beamline for schools

CERN

YEARS/ANS CERN

Beam lines at CERN, including T9

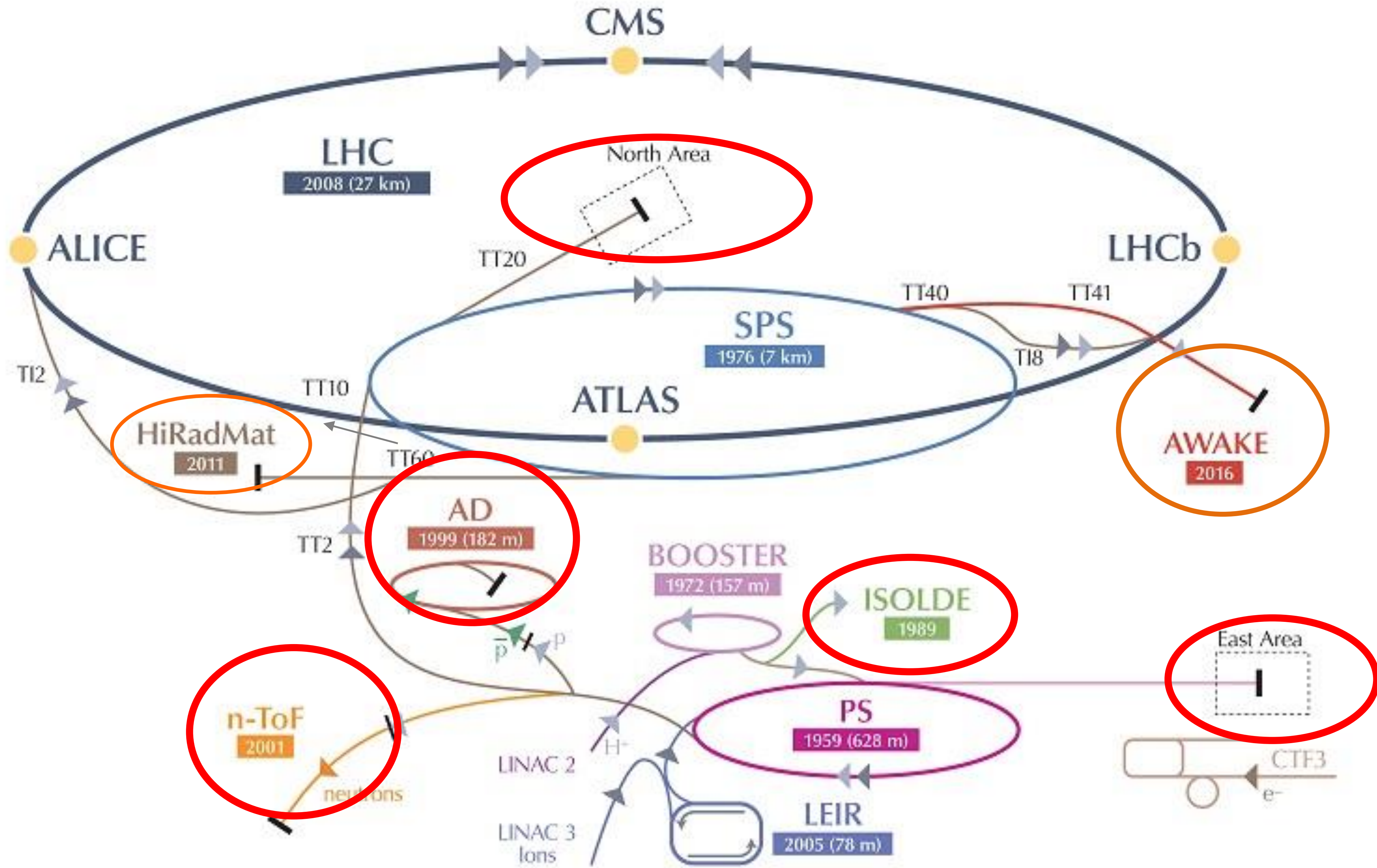
Beam Lines for Schools, 12 September 2015

Lau Gatignon / EN-MEF

CERN EN Engineering Department

SBA Secondary Beams & Areas

THE CERN ACCELERATOR COMPLEX WITH ITS EXPERIMENTAL AREAS



FIXED TARGET vs COLLIDERS

$E_{cms} \sim \sqrt{E_{beam}}$

e.g.: SPS: 27 GeV

Many particle types:

e.g. p, π, K, e, μ, ..

$E_{cms} \sim E_{beam}$

e.g.: LHC: 13000 GeV

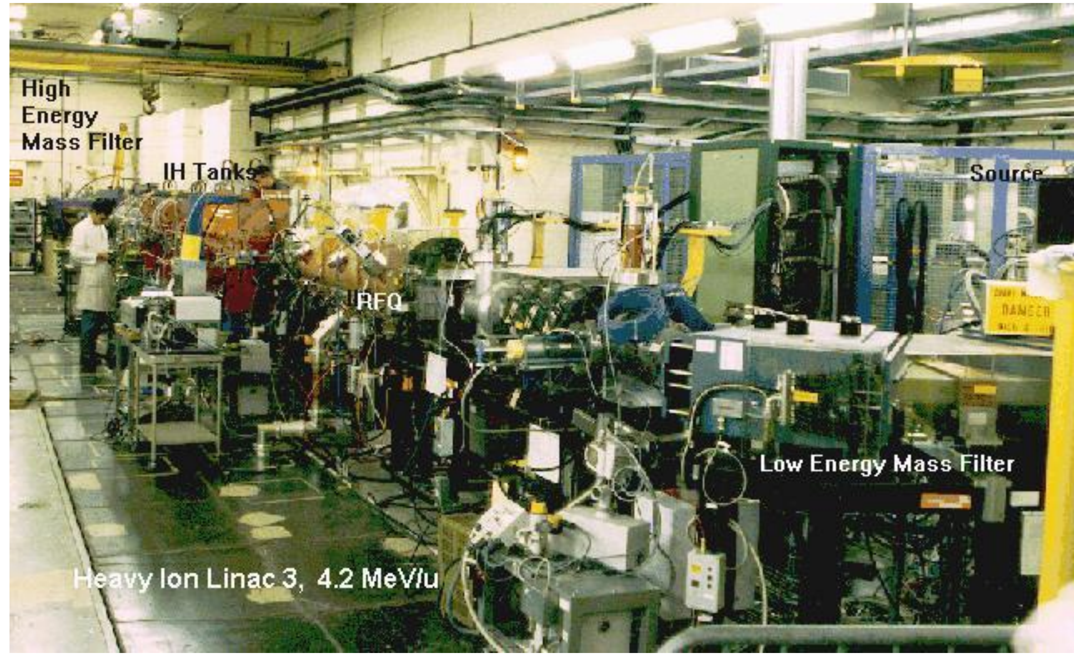
One particle type:

Protons (evtl ions)

Precision experiments,
Rare events

Discovery machines,
e.g. Higgs

The LINACs: where it all starts.....



Linac2: includes the proton source

Built from 1973 to 1978

Total length: ~33 m + 80 m transfer line

50 MeV kinetic energy

~170 mA protons

Linac3: includes the heavy ions source

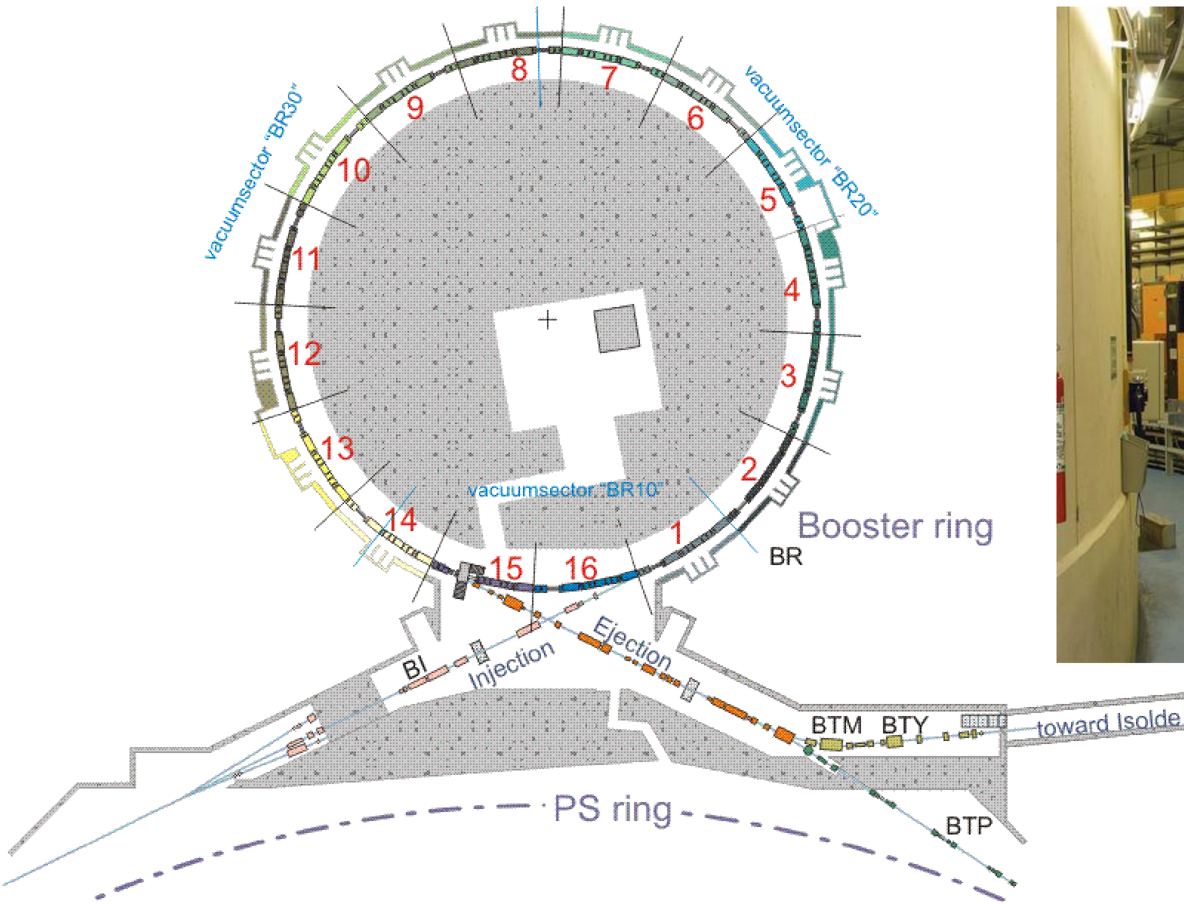
Commissioned in 1994

Total length: ~12 m + short transfer line

4.2 MeV/N

25 μA Pb^{54+}

The PS Booster (PSB)



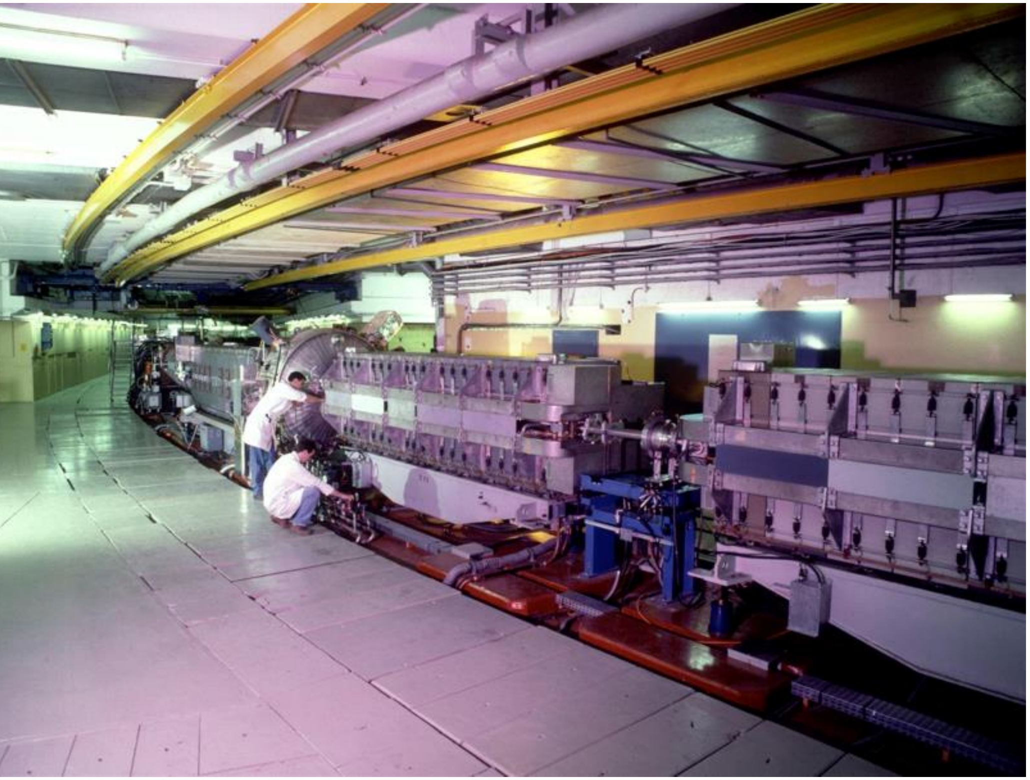
The PSB receives the beam from Linac2 and accelerates it to 1.4 GeV/c for ejection towards ISOLDE or into the PS.

