,e, h, μ, ions*)	4	NA63	One zone is dedicated to H4IRRAD.
H6	≤ 205 GeV/c	e, h, μ	3		
H8	≤ 450 GeV/c	p,e, h, μ, ions*)	4	UA9-T	One zone is dedicated to UA9-T. Micro-beam option for primary p. No electrons from γ conversion

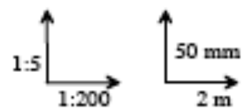
The maximum fluxes depend strongly on the momentum, charge, particle type, production angle, layout, shielding, equipment installed on the beam and on the access possibilities to the zones downstream. Constrained by radio-protection requirements!.
Typical fluxes are in the 10^5 to 10^6 per pulse range, but under certain conditions higher fluxes can be provided.

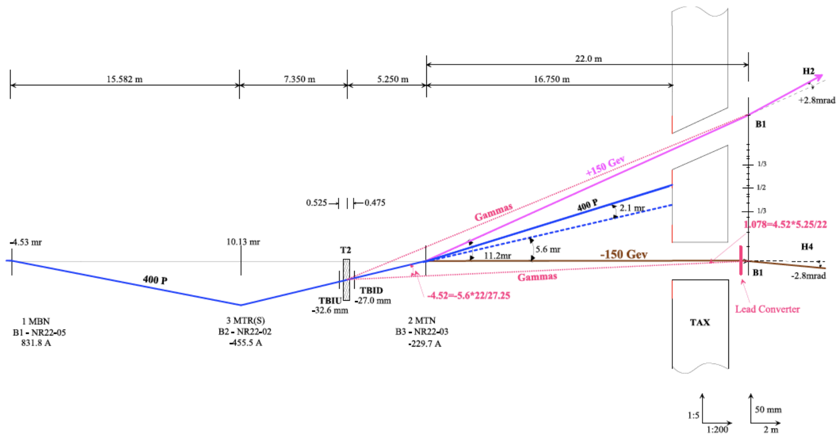
Please note that there is a coupling between beam lines from the same target: **Wobbling**

*) Up to LS1, only fragmented ion beams can be provided
After PS1, primary Pb, Ar and Xe beams are possible

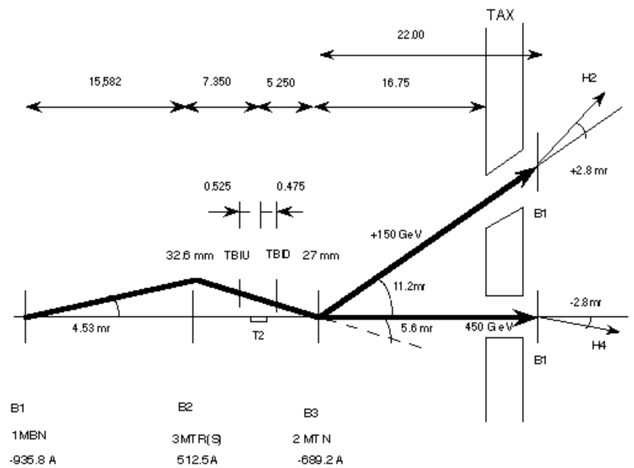
THE T2 WOBBLING STATION



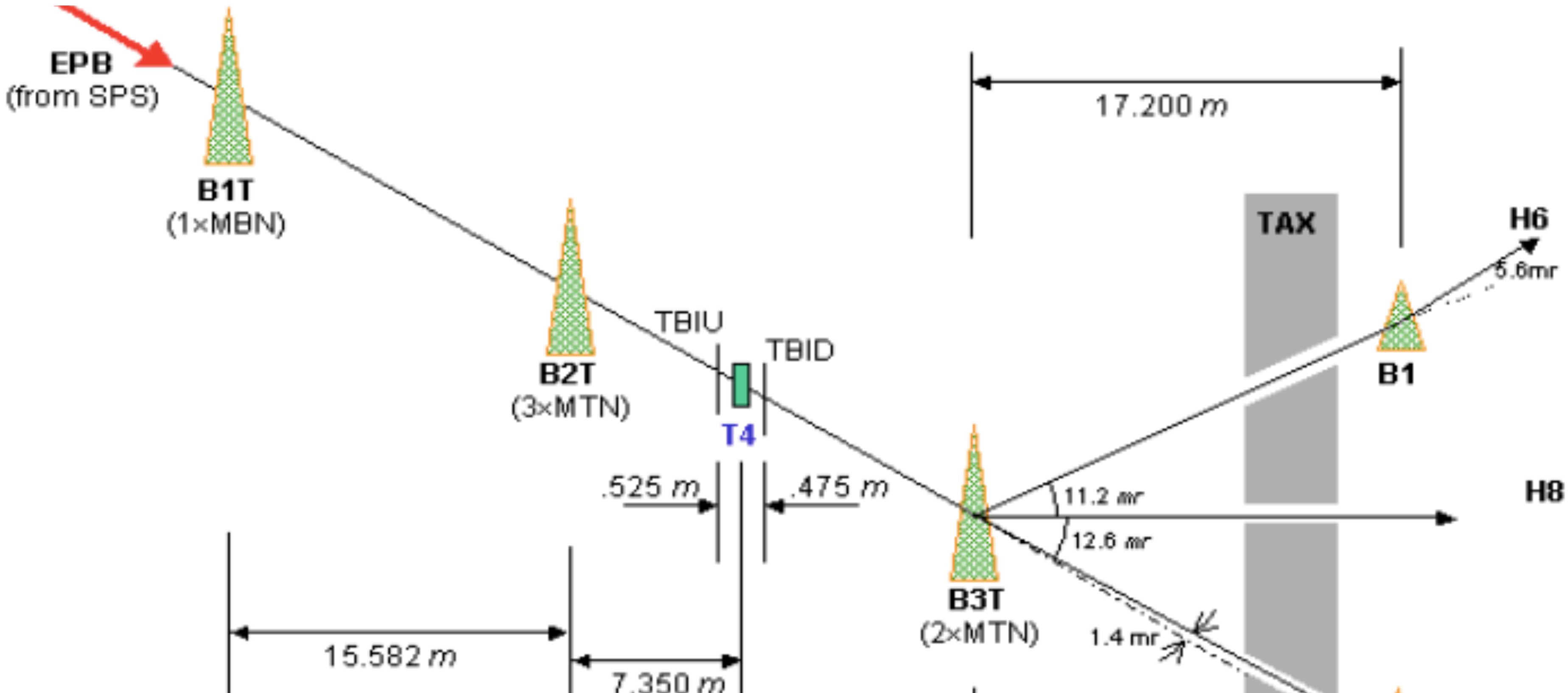


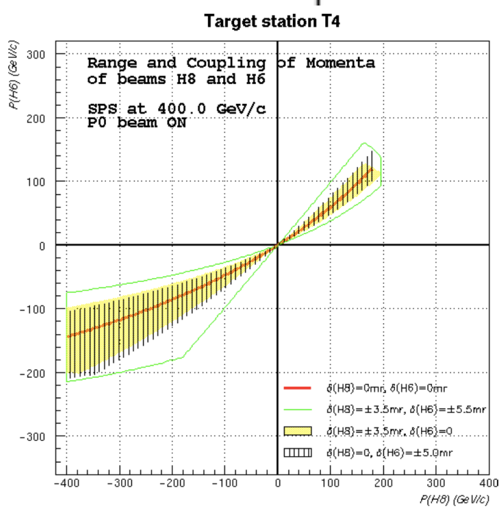


"Multi purpose" T2 Wobbling - Electrons in H2 & H4



THE T4 WOBBLING STATION

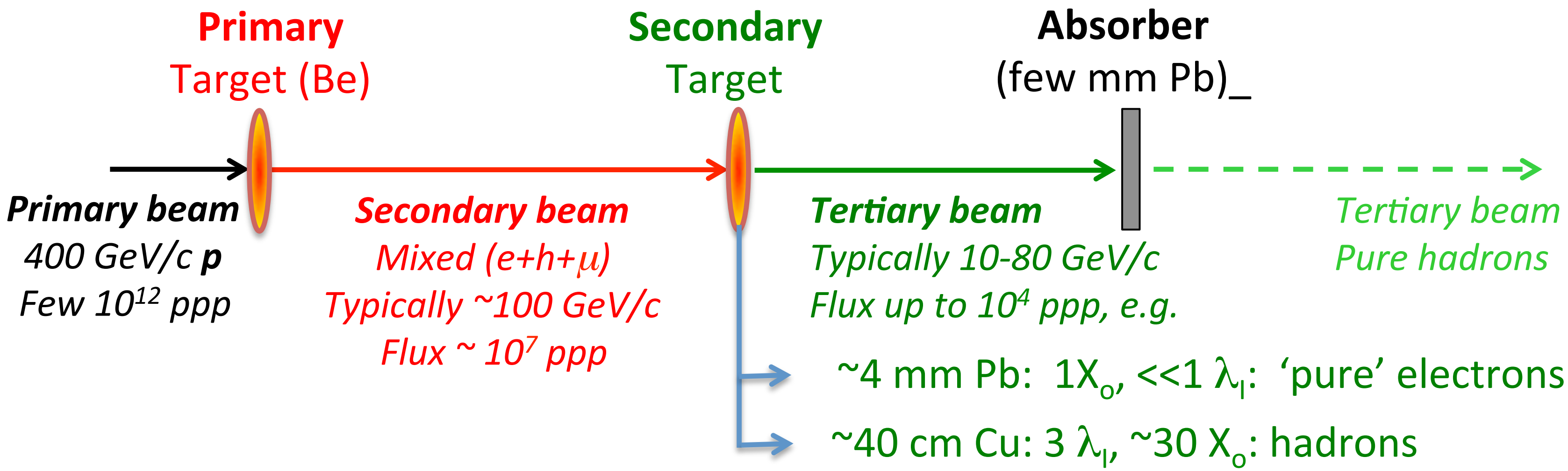




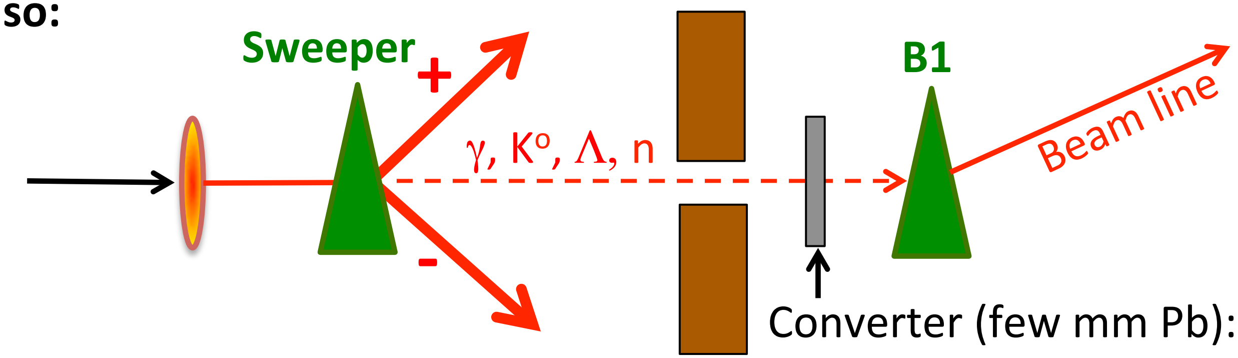
FLEXIBILITY IN EHN1 BEAMS

The Wobbling system in rich in options, but each change affects at least 2 beam lines.
Extra flexibility is provided by