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

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!

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 with a basic period of 1.2 seconds.

The PS servse many 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.

THE SUPER PROTON SYNCHROTRON (SPS)

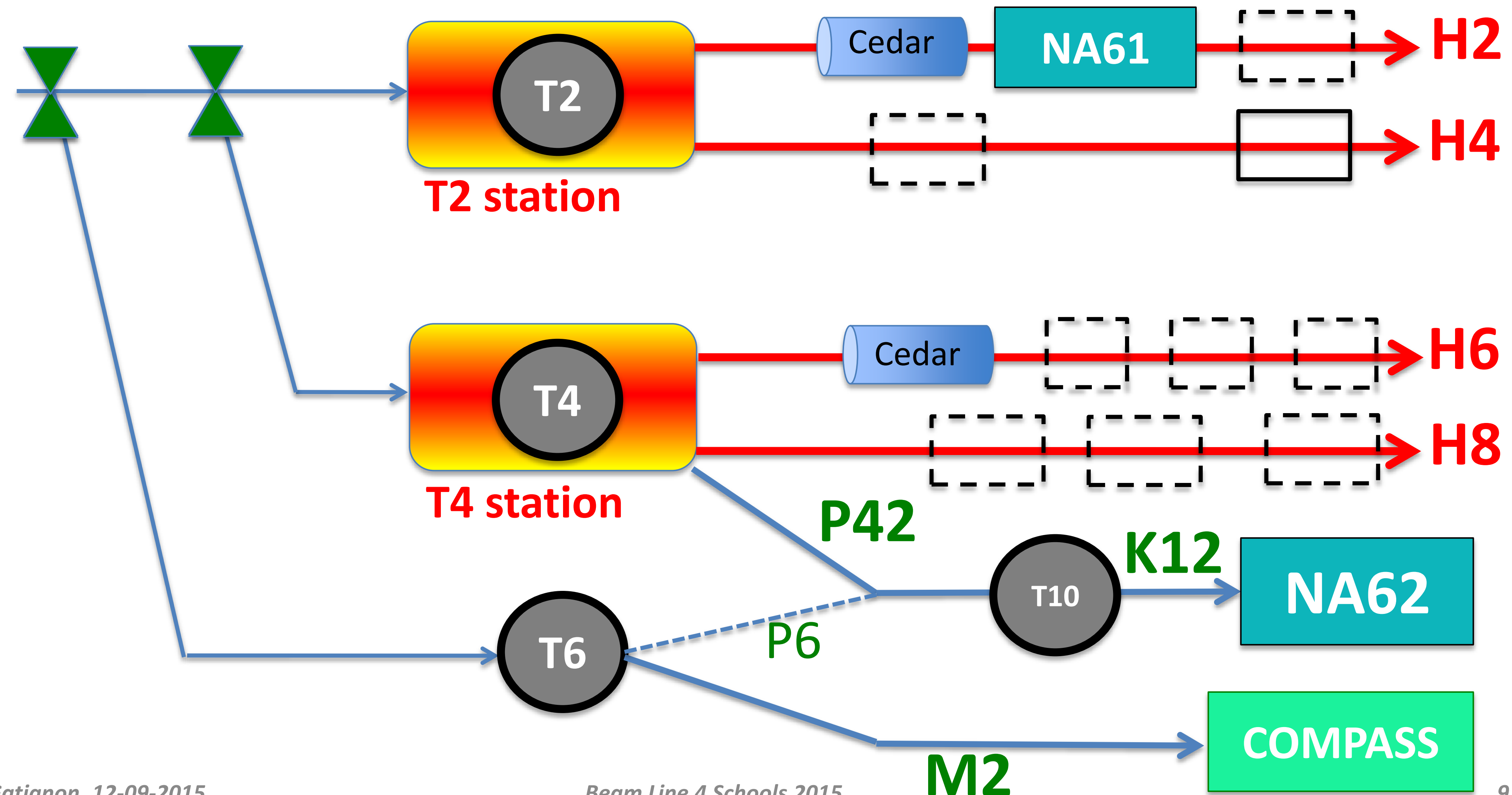
The Super Proton Synchrotron is the last accelerator in the injector chain before the LHC.
Its commissioning started in 1976, but the North Experimental Area started only in 1978.
Originally designed for fixed target proton operation at 300 GeV/c, it has operated up to 450 GeV/c for fixed target physics (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 protons are injected at 14 GeV/c and (nowadays) accelerated to 400 GeV/c.

North Area (SPS)

NORTH AREA BEAM LINES

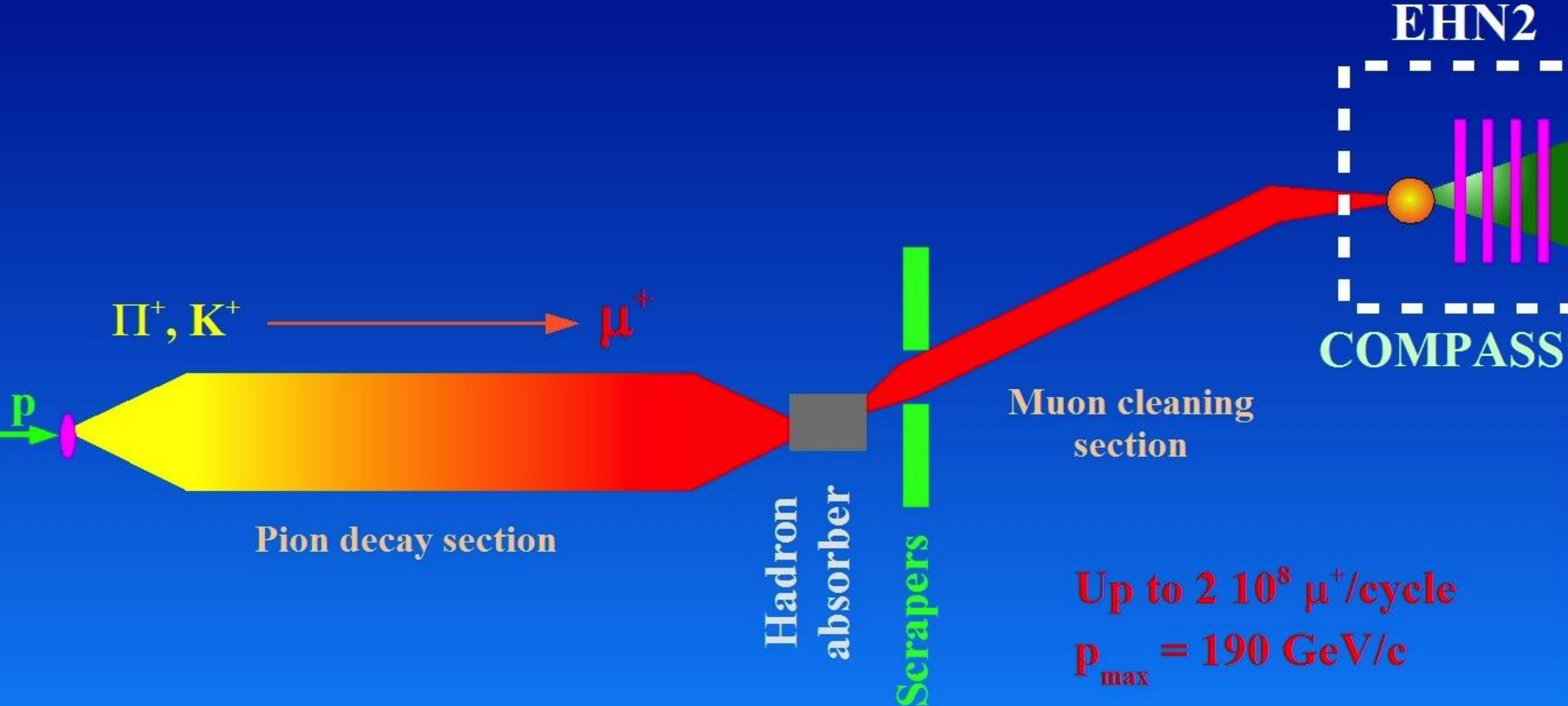
(Schematic view!)



THE EHN1 HALL

THE M2 MUON BEAM

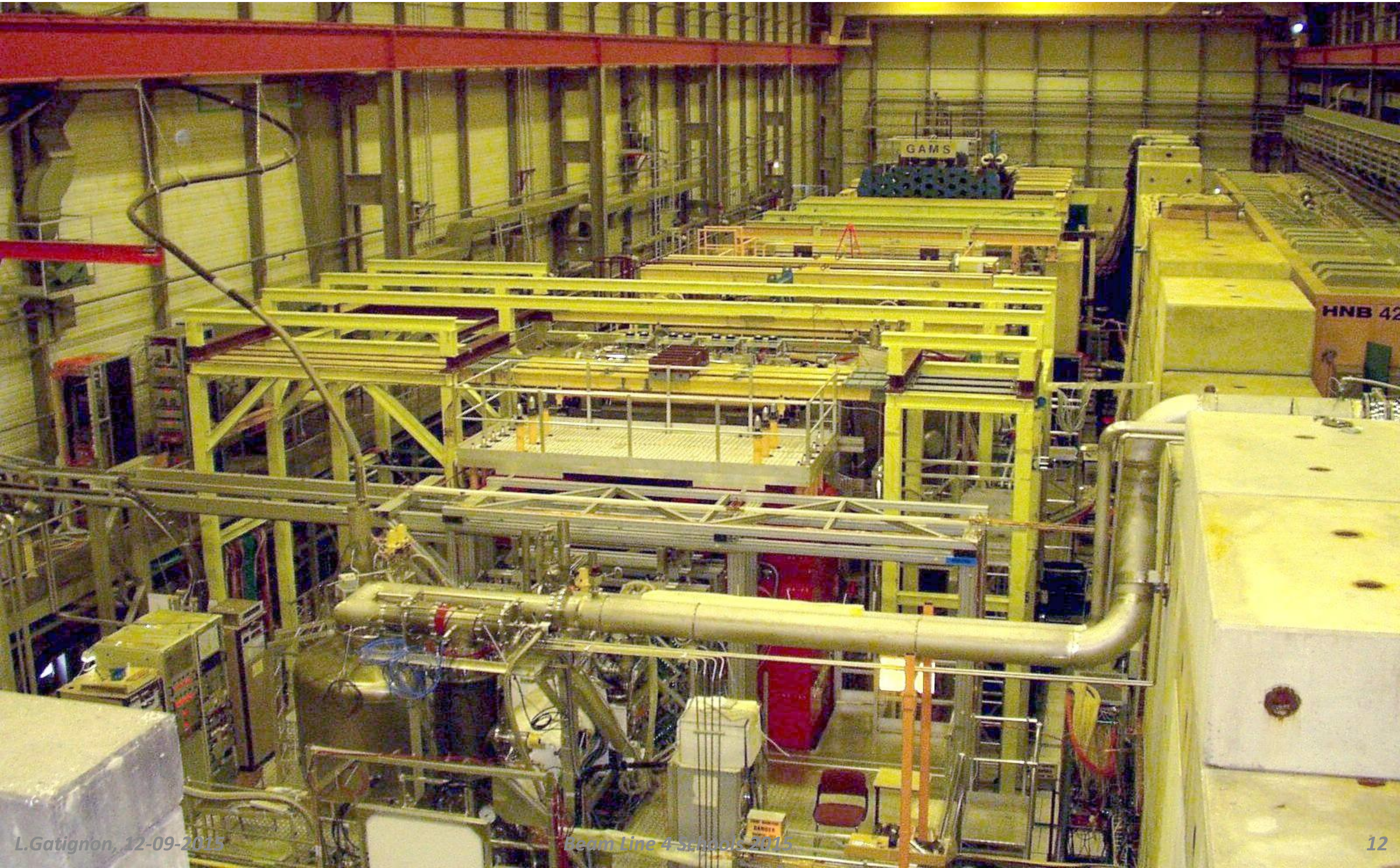
FOR COMPASS / NA58



Up to 2 10^8 μ^+/cycle

p_{max} = 190 GeV/c

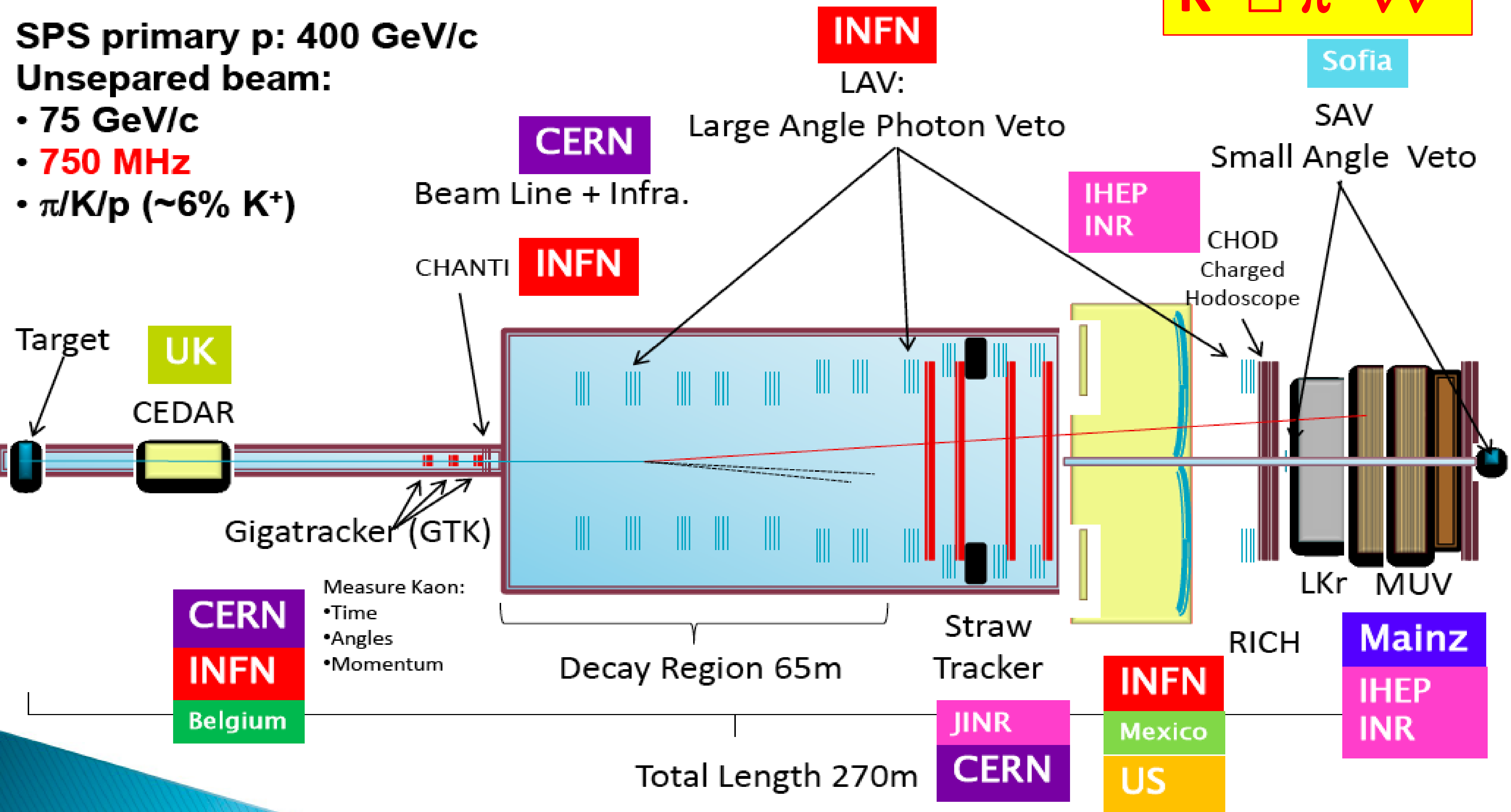
EHN2: COMPASS



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^+)**



5 June 2012

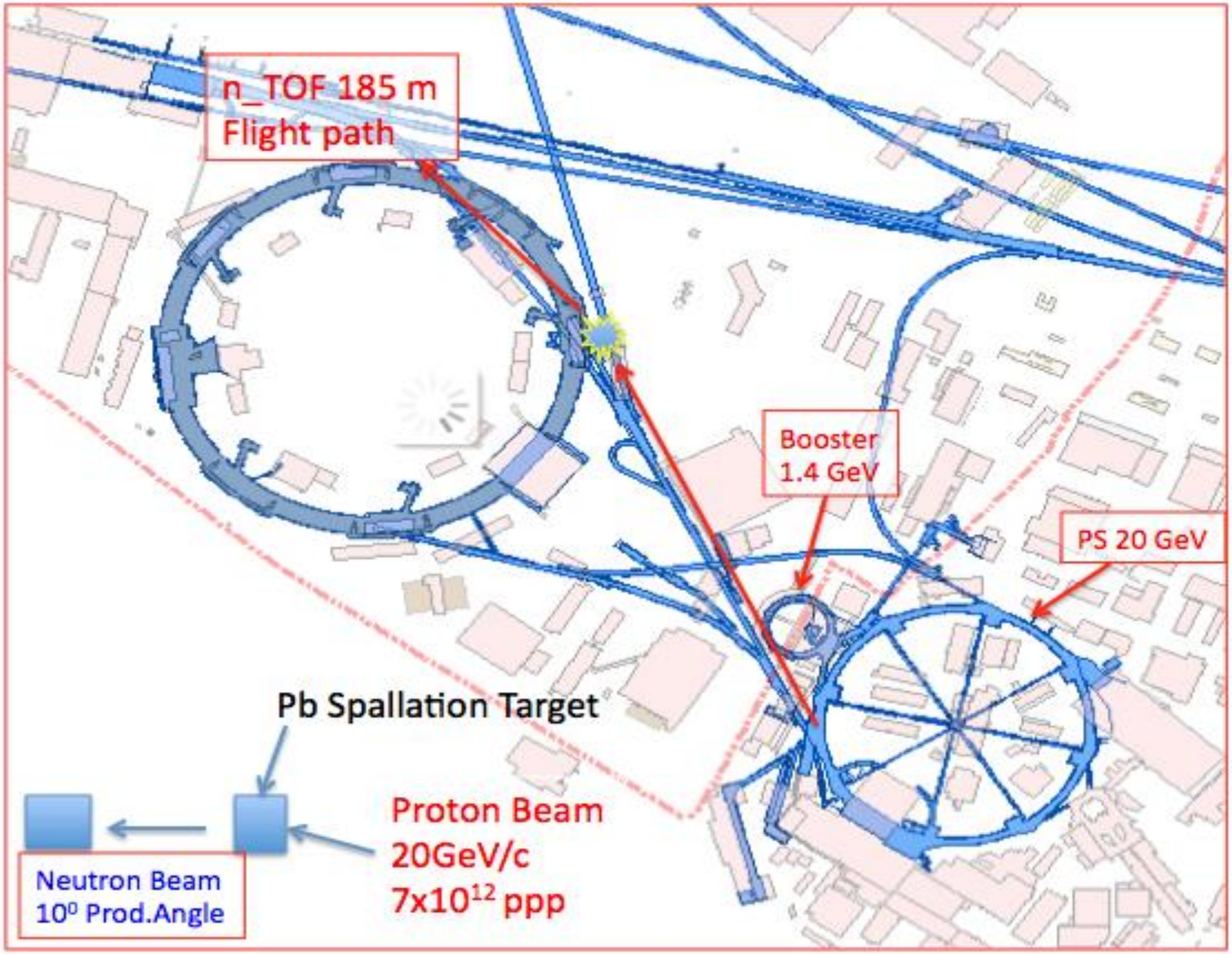

V28
SURVEY 4
SURVEY 4


V28
SURVEY 4
SURVEY 4

THE PHYSICS PROGRAMME AT THE PS

The East Area beam lines but also…..

nTOF: THE NEUTRON TIME OF FLIGHT FACILITY

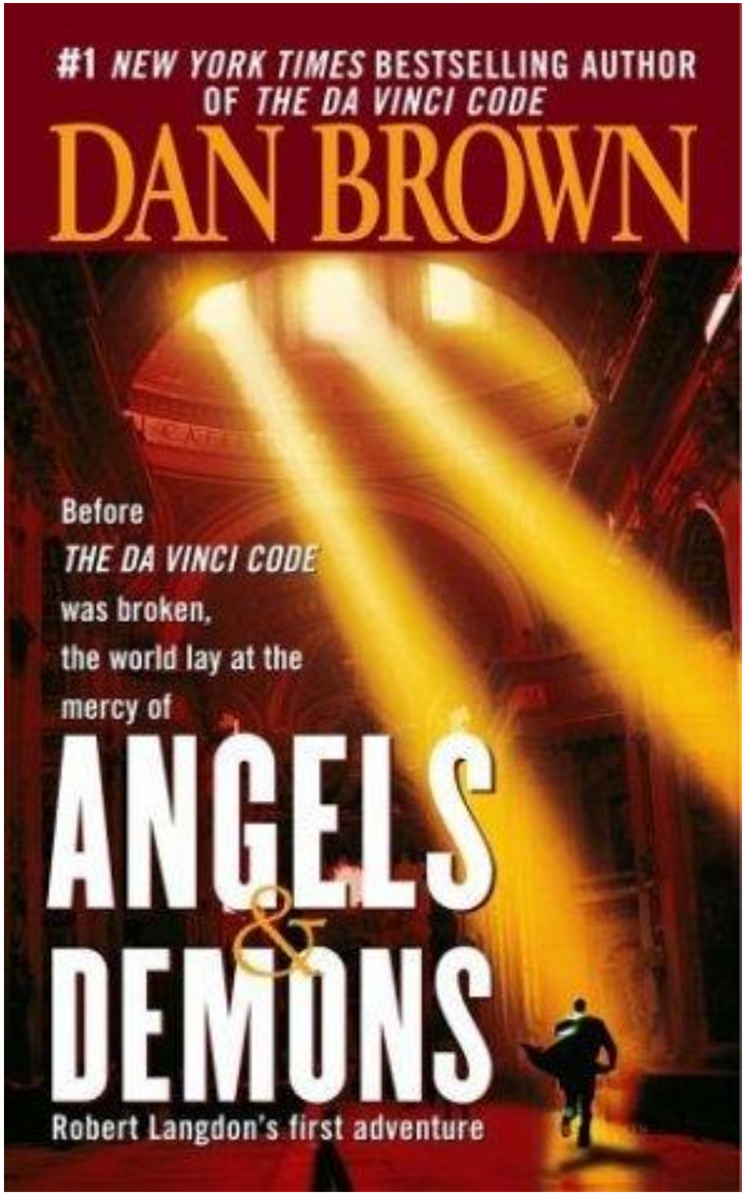


Neutrons are generated by a **pulsed** beam of 20 GeV/c protons (6 ns RMS), hitting a lead spallation target.