- Tertiary beams
- Electron beams from γ conversion: Use Pb converter
- Hadron beams from K^o and Λ decay (T2 beams only): no converter
- Muons only by stopping the hadrons (and electrons) in a collimator or dump



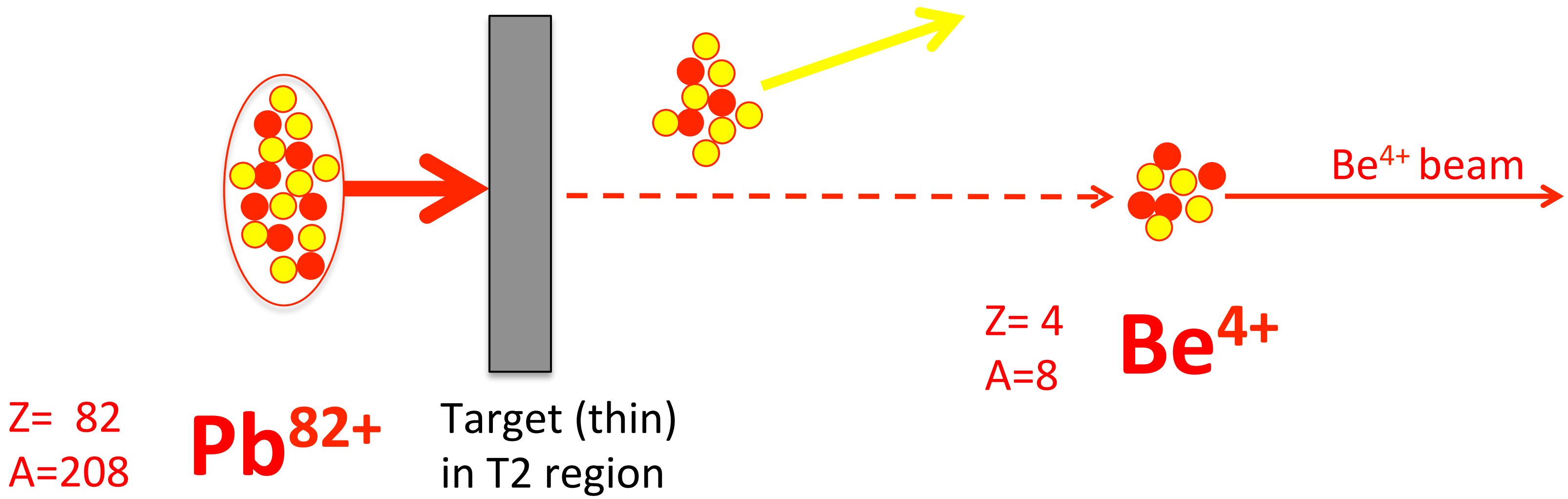
Also:



IN: beam mostly electrons
OUT: mostly π or p from K^o or Λ decay

FRAGMENTED ION BEAMS FOR NA61

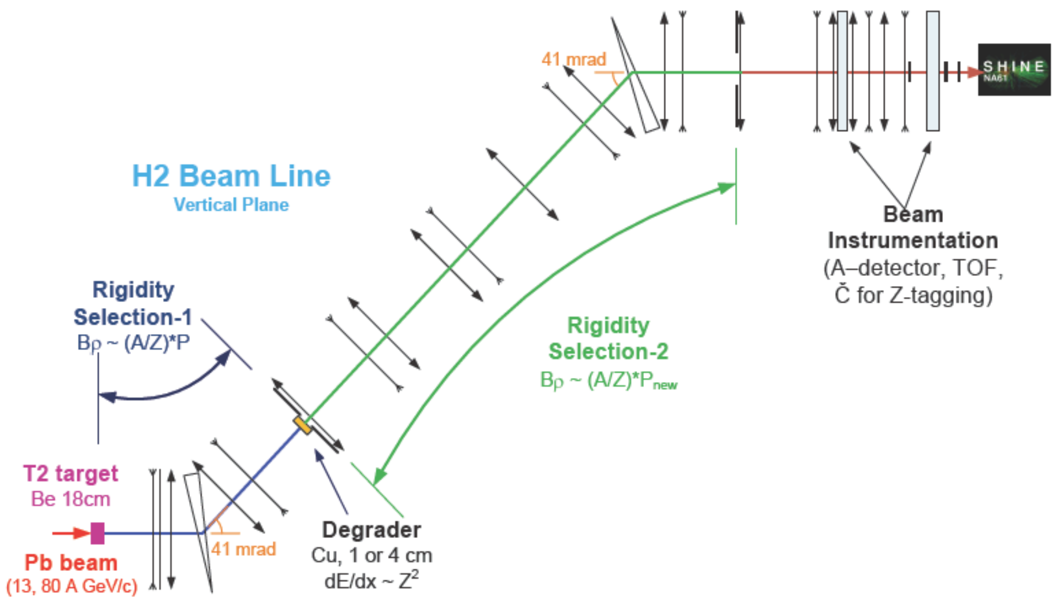
The NA61 experiment will scan a wide parameter space with different beam energies and ion species. However, any ion species needs very long setting-up time (many months) and therefore in each year the LHC and the SPS fixed target program must use the same primary ion species, normally Pb^{82+}.
In 2014 the SPS and the LHC will use primary Ar^{18+} ion beams, in 2015 Xe^{54+}, later again (primary) Pb^{82+}.
In the other years light ion beams can be produced by fragmentation of fully stripped Pb^{82+} beams.



e.g.: 400 GeV/c → (82/208)*400 = **158 GeV/N**   158 GeV/N → (8/4)*158 = **316 GeV/c**

The exact factor to be applied depends on the isotope selected. With the addition of a degrader in the beam line a sufficient rigidity resolution is obtained to achieve pure beams of light ion species. Unfortunately purity and intensity become marginal for the heavier species, where primary beams must be used instead.

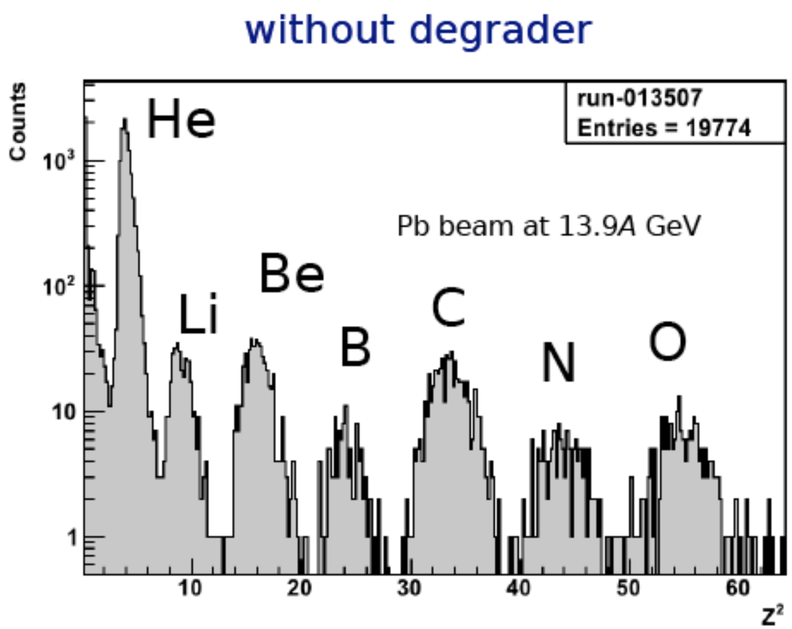
The H2 Beam Line as Ion Fragment Separator

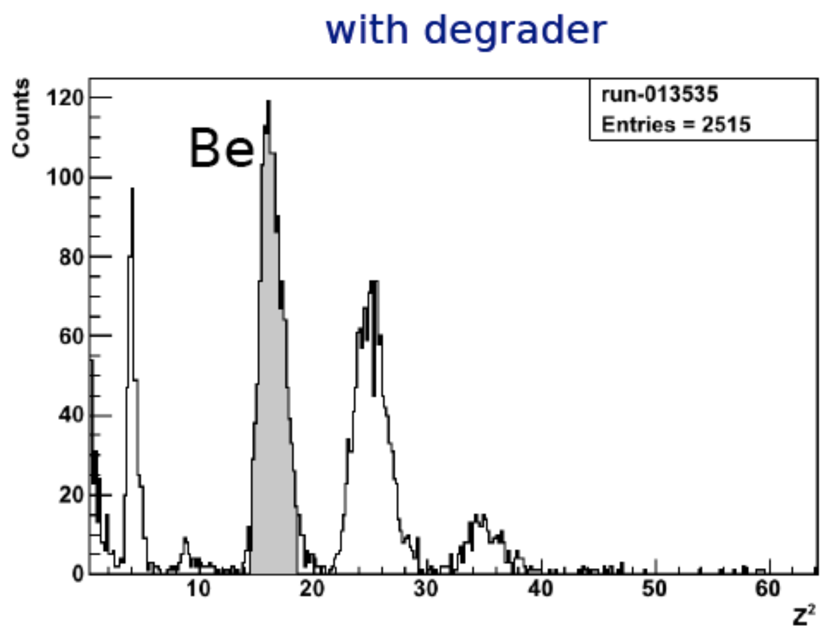


The target (18 cm Be) initiates the fragmentation. The target is followed by a first stage of rigidity selection (A/Z). However, the resolution is limited due to Fermi motion and scattering inside the target.

In the degrader the surviving ions loose energy ~Z^2. The second stage of the beam line takes this dE/dx into account to refine the final fragment selection.

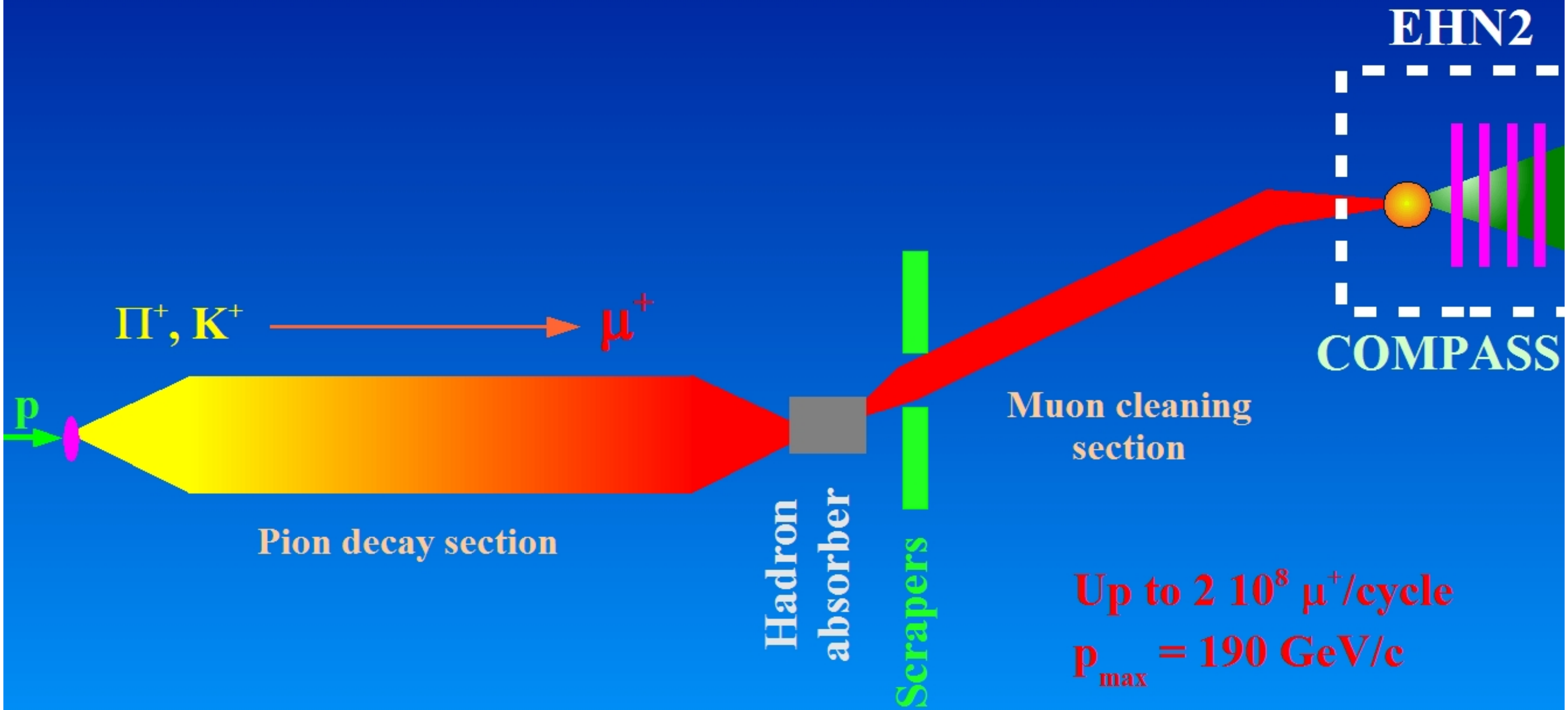
The Z-selection



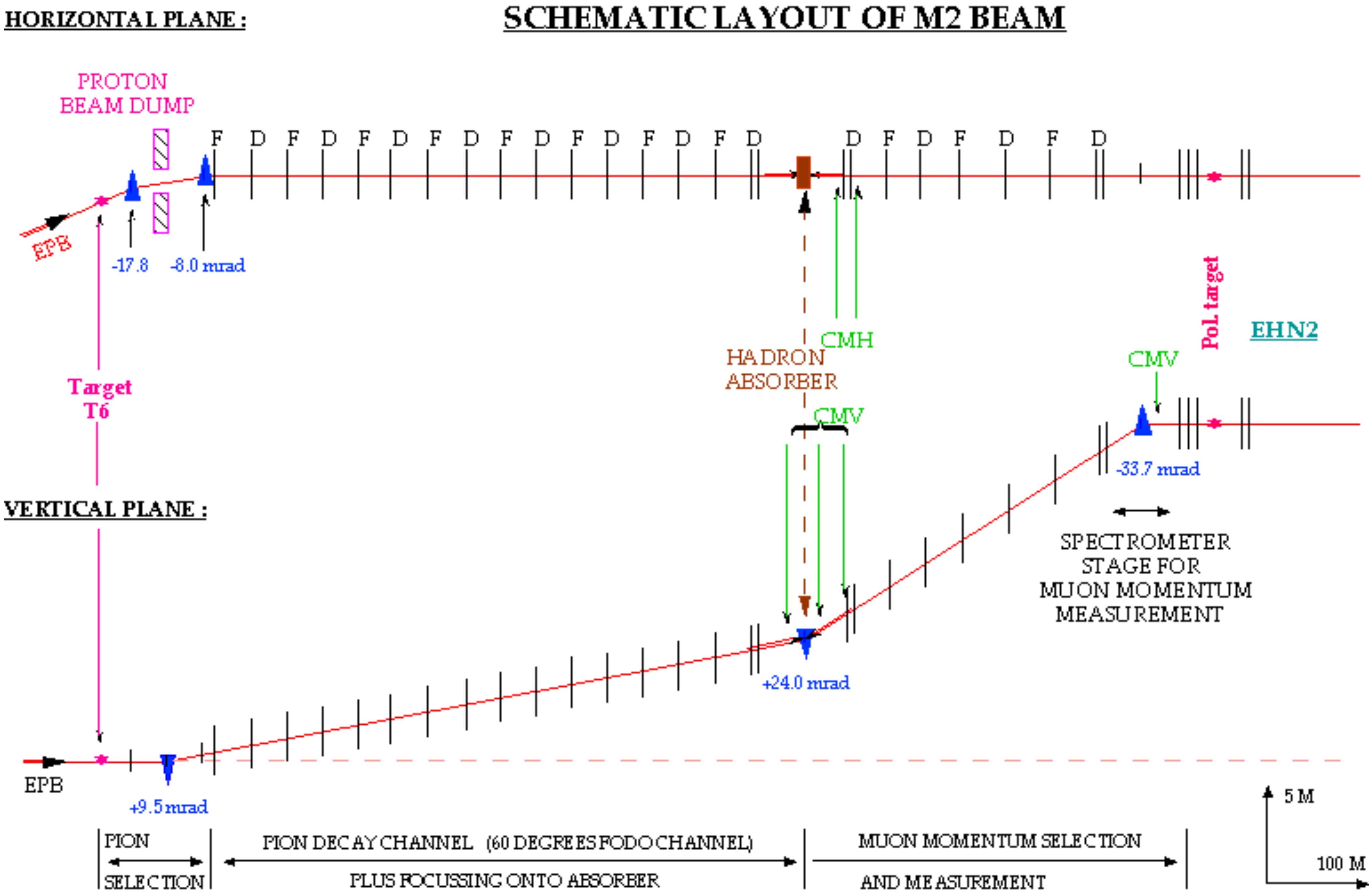


THE M2 MUON BEAM

FOR COMPASS / NA58



SCHEMATIC LAYOUT OF M2 BEAM



THE MUON AND HADRON BEAMS FOR COMPASS

The M2 beam line is ~ 1200 m long from the T6 production target to the end of the EHN2 hall.

It can be operated in three different modes:

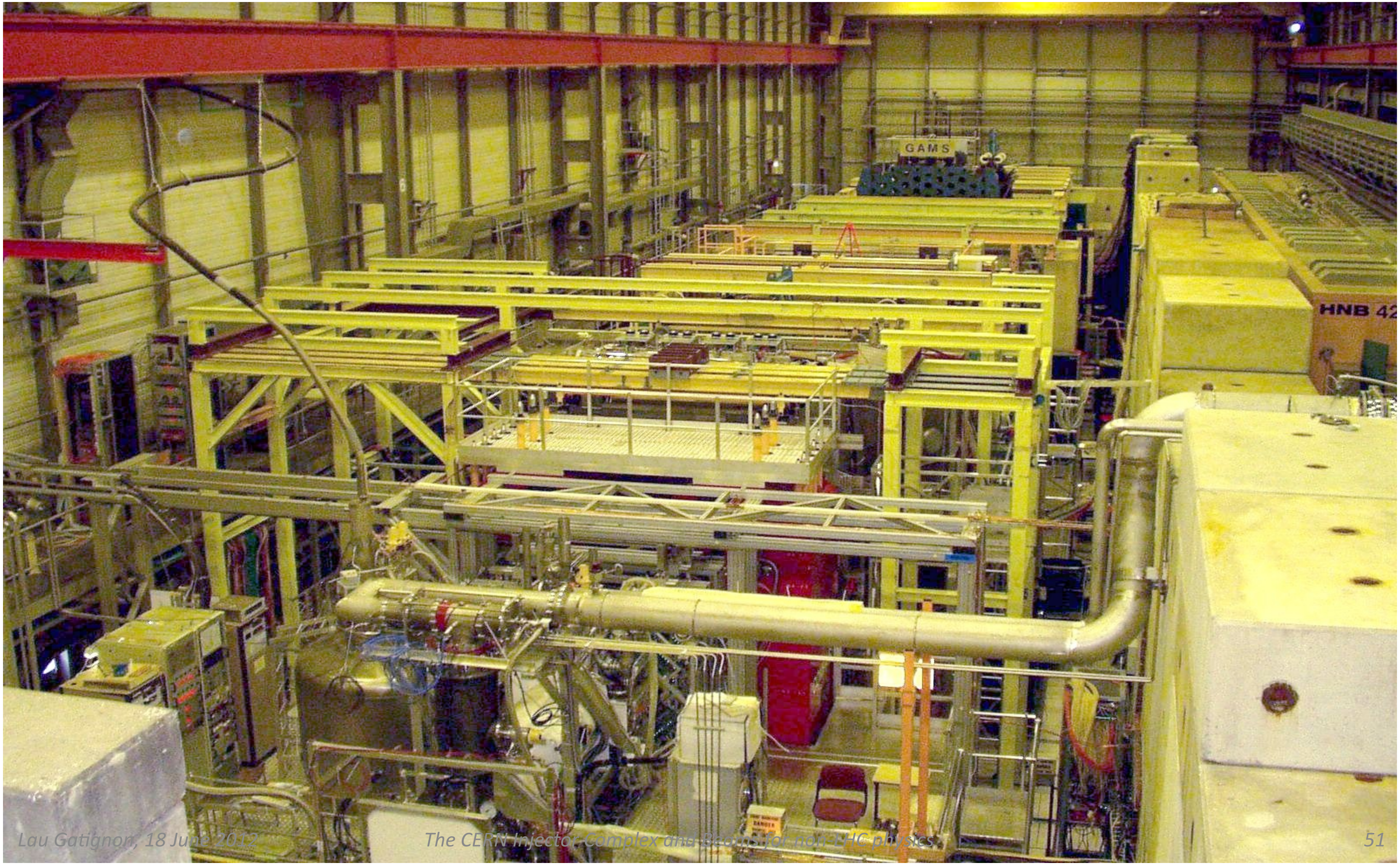
- As a high-energy, high-intensity muon beam. Normally for muon momenta up to 200 GeV/c. Higher momenta are in theory possible, but the flux drops very rapidly with beam momentum.
- As a high-intensity secondary hadron beam for momenta up to 280 GeV/c
- As a low-energy, low-intensity (and low-quality) in-situ electron calibration beam.