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 Antiproton Decelerator (AD)



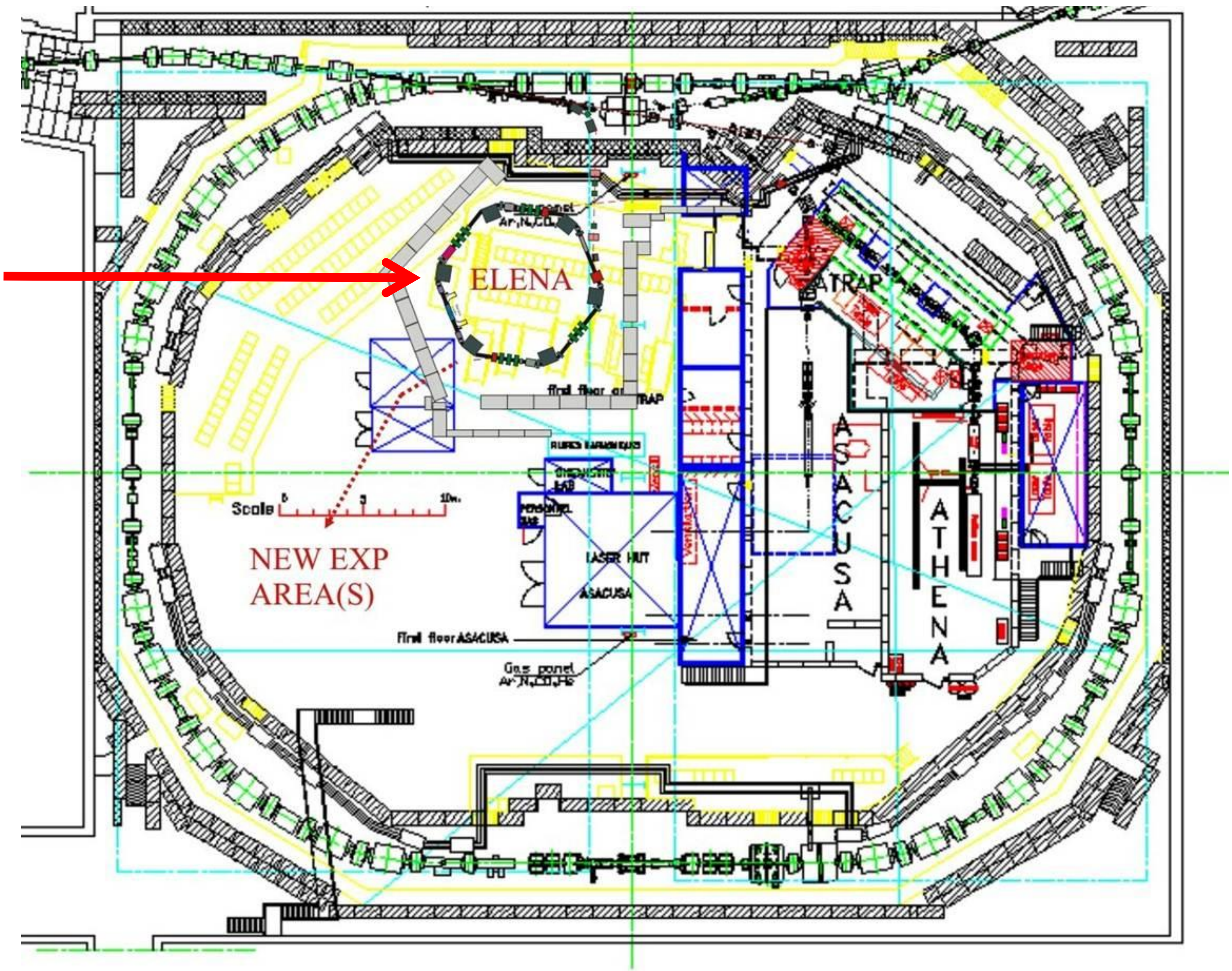
Antiprotons are produced from pulses of $1.5\ 10^{13}$ protons at 26 GeV/c on a Iridium production target, followed by a magnetic horn.

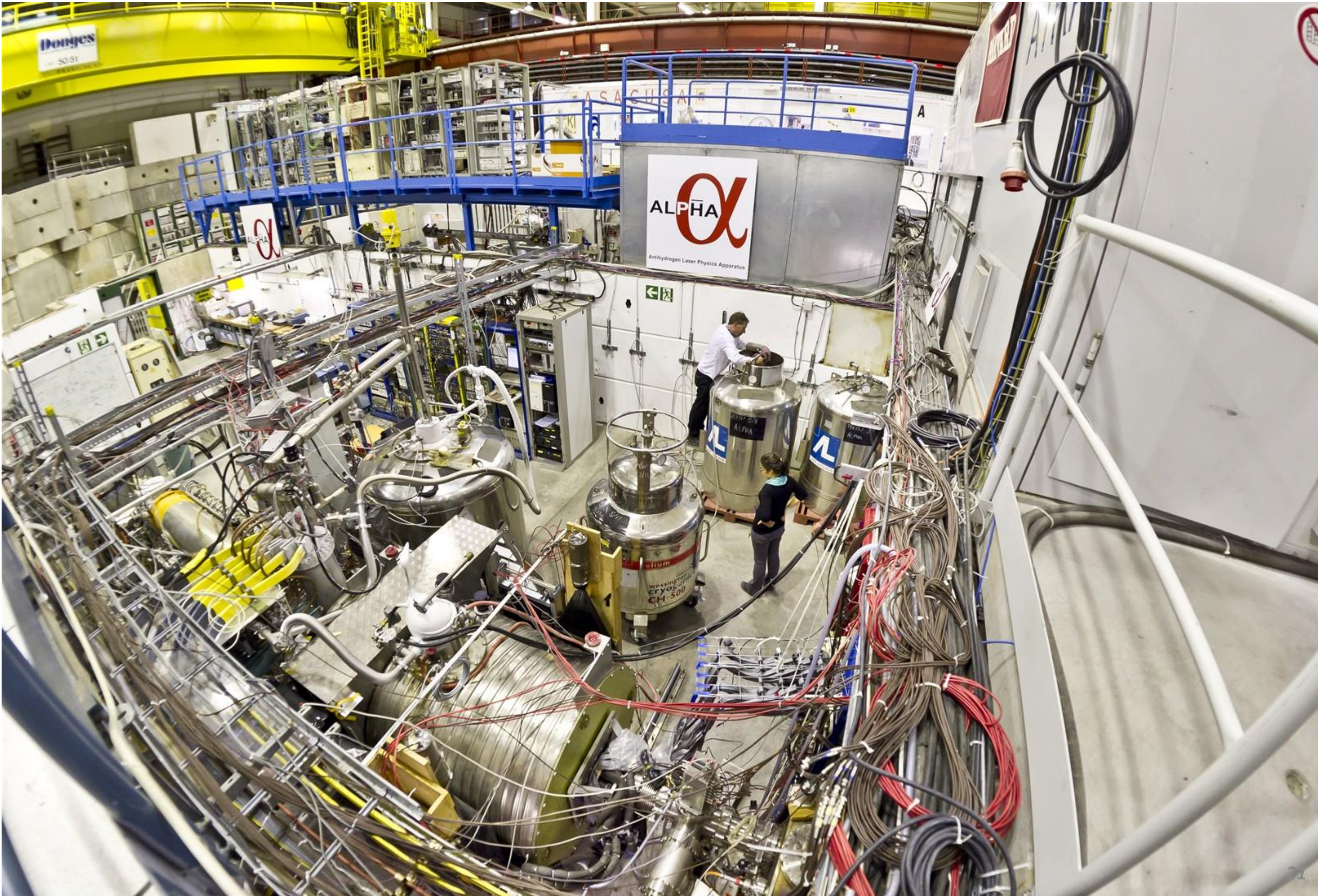
The antiprotons are then decelerated to 100 MeV/c. During this deceleration, the beam is again cooled several times with stochastic and electron cooling to counteract adiabatic blow-up during the energy decrease.