The main parameters are listed in the table below:

Beam Mode	Momentum (GeV/c)	Max. Flux (ppp)	Typical $\Delta p/p$ (%)	Typical RMS spot at target	Polarisation	Absorber (9.9 m Be)
Muons	+208/190 +172/160	~2 10^8 4.5 10^8	3%	8 x 8 mm	80%	IN
Hadrons	+190 -190 Max. 280	10^8 (RP)	-	5x5 mm	-	OUT
Electrons	-10 to -40	< 2 10^4	-	> 10x10 mm	-	OUT

Each mode has its own optics definition. The hadron mode has a parallel section with 2 Cedars

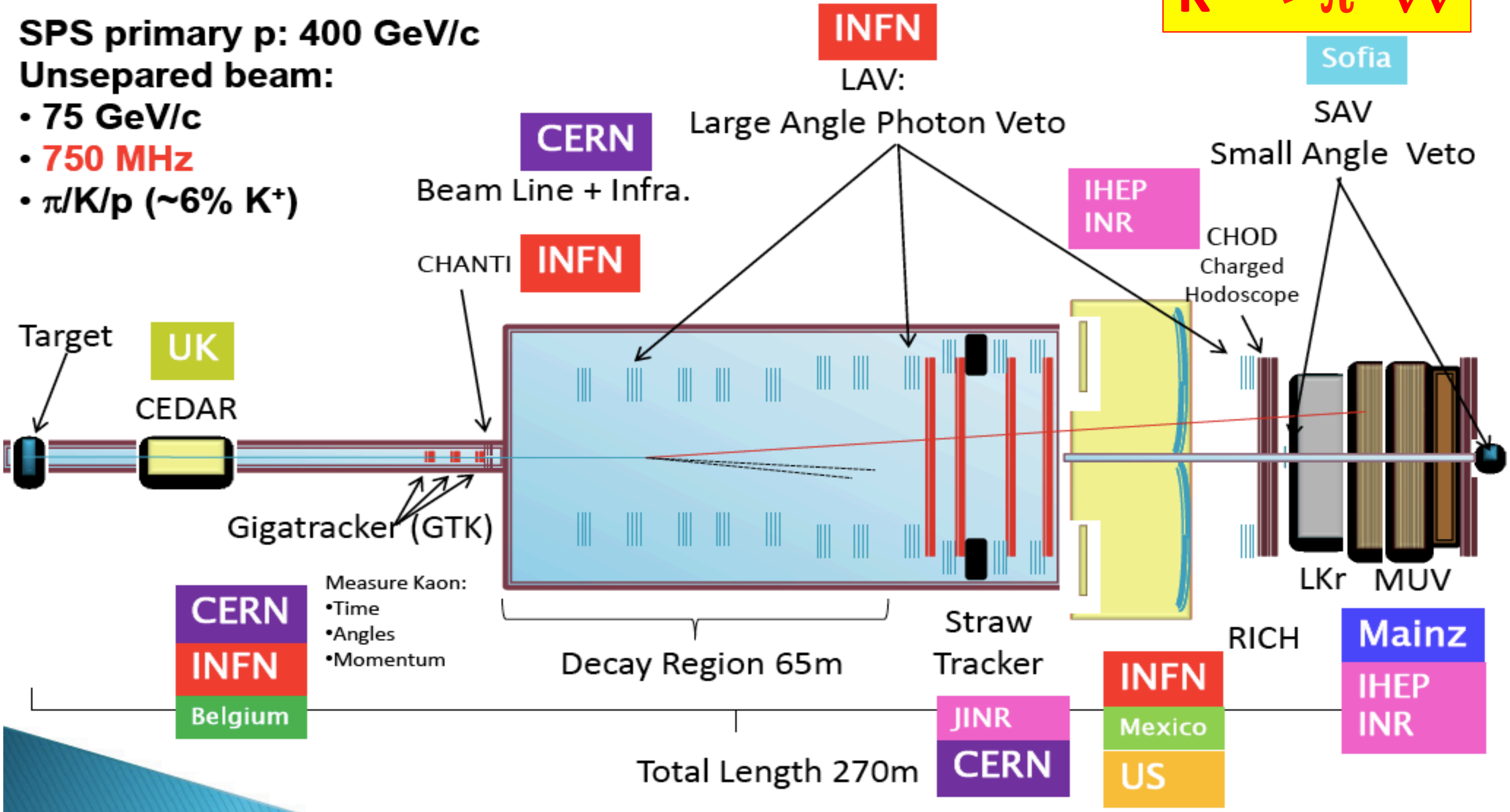
EHN2: COMPASS



NA62 Beam & Detectors

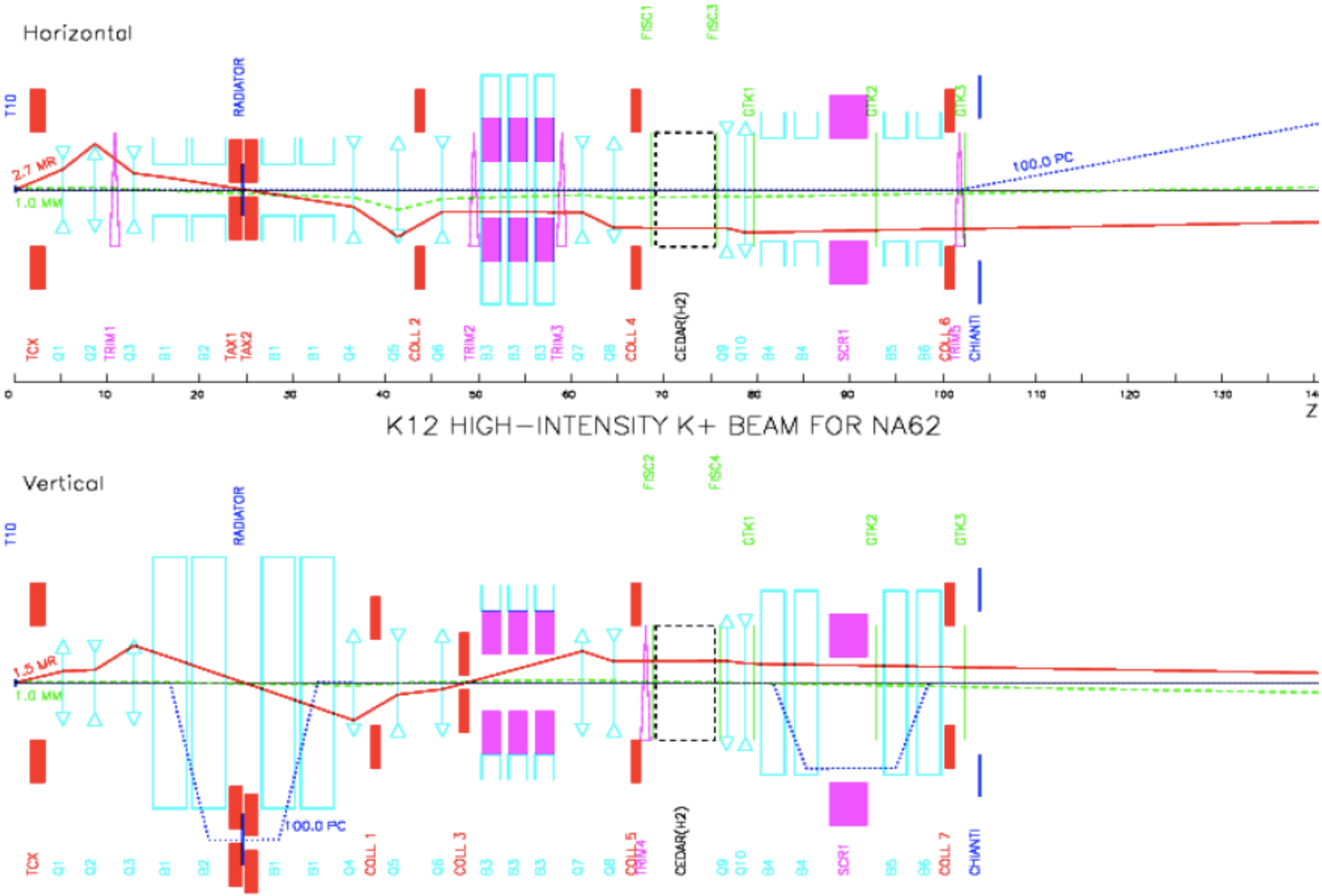
$K^+ \rightarrow \pi^+ \nu\bar{\nu}$

SPS primary p: 400 GeV/c
Unsepared beam:
- **75 GeV/c**
- **750 MHz**
- **π/K/p (~6% K⁺)**



Main design consideration for new K12 beam for NA62:

- **High intensity K^+ beam** for the very rare decay mode $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ (B.P. ~ 10^{-10})
- Momentum: 75 GeV/c because close to maximum K^+ flux.
- Carefully **matched to hermeticity of NA62 veto system**, which assumes $15 < p_\pi < 35$ GeV/c. The veto system must detect a missing energy of at least 40 GeV with extremely high efficiency. Beam size and trajectory must therefore fit very finely with detector acceptance.
- The beam momentum is defined by a first 'achromat' section of 4 dipoles and a pair of 'TAX' dump collimators. The momentum and direction of each individual particle is measured (at almost 1 GHz rate) in a second achromat.
- A parallel section has been included in the design to house a modified **CEDAR Cerenkov counter** to tag the K^+ component in the beam (~6%).
- A r**adiator** allows to strongly reduce the positron component in the beam
- A **magnetic collimation system**, combined with optimised layout of return fields in the momentum measurement section allows to minimise muon backgrounds into the apparatus.
- The beam line geometry is adapted to accommodate for a **spectrometer** in the experiment.
- At the end of the beam line the charged beam is separated further from the neutral to allow vetoing against neutral particles on-axis.


Horizontal
Vertical
K12 HIGH−INTENSITY K+ BEAM FOR NA62
Z
2.7 MR
1.5 MR
1.0 MM
100.0 PC
T10
RADIATOR
FISC1
FISC3
FISC2
FISC4
GTK1
GTK2
GTK3
CEDAR(H2)
TCX
TAX1
TAX2
COLL 1
COLL 2
COLL 3
COLL 4
COLL 5
COLL 6
COLL 7
TRIM1
TRIM2
TRIM3
TRIM4
TRIM5
SCR1
CHIANTI
0
10
20
30
40
50
60
70
80
90
100
110
120
130

Beam Experiment	K12K+K- NA48/2	**K12HIKA+** NA62	Comparison FACTOR [12]
SPS Protons per s of spill length Instantaneous Proton Rate per effective s	$\sim 2 \times 10^{11}$ 3.3×10^{11}	0.7×10^{12} **1.1×10^{12}** (equiv. $1.0\ 10^{12}$) [13]	3.0
SPS Duty Cycle (s / s) Effective Duty Cycle (s / s)	4.8/16.8 = 0.29 ~0.18	~0.3 ~0.2	~1.1
Beam Acceptance x_0', y_0' (mr)	± 0.36, ± 0.36	± 2.7, ± 1.5	
Solid Angle (µsterad)	≈ 0.4	≈ 12.7	32
Mean K^+ Momentum $<p_K>$ (GeV/c)	60	**75**	K^+ 1.4 π^+ 1.5 Total Hadrons 1.6
Momentum Band: - Effective $\Delta p/p$ (%) - r.m.s. $\Delta p/p$ (%)	 ± 5 ≈ 3.7	 ± 1.65 **1.0**	 0.33
r.m.s. Divergence: x', y' (mr) at CEDAR		0.07, 0.07	
2 r.m.s. Beam Size (mm) Area at KABES [4]/ GTK 3 (mm^2) r.m.s. Divergence: x', y' (mr)	r= ~15 ~700 ≈ 0.05, 0.05	x= ± 27.5, y= ± 11.4 ~980 0.09, 0.10	 ~1.4
Decay Fiducial Length: (m) Δz (τ_{K+}) Decay Fraction: $(1 - e^{-\Delta z})$	50 0.111 0.105	**60** 0.107 0.101	 0.96
Inst.Beam Rate / s (MHz): p **K^+** π^+ e^+, μ^+ Total	2.9 1.0 11.1 ~3 , ~0.13 ~18	173 **45** 525 ~0.3 , ~6 **750**	60 45 47 ~0.1 , ~45 ~42

TCC8 (where the K12 beam is being installed) in fall 2011

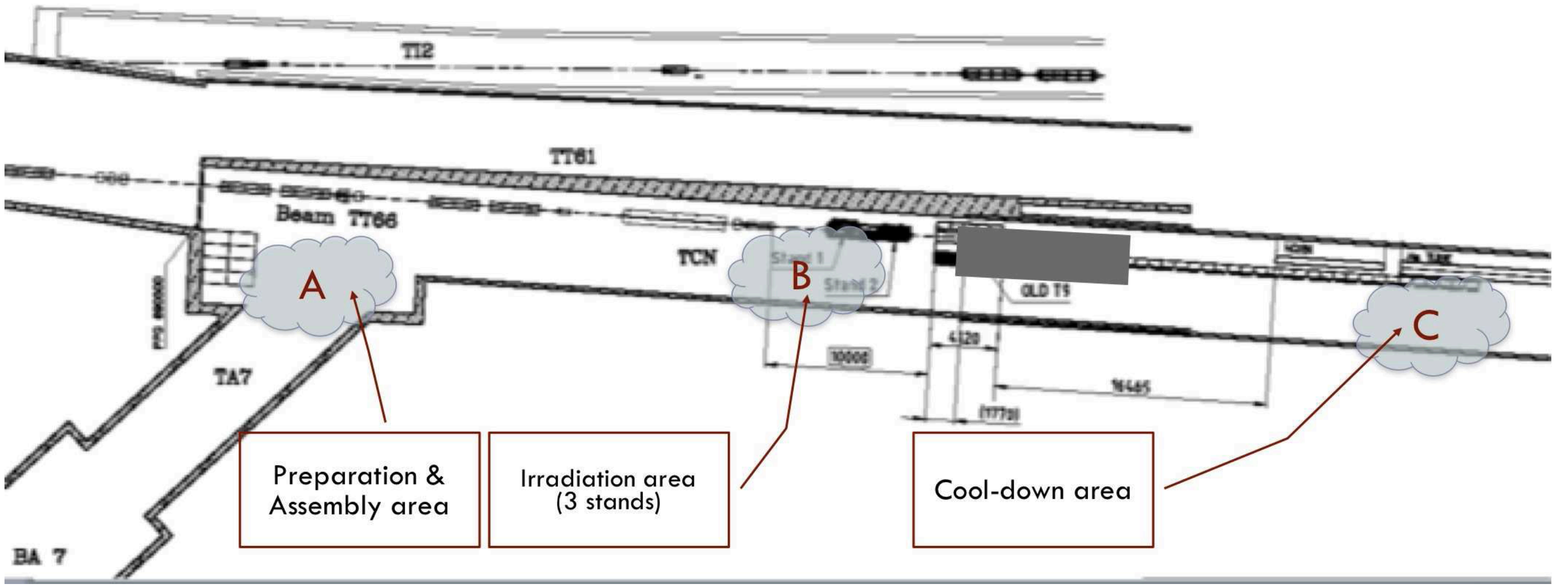

5 June 2012

HiRadMat

The HiRadMat facility is a new facility at CERN, designed to provide high-intensity pulsed beams to an irradiation area where material samples and accelerator components can be tested under the **effect of pulsed beams**. It uses a 440 GeV/c proton beam with a pulse length of **7.2 μsec** with a maximum pulse energy of **3.4 MJ**.

The facility is located in the old WANF target cavern near the West Area.
It uses the same extraction channel as the TI2 transfer line to the LHC.

The facility is designed for a maximum of 10^{16} protons per year, distributed among ten experiments.
It is thus not intended to accumulate large doses.

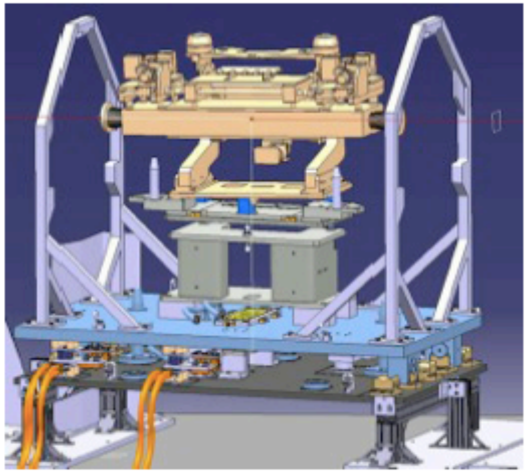


Preparing for experiments

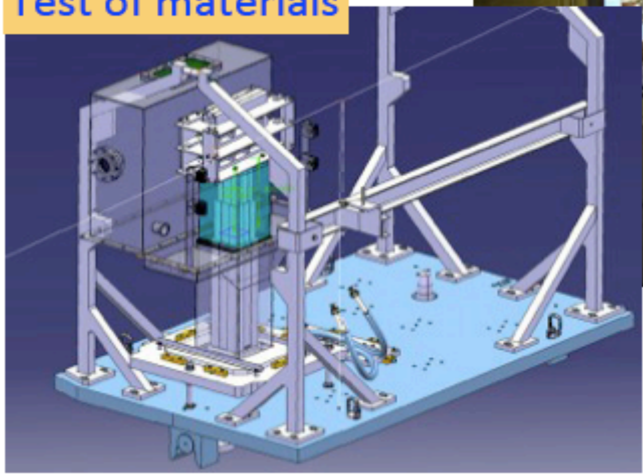
- Interface table for installation of experiments

- Remote operations

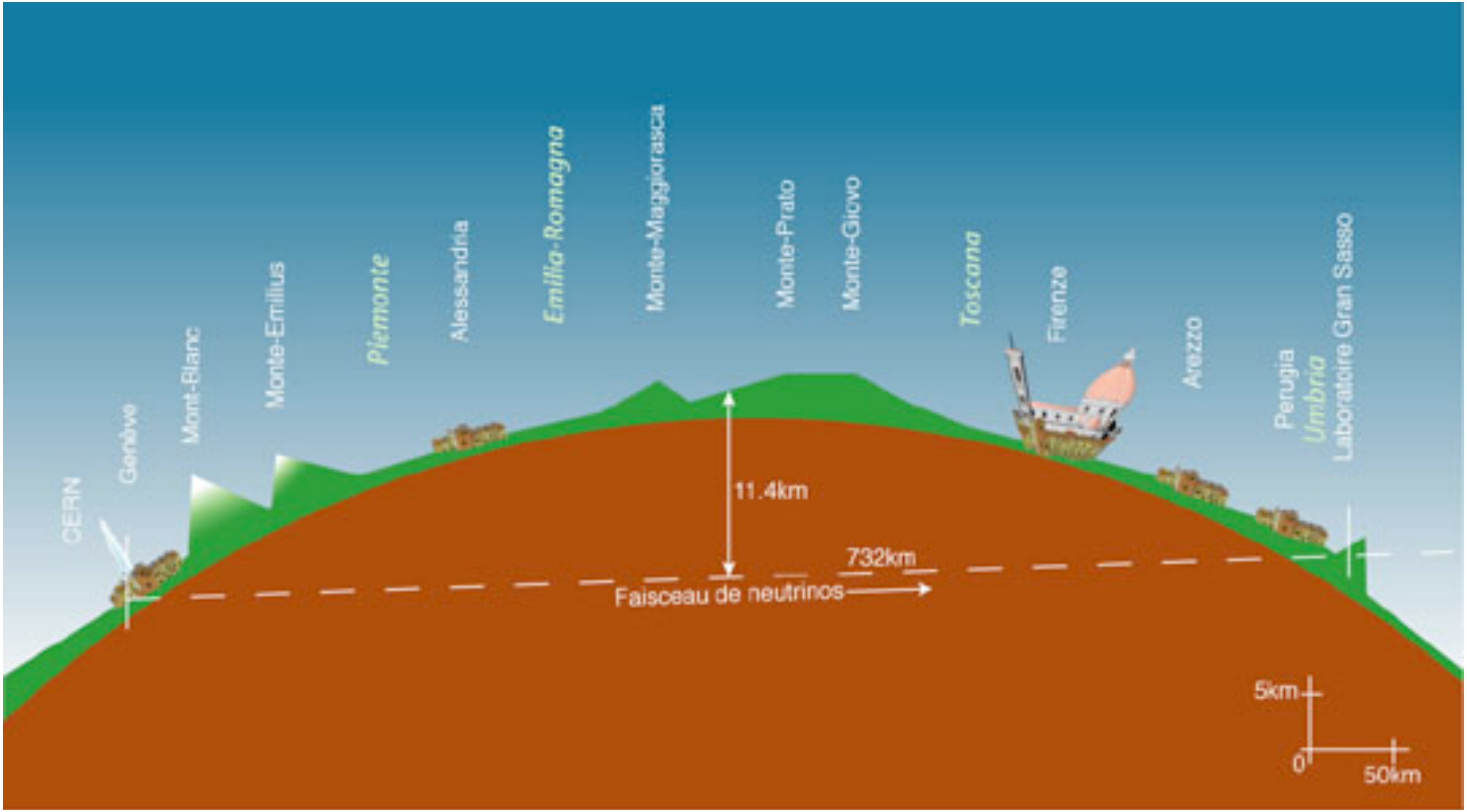
Test of collimators



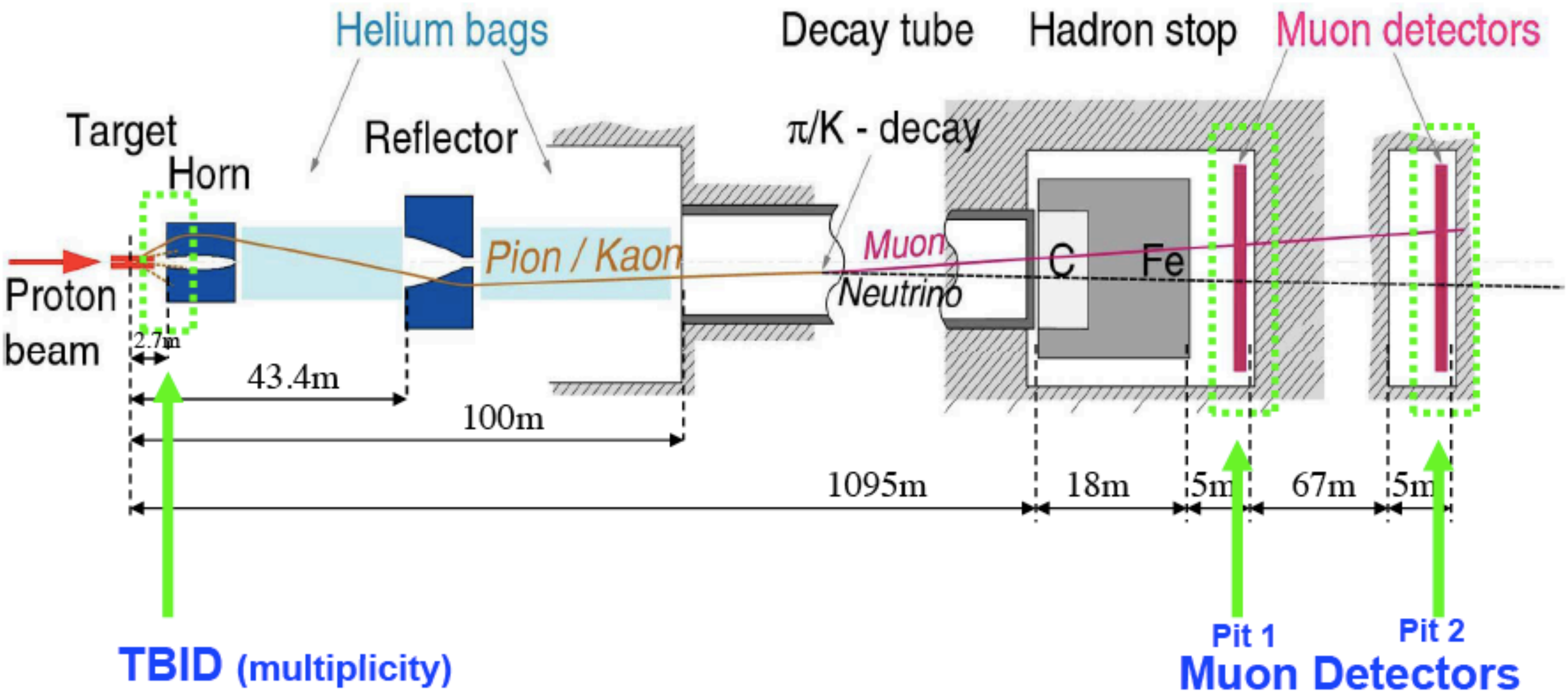
Test of materials



The CERN Neutrino Beam (CNGS)