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

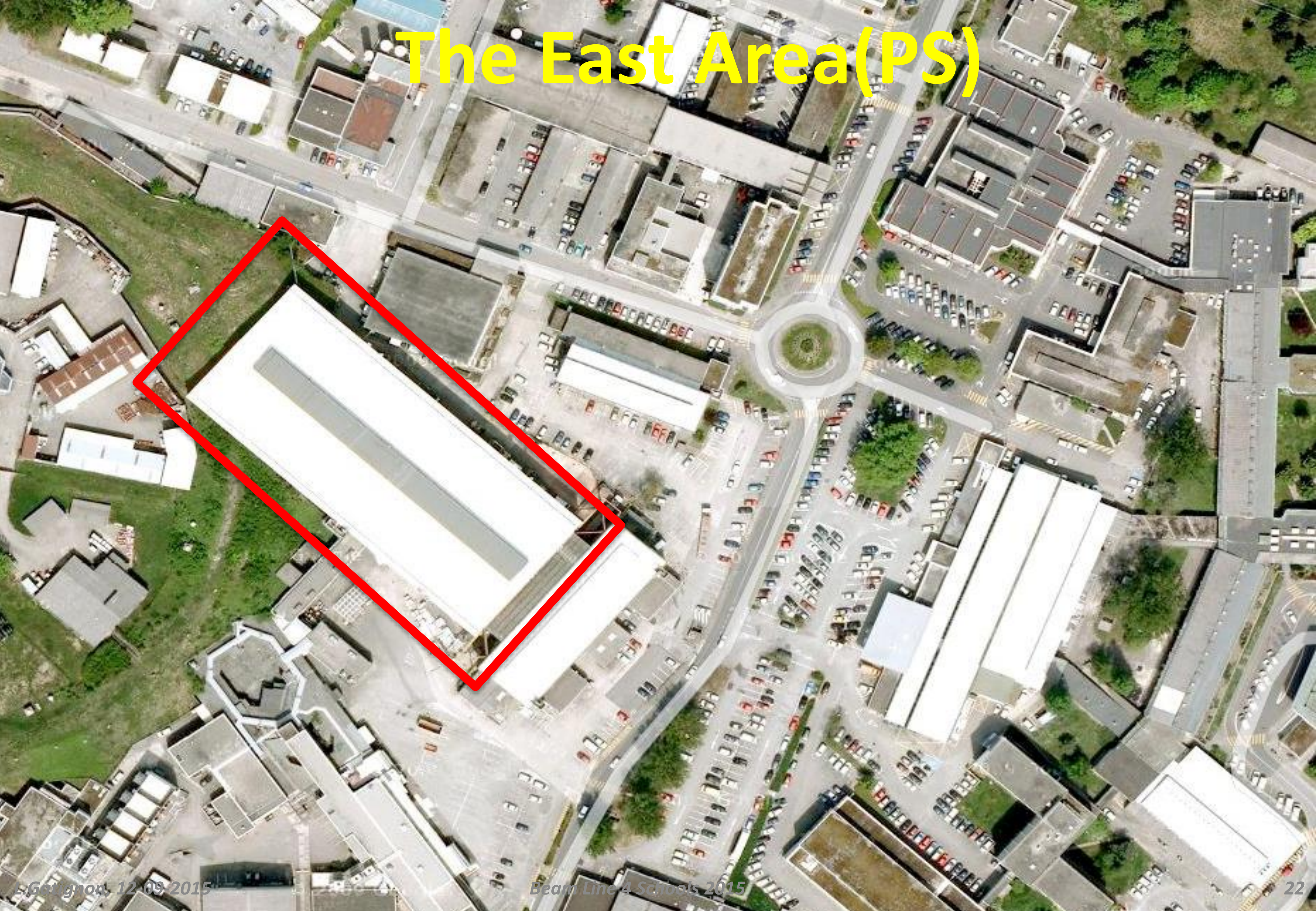
The AD machine

For 2017

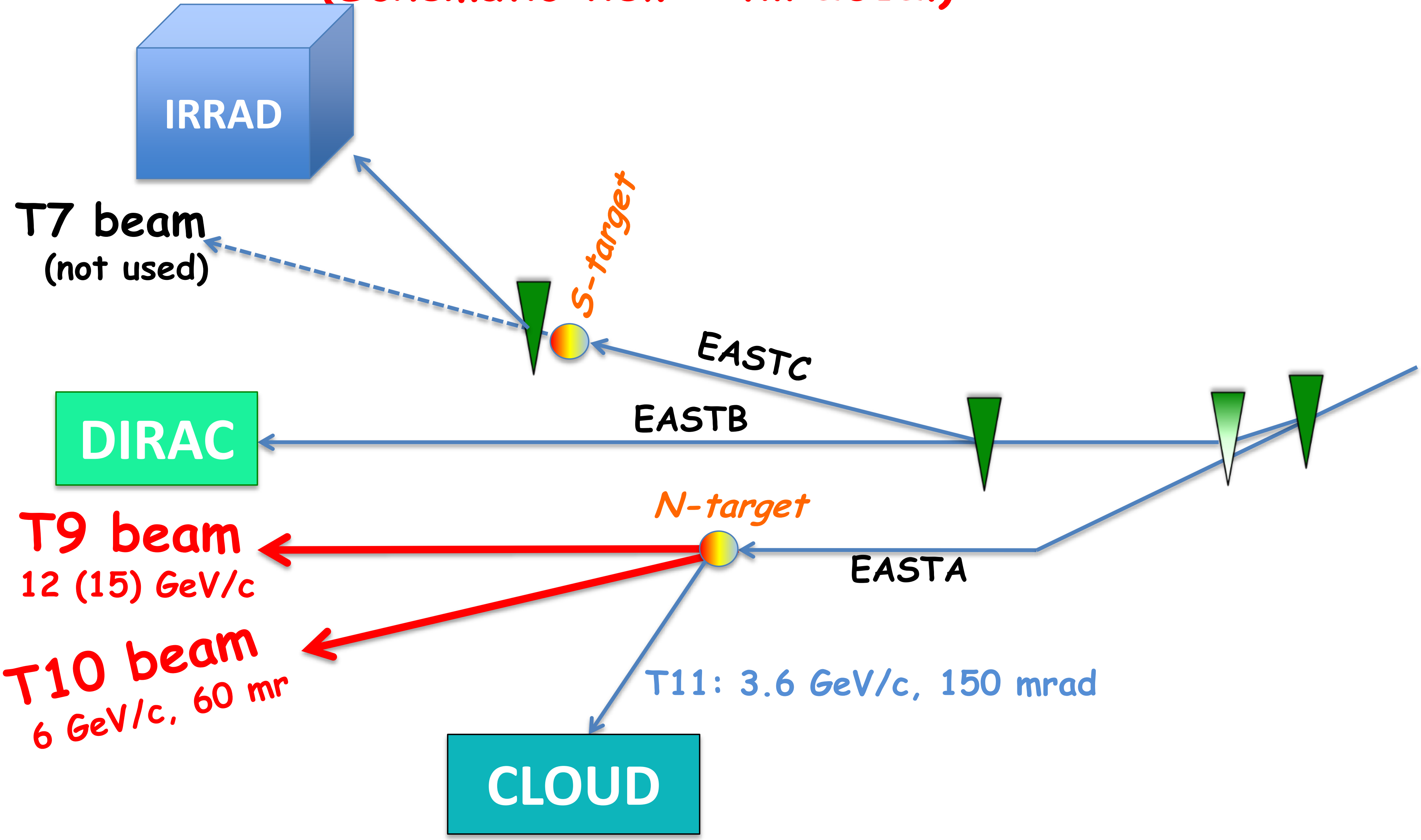



Donges
ALPHA
Antihydrogen Laser Physics Apparatus
ASACUSA

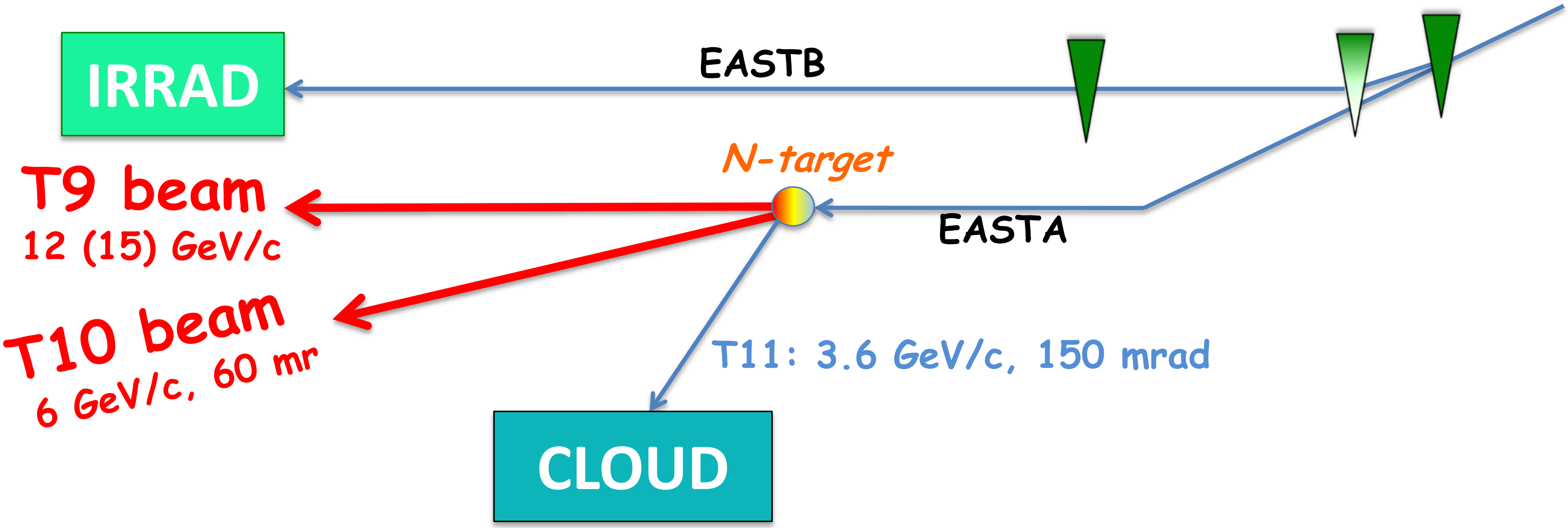
The East Area(PS)



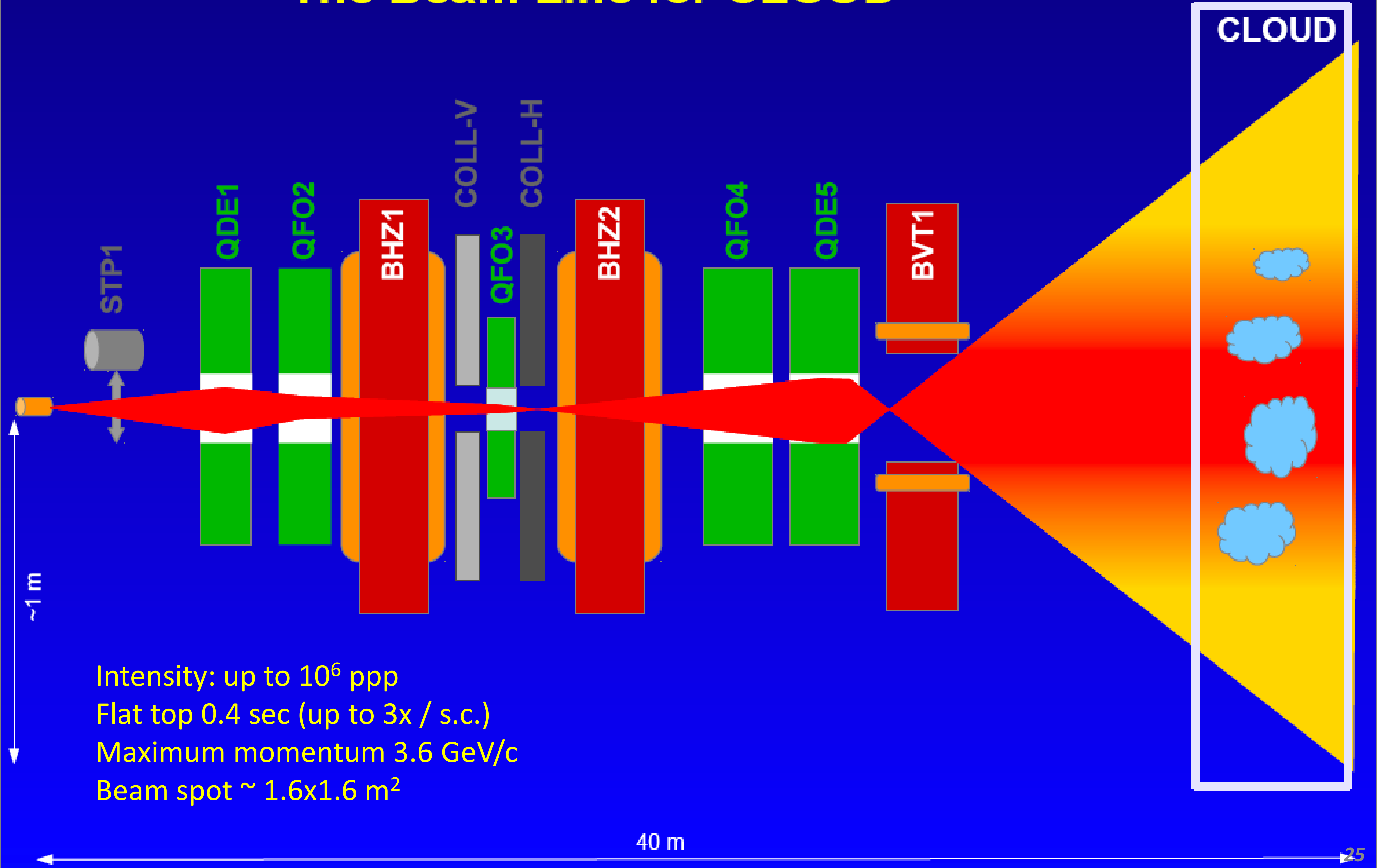
The East Area Beams
(Schematic view - till 2012!)



The East Area Beams
(Schematic view - From 2014!)



The Beam Line for CLOUD

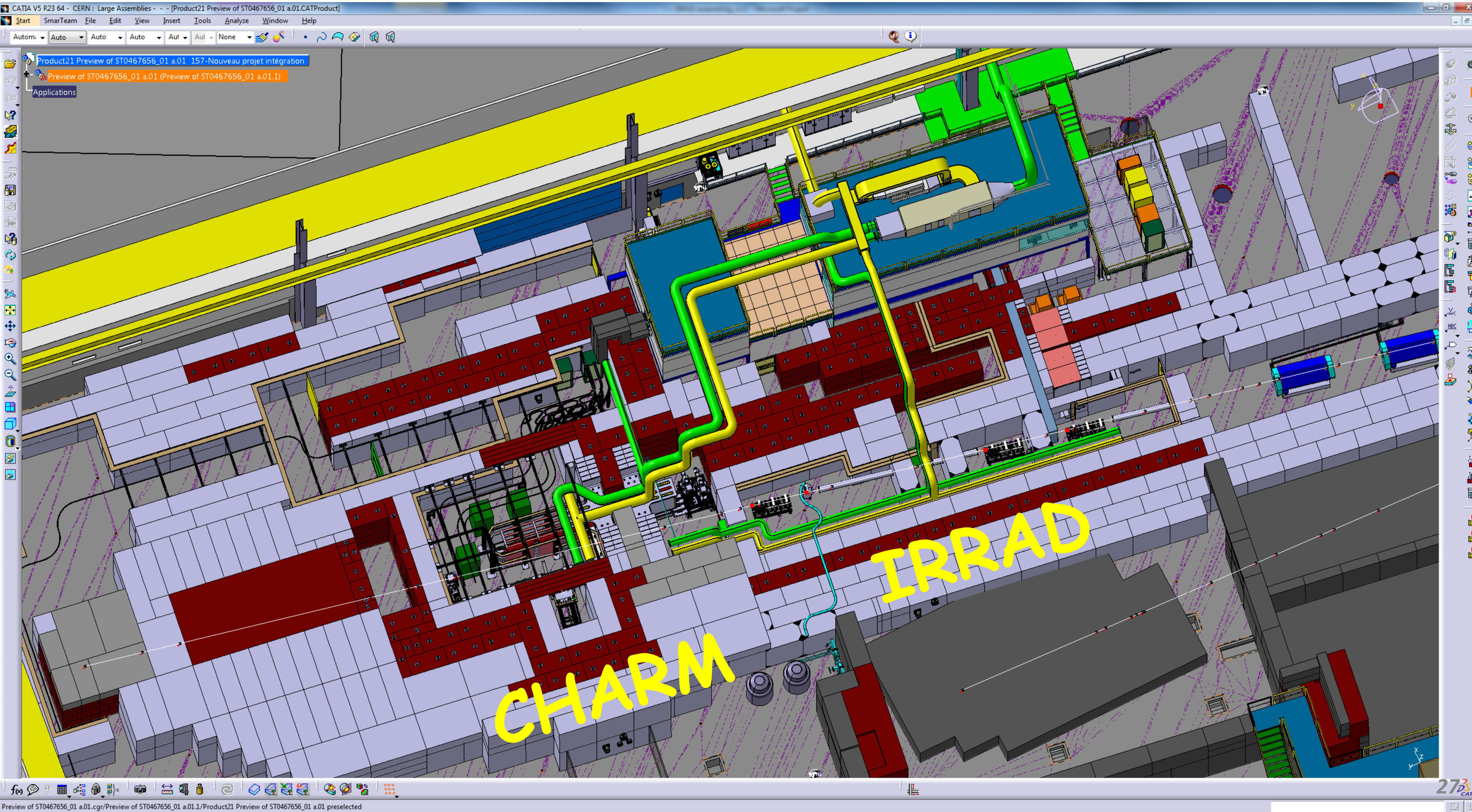


Intensity: up to 10^6 ppp
Flat top 0.4 sec (up to 3x / s.c.)
Maximum momentum 3.6 GeV/c
Beam spot ~ $1.6 \times 1.6\ m^2$