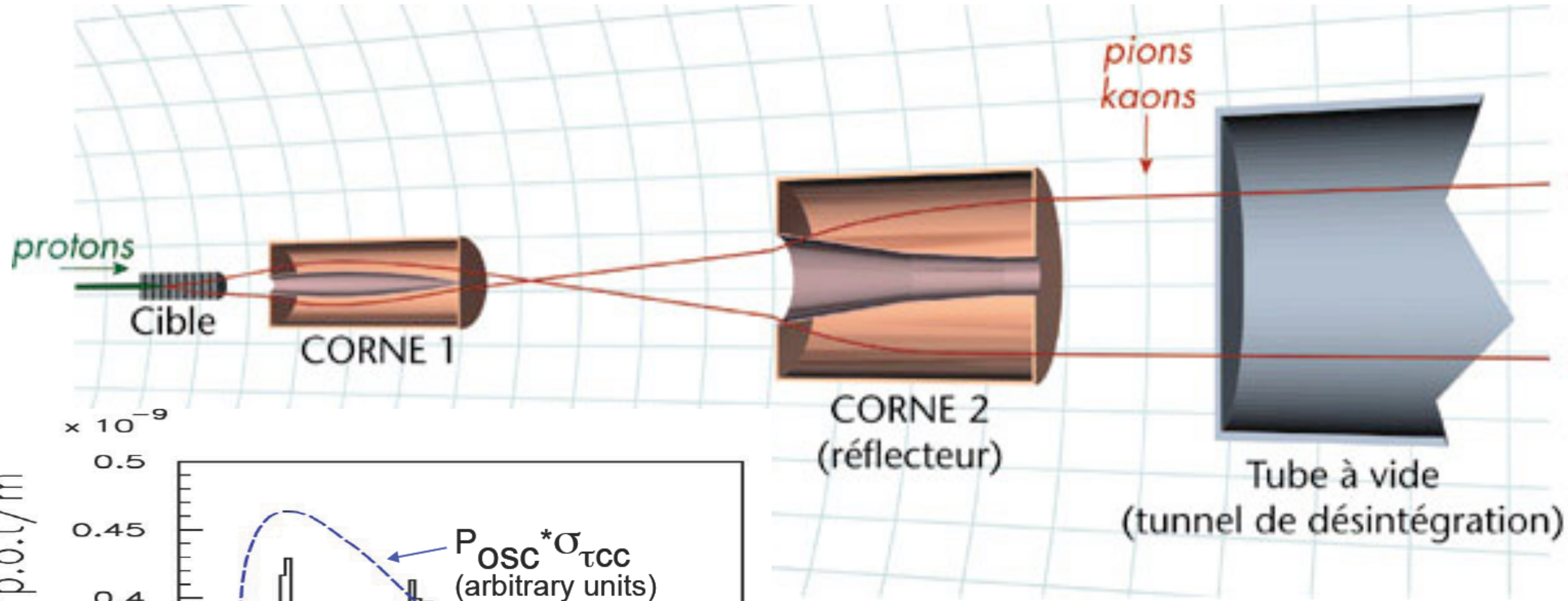


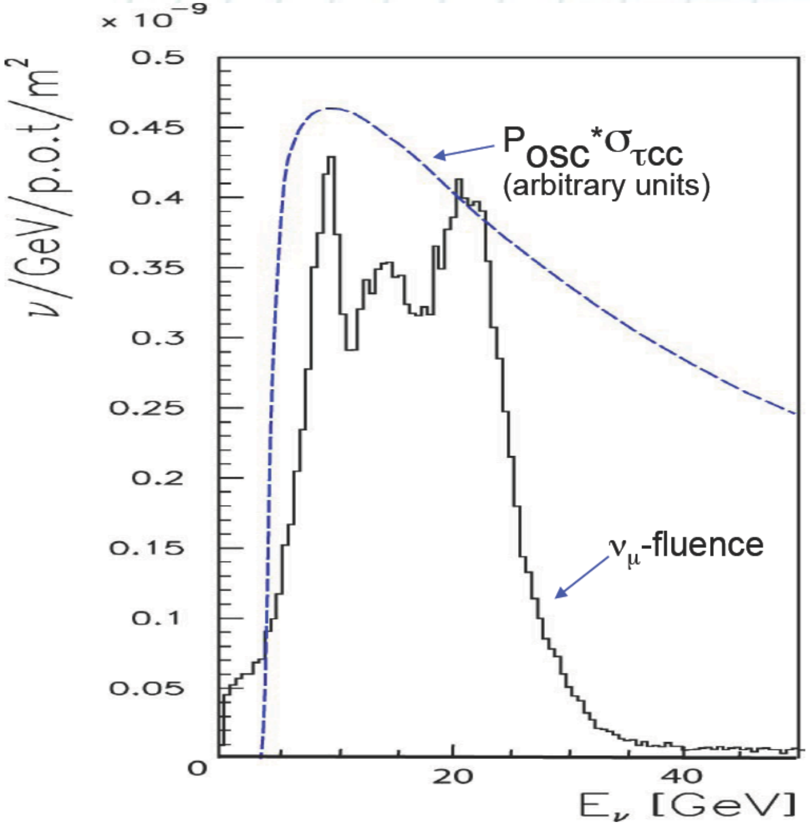
CNGS Layout



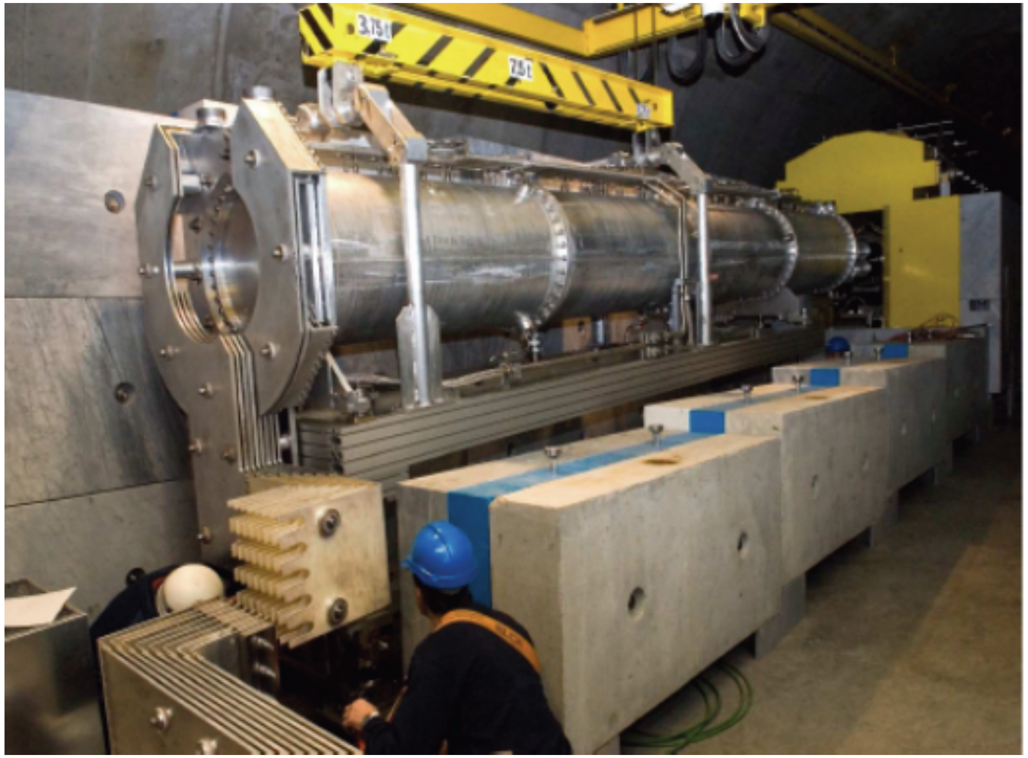
$p + C \rightarrow$ (interactions) $\rightarrow \pi^+, \; K^+ \rightarrow$ (decay in flight) $\rightarrow \mu^+ + \nu_\mu$

The pion collection system

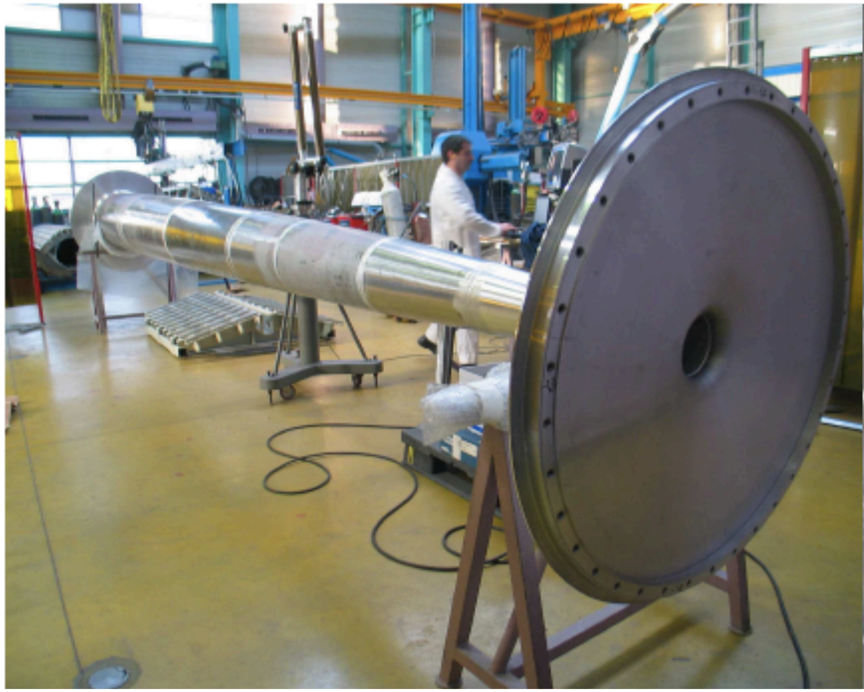


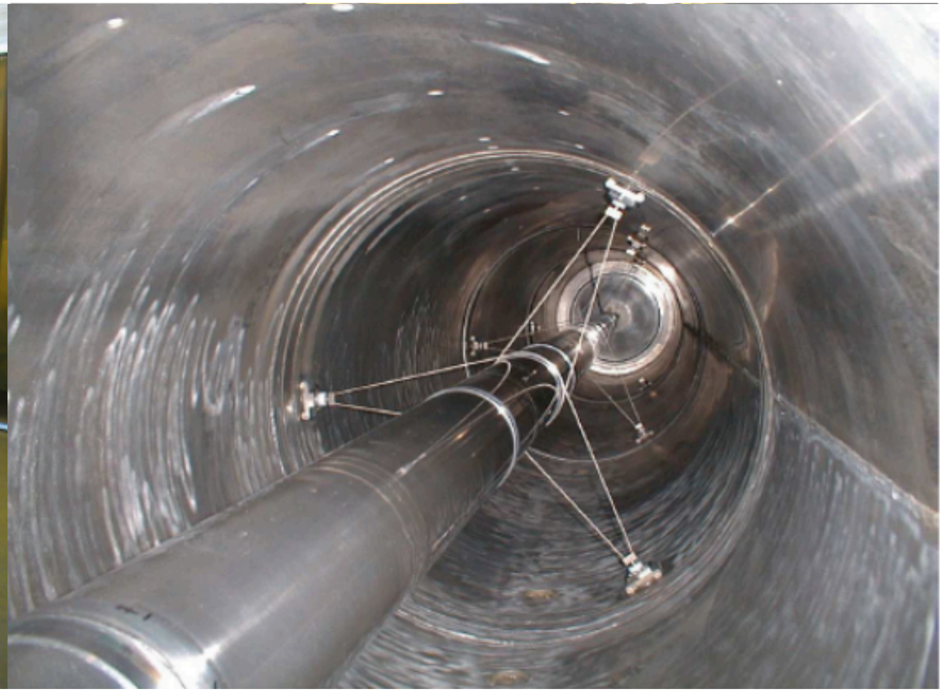


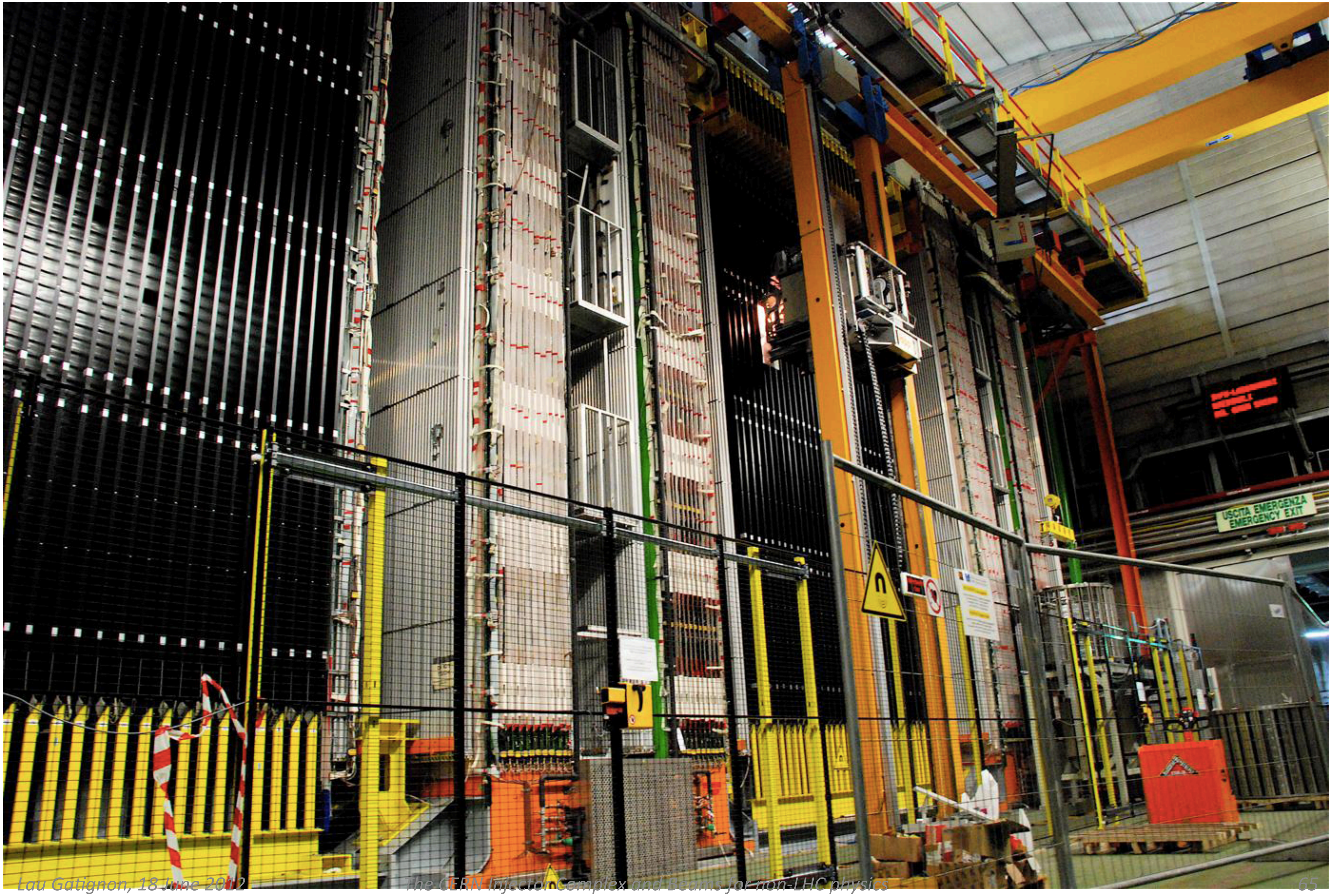

The CNGS target



- *internal conductors: parabolic shape, only 1.8 mm thickness to minimize absorptions/reinteractions but sufficient for mechanical stability*
- *no material in between inner/outer conductor!*






USCITA EMERGENZA
EMERGENCY EXIT

FUTURE PLANS FOR NEUTRINOS

Ideas exist for future neutrino beams, in particular a short baseline on the Prevessin site at CERN, based on an extraction from the SPS.
Both a near and far detector, as well as possibly an intermediate detector, are foreseen in a recent proposal to the SPSC presented by Carlo Rubbia.

This project is still in the early phases of discussion and nothing is approved yet.
In the following slide we just show one option, but alternative options are also under study.

SHORT BASELINE NEUTRINO BEAM IN THE SPS NORTH AREA

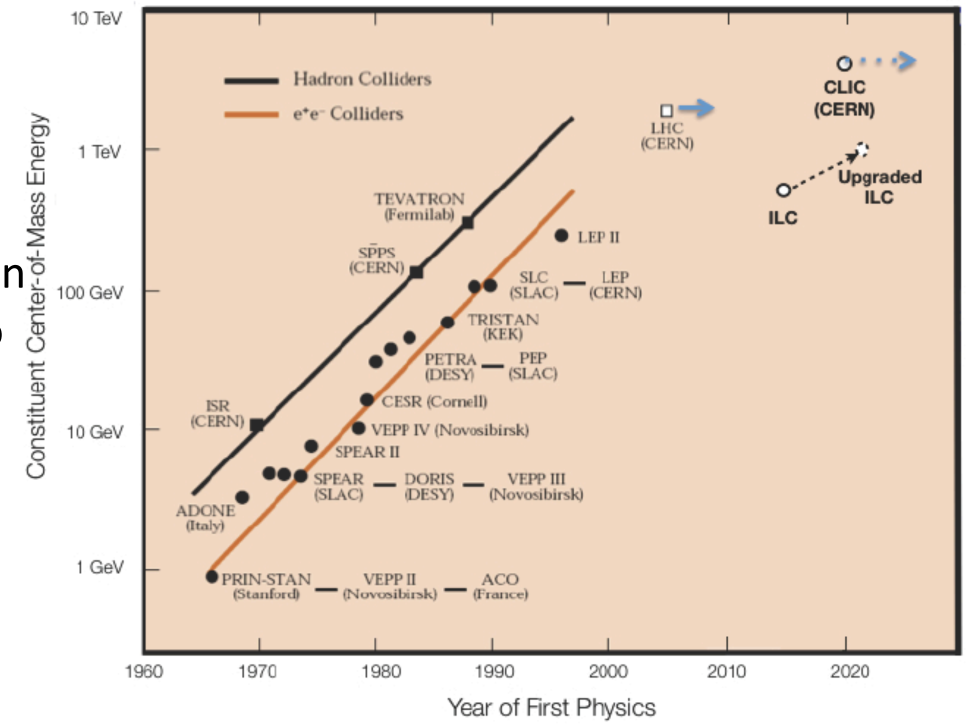
Layout parameters

- primary beam : **100 GeV**, ν-beam : **~2 GeV**
- target station at the TCC2 level (**~11m underground**)
  - Lateral distance defined by the location of the near&far detectors
  - sufficient distance from TCC2 to allow works during NA operation
  - not really mandatory but better if we can, at least for civils
  - Cavern design like NuMI (LBNE)
- decay pipe : **80m, 3m** diameter
- beam dump : **15m of Fe** with graphite core, followed by μ stations
- ν-beam angle : pointing upwards
  - at -3m in the far detector --> **~5mrad slope**

PPWA TEST FACILITY

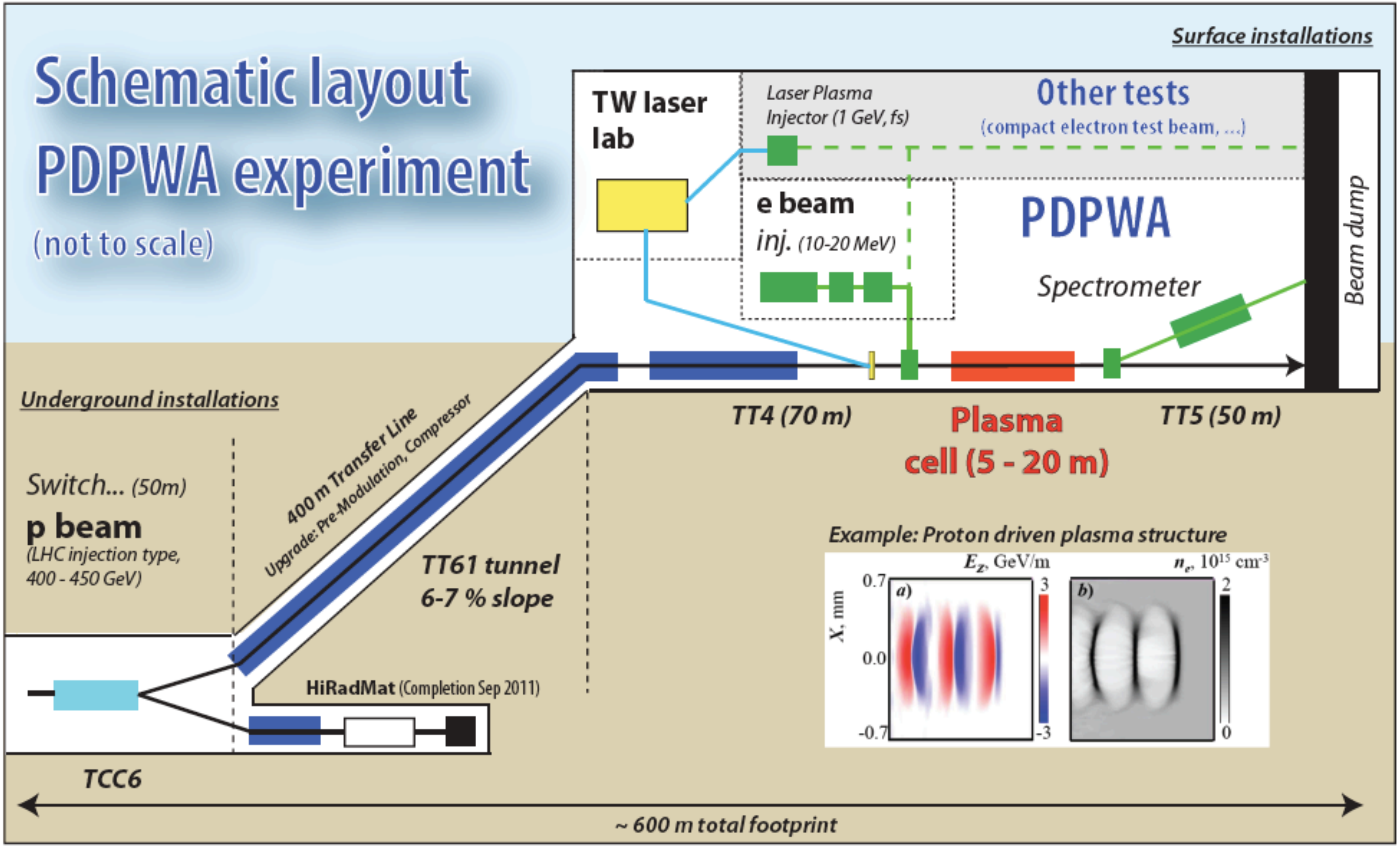
With present technology high energy e^+e^- colliders become increasingly long, expensive and difficult.