THE CLOUD EXPERIMENT IN THE T11 BEAM

Two new irradiation facilities:

IRRAD – proton irradiations
CHARM – mixd field irradiations

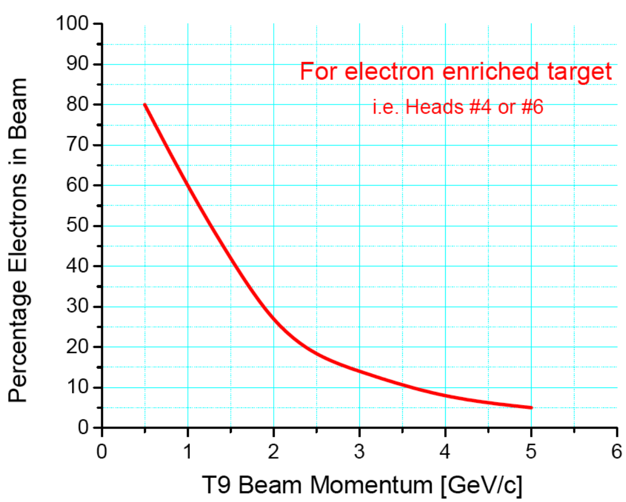


East Area Test Beams

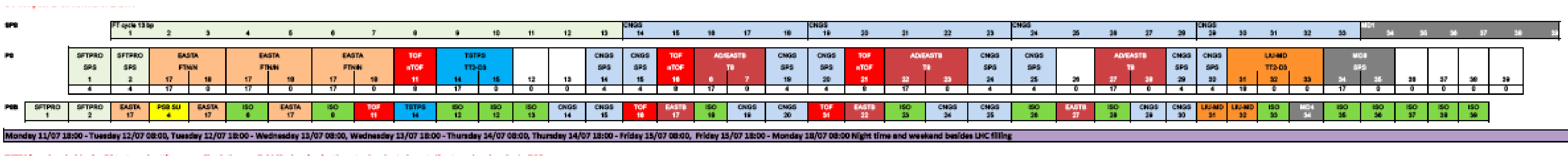
The **T9** and T10 beam lines are **mixed beams**.
Their maximum intensity is 10^6 per EASTA cycle.
Both beams are served from a common target, together also with the T11 beam for CLOUD.
The flat top is 0.4 seconds.
The number of EASTA cycles is normally 3 per super-cycle of 21.6 seconds.

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

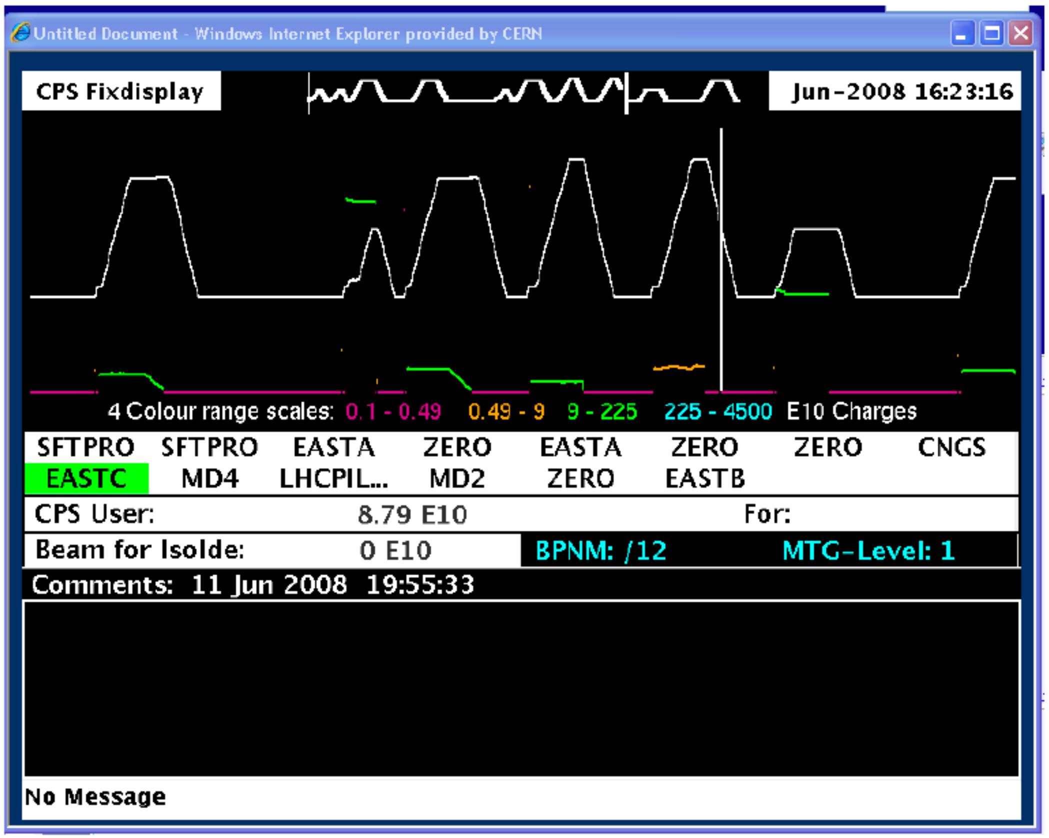


EXAMPLE OF A PS SUPER-CYCLE



Or e.g. :

(part of s.c.)



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

2014 Basic Super cycles (24-09-2013)

Days (Mo, Tu, We, Thu, Fr, from 08:00 until 18:00)

	SPS	PS	PSB
1	NA fixed target	SFTPRO SPS	SFTPRO
2		SFTPRO SPS	SFTPRO
3		AD/EASTB FTN/TB (irrad)	EASTB
4			ISO
5		AD/EASTB FTN/TB (irrad)	EASTB
6			ISO
7		AD/EASTB FTN/TB (irrad)	EASTB
8			ISO
9			PSB-MD
10	NA fixed target	SFTPRO SPS	SFTPRO
11		SFTPRO SPS	SFTPRO
12		EASTA FTN/N	EASTA
13			ISO
14		EASTA FTN/N	EASTA
15			ISO
16		TOF nTOF	TOF
17			ISO
18		SPS-MD SPS-DUMP	LHC25A
19	SPS MD		LHC25B
20			ISO
21		TOF nTOF	TOF
22		TOF nTOF	TOF
23			ISO
24		PS-MD TT2-D3	PS-MD
25			ISO

Nights and weekends

	SPS	PS	PSB
1	NA fixed target	SFTPRO SPS	SFTPRO
2		SFTPRO SPS	SFTPRO
3		AD/EASTB FTN/TB (irrad)	EASTB
4			ISO
5		AD/EASTB FTN/TB (irrad)	EASTB
6			ISO
7		AD/EASTB FTN/TB (irrad)	EASTB
8			ISO
9		TOF nTOF	TOF
10			ISO
11		TOF nTOF	TOF
12			PSB-MD
13	NA fixed target	SFTPRO SPS	SFTPRO
14		SFTPRO SPS	SFTPRO
15		EASTA FTN/N	EASTA
16			ISO
17		EASTA FTN/N	EASTA
18			ISO
19		TOF nTOF	TOF
20			ISO
21			ISO
22			ISO
23		PS-MD TT2-D3	PS-MD
24			ISO

LHC filling (from 2015 onwards)

	SPS	PS	PSB
1	NA fixed target	SFTPRO SPS	SFTPRO
2		SFTPRO SPS	SFTPRO
3		AD/EASTB FTN/TB (irrad)	EASTB
4			ISO
5		AD/EASTB FTN/TB (irrad)	EASTB
6			ISO
7		PS-MD TT2-D3	PS-MD
8			ISO
9		TOF nTOF	TOF
10	LHC	LHC25 SPS-DUMP	LHC25A
11			LHC25B
12			ISO
13		LHC25 SPS-DUMP	LHC25A
14			LHC25B
15			ISO
16		LHC25 SPS-DUMP	LHC25A
17			LHC25B
18			ISO
19		LHC25 SPS-DUMP	LHC25A
20			LHC25B
21			ISO
22		EASTA FTN/N	EASTA
23			PSB-MD
24		TOF nTOF	TOF
25		TOF nTOF	TOF
26			ISO
27			ISO

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 IRRAD and CHARM facilities
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

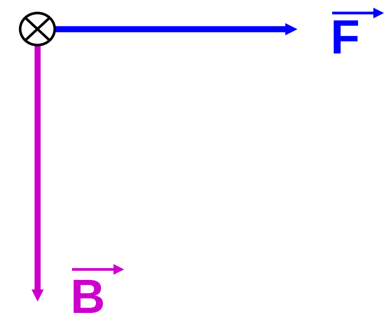
*) The SPS circumference is 11 times the PS one. Need 1/11th of SPS for kicker switching and 5 turns of the PS to fill one half. The so-called CT extraction takes 5 turns.

SOME BEAM PHYSICS

PARTICLES IN A MAGNETIC FIELD

In a magnetic field, the force is perpendicular to the velocity of the particle and to the field:

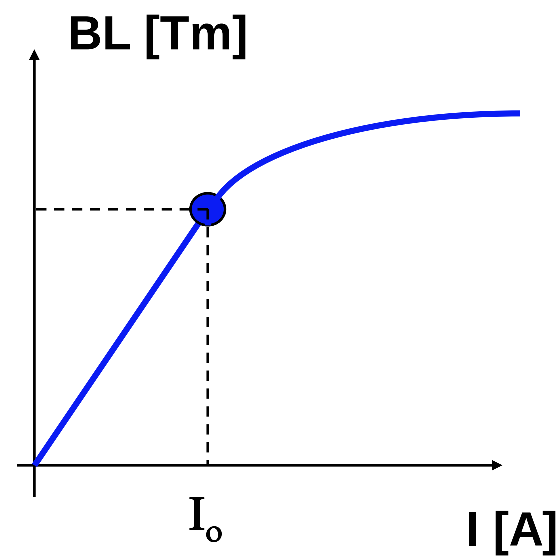
$$\vec{F} = q\,\vec{v} \times \vec{B}$$



In a uniform magnetic field the deflection of a particle depends on the product of field B and length L of the magnet:

$$\theta\ [\text{rad}] = 0.3\ q\ BL\ [\text{Tm}]\ /\ p\ [\text{GeV/c}]$$

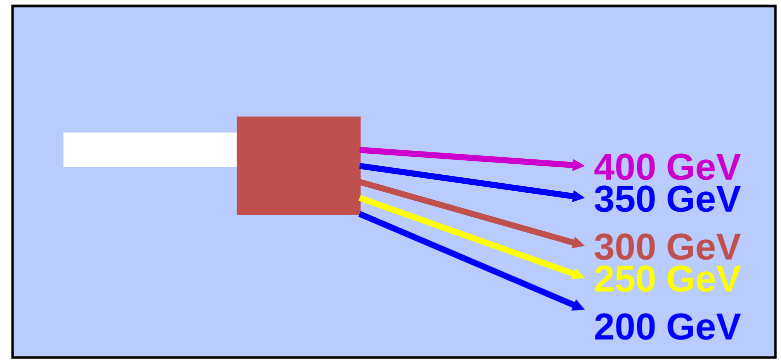
For a given magnet, the length is fixed but the field B (and hence the BL) can be controlled via its current I.

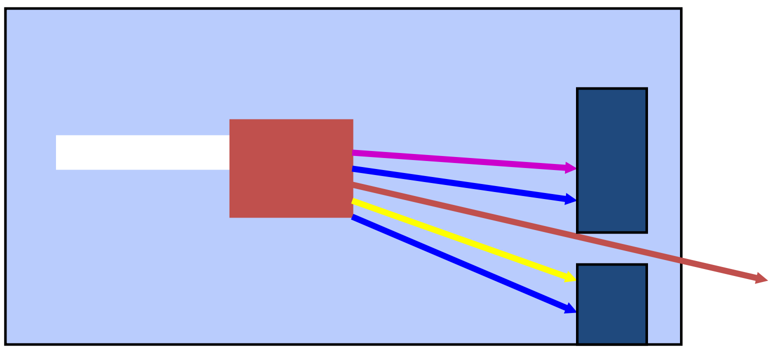


BENDs

$$\theta = 0.3 \frac{BL}{p}$$

A dipole acts like a prism:

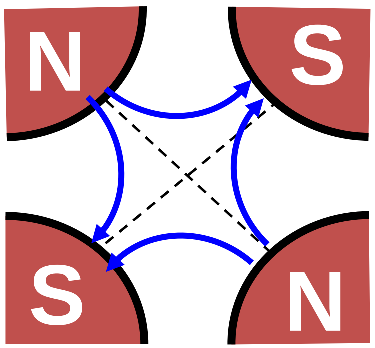




Together with a collimator, a dipole can be used to define a momentum p

The Δp depends on the gap width

QUADRUPOLES

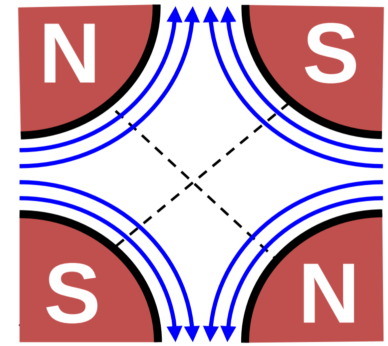


B-field lines

$\vec{B}$ ~ field line density

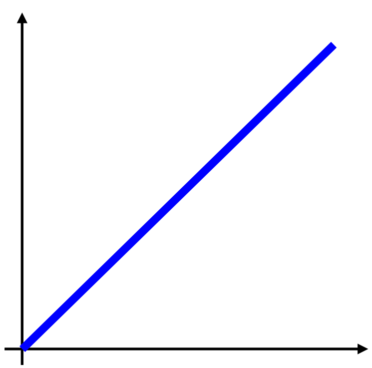
Focus in Horizontal plane
Defocus in Vertical plane

or vice versa



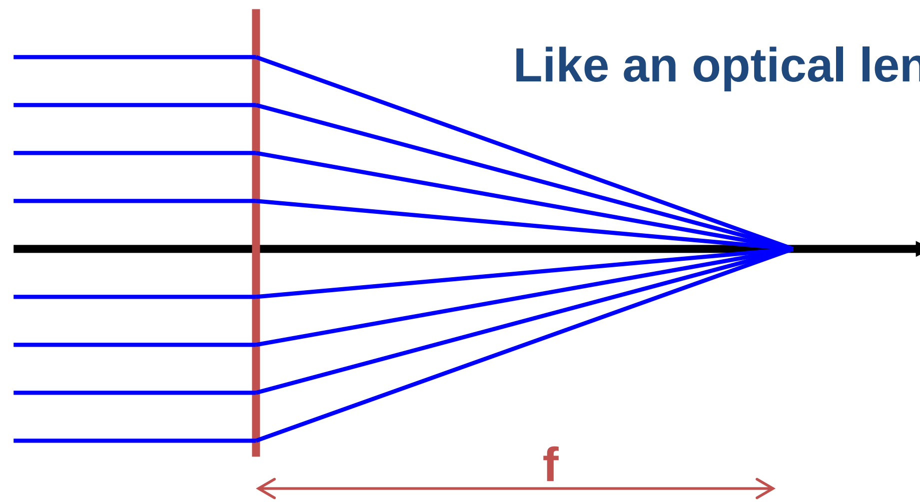
Magnetic force

B, F, Gradient

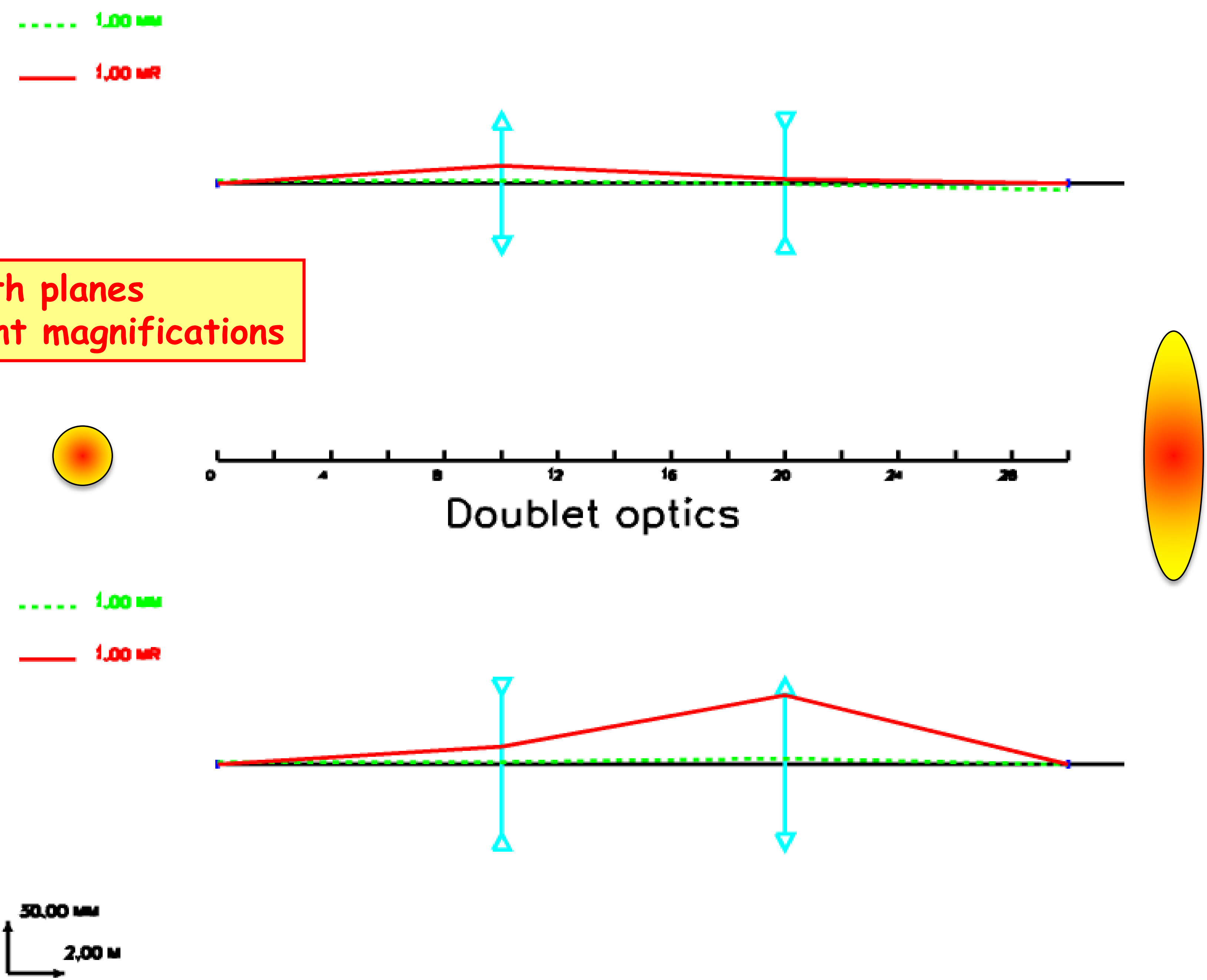


Distance from axis

Like an optical lense !

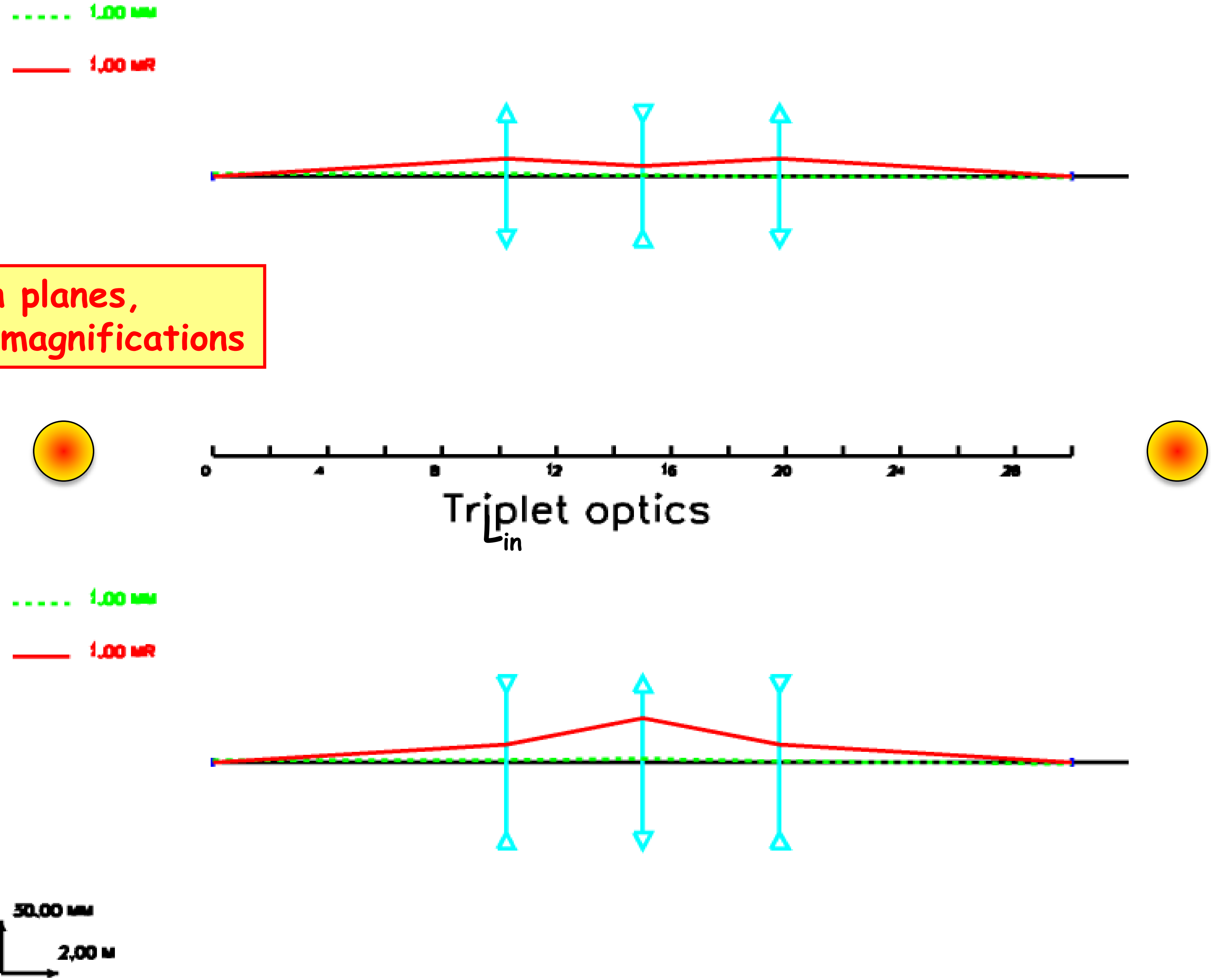


Focus in both planes
But different magnifications



Focus in both planes,
Control over magnifications

Triplet optics



Matrix elements

More useful for calculating

Transfer matrix R

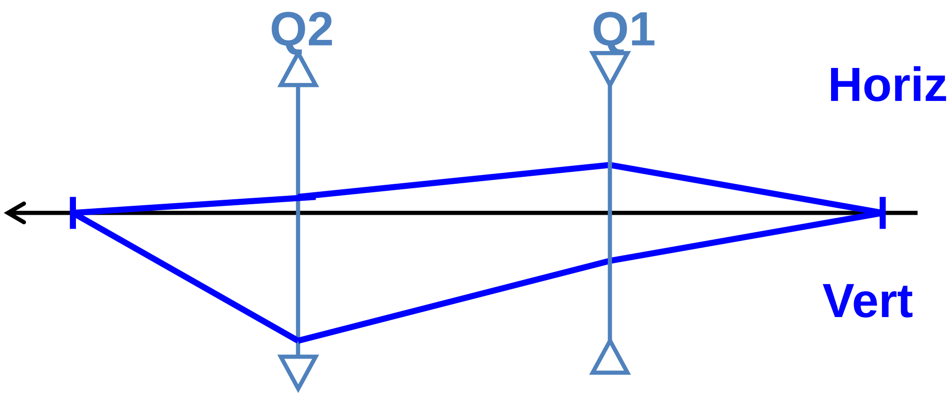
$$\begin{pmatrix} X_1 \\ X_1' \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{pmatrix} \begin{pmatrix} X_o \\ X_o' \end{pmatrix} = \begin{pmatrix} R_{11} X_o + R_{12} X_o' \\ R_{21} X_o + R_{22} X_o' \end{pmatrix}$$

e.g. : Drift space L: $\begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix}$ Quadrupole: $\begin{pmatrix} 1 & 0 \\ -1/f & 1 \end{pmatrix}$