Plasma e- beam or laser driven wakefield acceleration are being pursued in various laboratories as a way to achieve significantly higher gradients.
However, for a multi-TeV linear collider a large number of accelerating stages would be required.
Proton driven plasma wakefield acceleration, using a high-energy proton beam as driver, has been suggested as an alternative.



Recently a Letter of Intent has been submitted to the SPSC, which received significant interest.
Very preliminary studies for building a test facility at CERN are under way.
Such a facility could profit from the existing extraction for TI2 and HiRadMat in the West Area.

PPWA TEST FACILITY



FINAL REMARKS

CERN has an active fixed target physics programme.

This programme is complementary to the collider physics experiments.

One studies subtle effects with detectors that in many cases are optimised for specific physics measurements (therefore often very elegant!).
The details of many of the experiments will be addressed in the remaining lectures in this series.

These experiments are indeed smaller than the experiments at the LHC, but they nevertheless occupy up to 250 physicists and can take up to 20 years from conception/proposal to final results!

These experiments are served by a large complex of beam lines, which are interesting on their own!

ACKNOWLEDGEMENTS

Many thanks to

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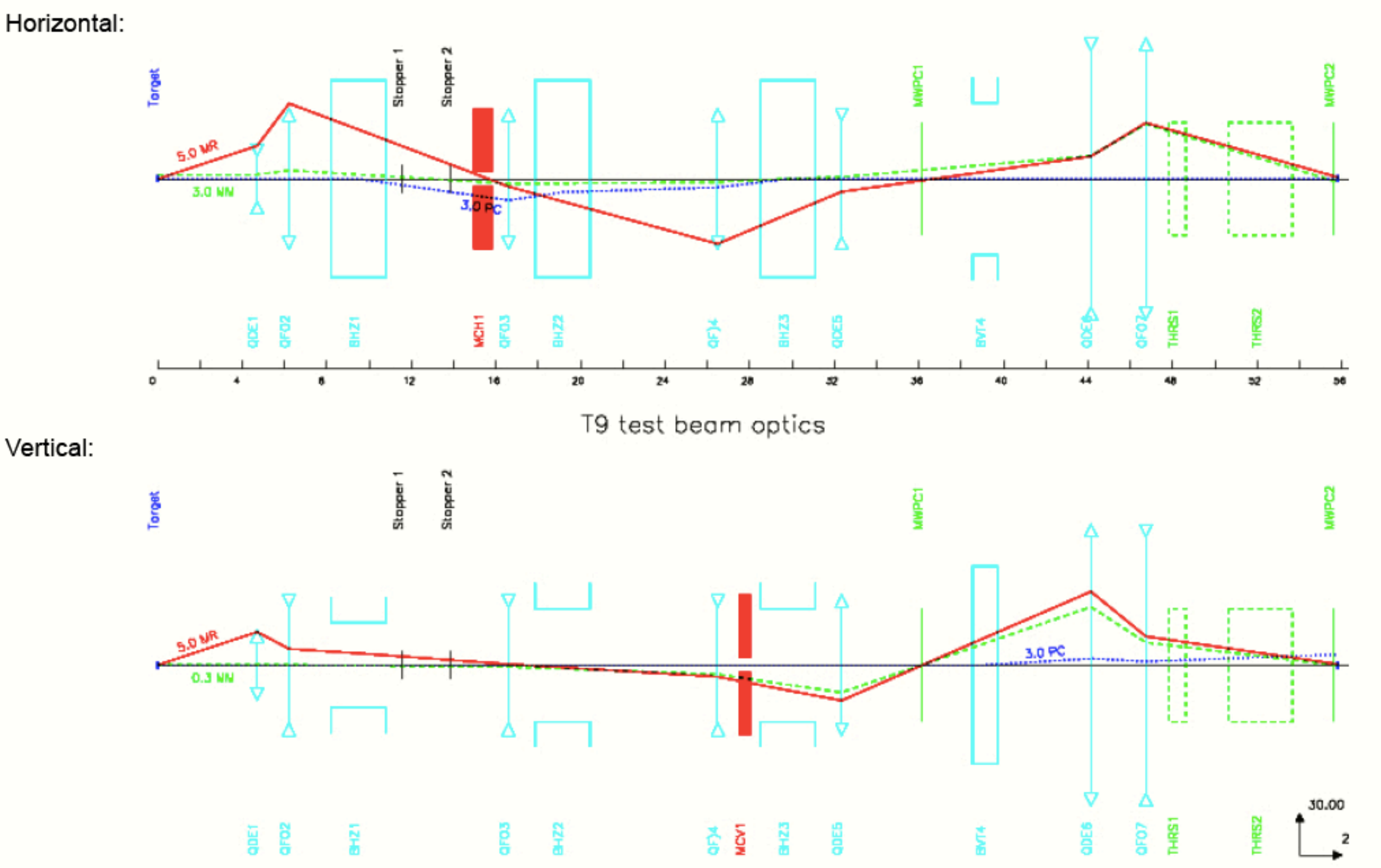
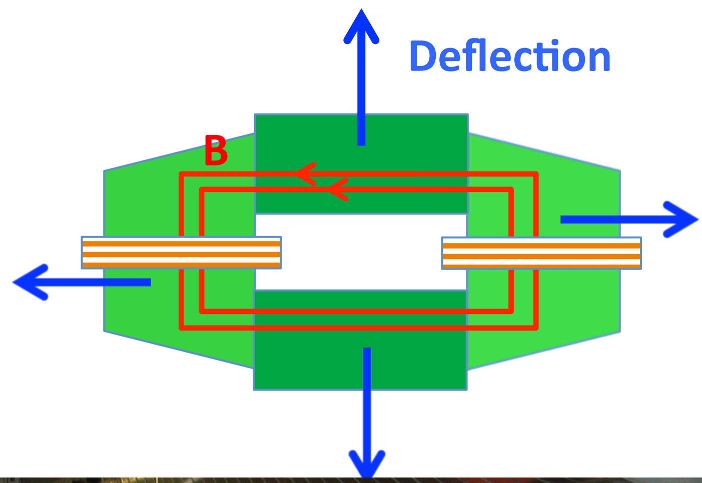
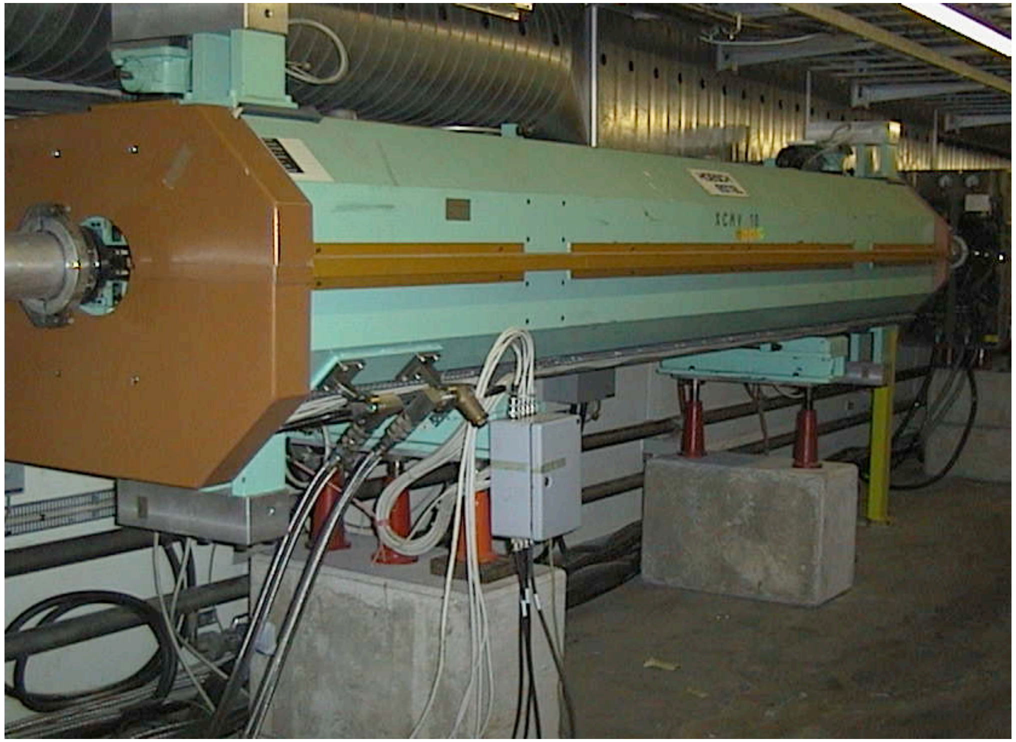
SPARE SLIDES


Horizontal:
Target
Stopper 1
Stopper 2
MWPC1
MWPC2
5.0 MR
3.0 NN
3.0 PC
QDE1
QFO2
BHZ1
MCH1
QFO3
BHZ2
BHZ3
QDE5
BVT4
QDE6
QFO7
THRS1
THRS2
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
T9 test beam optics
Vertical:
Target
Stopper 1
Stopper 2
MWPC1
MWPC2
5.0 MR
0.3 NN
3.0 PC
QDE1
QFO2
BHZ1
QFO3
BHZ2
MCV1
BHZ3
QDE5
BVT4
QDE6
QFO7
THRS1
THRS2
30.00
2

HALO REDUCTION IN THE MUON BEAM

A typical feature of muons is that they traverse material rather easily. Classical collimation is not useful in a μ beam. Therefore a scheme with magnetic collimation has been applied, based on toroids. The beam is equipped with 9 SCRAPERS (5 m long each) and 4 MIBS (3.2 to 8 m long). The large length is required to minimise the scattering effect of the yoke ($\sim \sqrt{L}$) w.r.t. the magnetic deflection, which is proportional to L.





The Lecture Series

This is the first out of a series of 4 lectures covering the fixed target physics program at CERN.

The other lectures are:

• **QCD and Hadron Physics**	Gerhard Mallot	Wednesday
• **Flavor / Neutrino Physics**	Augusto Ceccucci	Thursday
• **Antimatter ($\bar{H}$ at AD)**	Geoffrey Hangst	Friday

The following lectures take place in the PS amphitheater 6-2-024