(f = focal length)

Generalisation to real systems

The matrix of a system is the product of the individual matrices:



$$\begin{pmatrix}1 & L_3\\0 & 1\end{pmatrix}\begin{pmatrix}1 & 0\\{}^{1}/_{f2} & 1\end{pmatrix}\begin{pmatrix}1 & L_2\\0 & 1\end{pmatrix}\begin{pmatrix}1 & 0\\-{}^{1}/_{f1} & 1\end{pmatrix}\begin{pmatrix}1 & L_1\\0 & 1\end{pmatrix}\begin{pmatrix}X_o\\X_o'\end{pmatrix}$$

But also include:

Y-coordinates
Momentum p

$$\begin{pmatrix}X\\X'\\Y\\Y'\\L\\\Delta p/p\end{pmatrix}$$

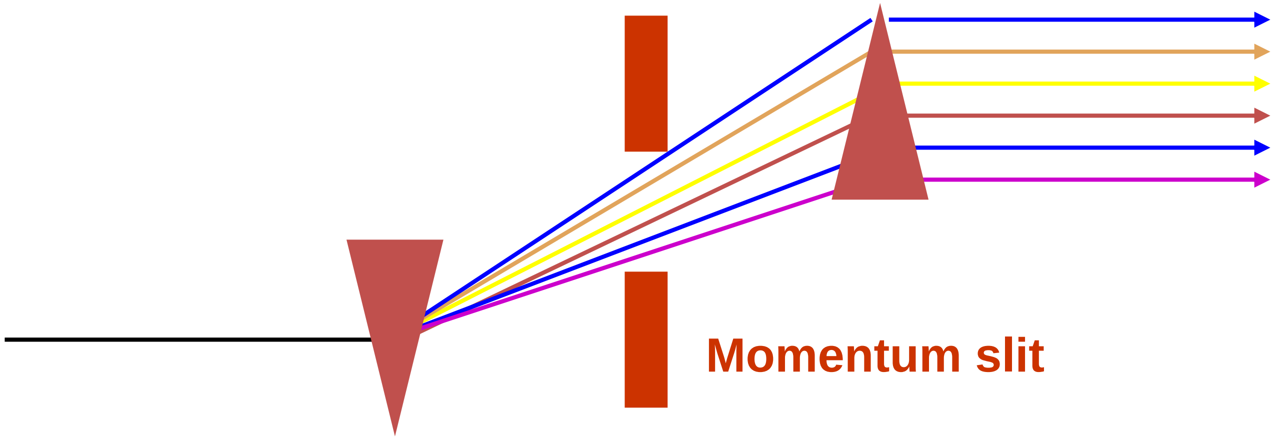
6x6 matrices !

Doublet optics — TRANSPORT RUN25/02/03

POSITION METERS	TYPE		STRENGTH T*M,T/M*M T/M**2*M	HORIZONTAL R11 MM/MM	R12 MM/MR	R21 MR/MM	R22 MR/MR	VERTICAL R33 MM/MM	R34 MM/MR	R43 MR/MM	R44 MR/MR	DISPERSION R16 MM/PC	R26 MR/PC	R36 MM/PC	R46 MR/PC
0.000	3	TARGET		1.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
9.000	3			1.000	9.000	0.000	1.000	1.000	9.000	0.000	1.000	0.000	0.000	0.000	0.000
11.000	5	Q1	61.9865	0.820	9.257	-0.175	-0.751	1.192	12.851	0.198	2.970	0.000	0.000	0.000	0.000
19.000	3			-0.576	3.250	-0.175	-0.751	2.772	36.609	0.198	2.970	0.000	0.000	0.000	0.000
21.000	5	Q2	-61.9865	-1.058	2.276	-0.322	-0.253	2.644	35.592	-0.322	-3.955	0.000	0.000	0.000	0.000
30.000	3			-3.955	0.000	-0.322	-0.253	-0.253	0.000	-0.322	-3.955	0.000	0.000	0.000	0.000
30.000	3	FOCUS		-3.955	0.000	-0.322	-0.253	-0.253	0.000	-0.322	-3.955	0.000	0.000	0.000	0.000

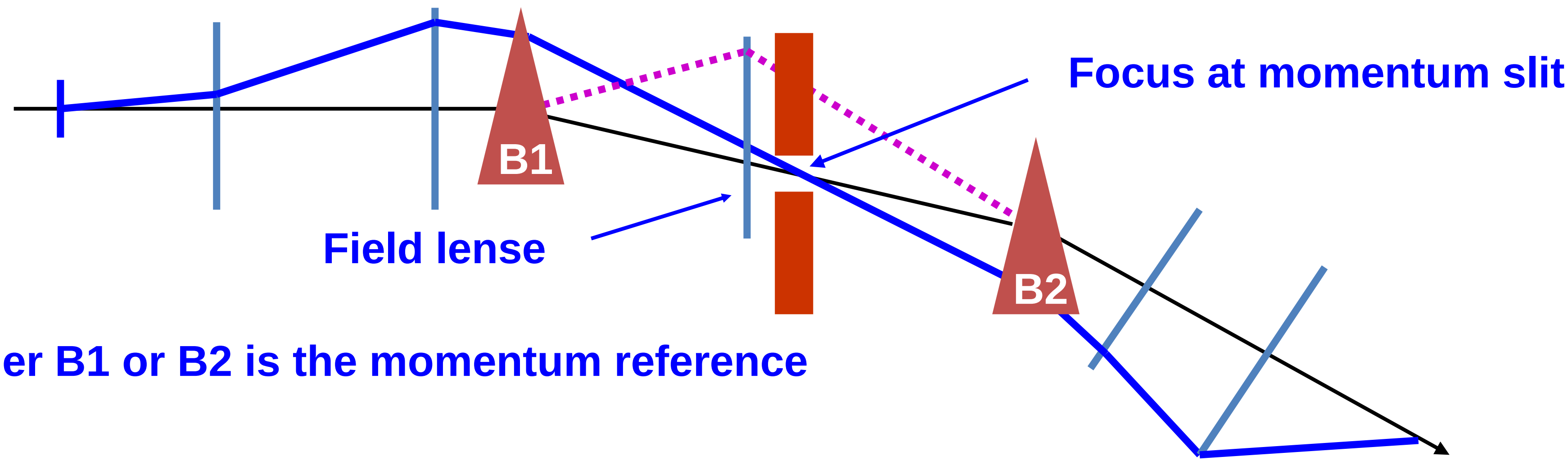
DISPERSION

Dispersion is necessary in secondary (tertiary) beams to define the momentum:



However, for good beam performance you must:

- **optimise momentum resolution** → **focus at momentum slit**
- **get rid of dispersion at the end of the beam line** → **field lense**

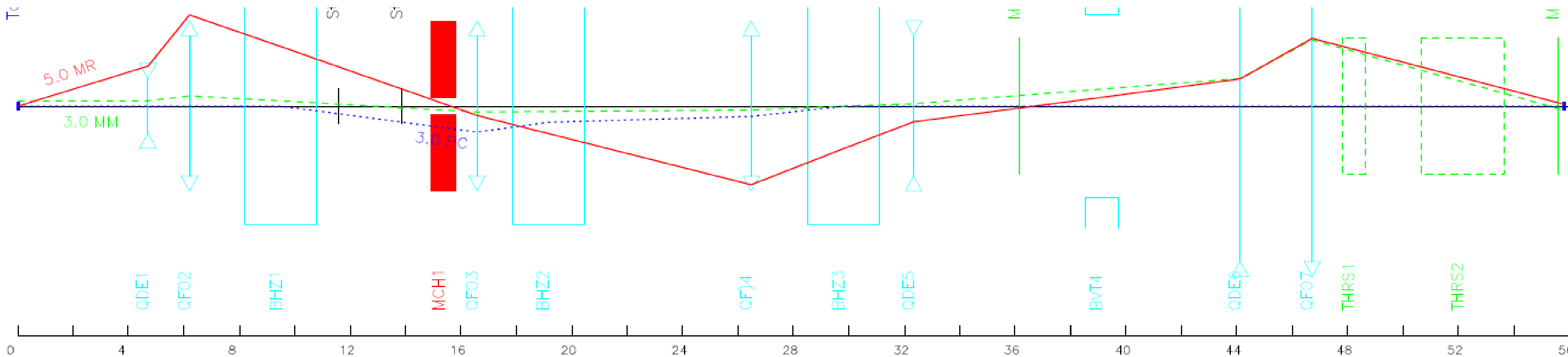


Either B1 or B2 is the momentum reference

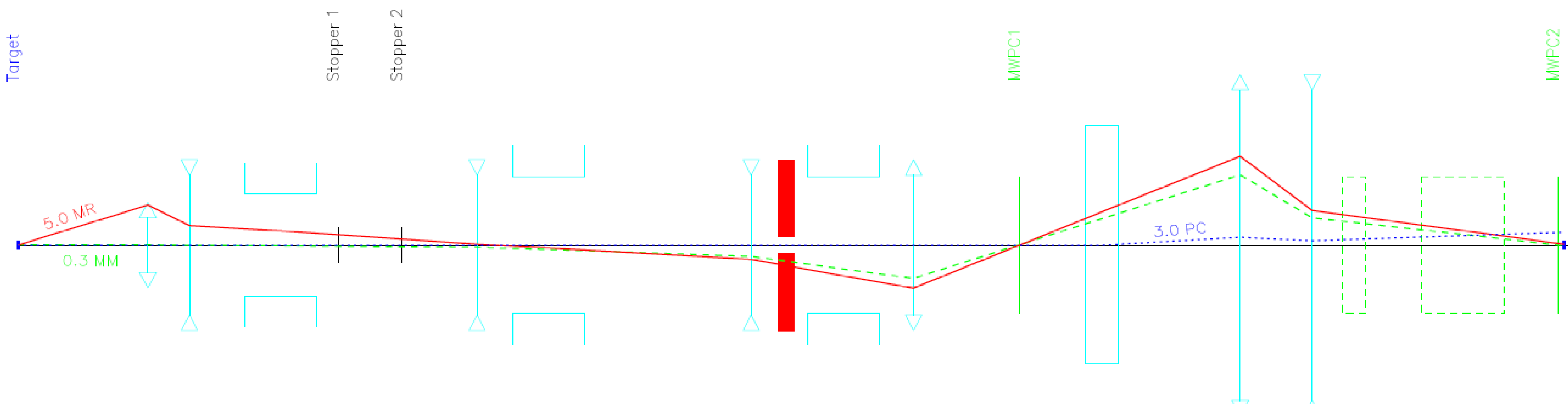
TRANSPORT TABLE:

1T9 test beam optics TRANSPORT RUN28/02/08

0POSITION METERS	TYPE		STRENGTH T*M,T/M*M T/M**2*M	HORIZONTAL R11 MM/MM	R12 MM/MR	R21 MR/MM	R22 MR/MR	VERTICAL R33 MM/MM	R34 MM/MR	R43 MR/MM	R44 MR/MR	DISPERSION R16 MM/PC	R26 MR/PC	R36 MM/PC	R46 MR/PC
0.000	3	PG3H		1.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
4.310	3			1.000	4.310	0.000	1.000	1.000	4.310	0.000	1.000	0.000	0.000	0.000	0.000
5.090	5	QDE1	-29.9058	1.242	6.196	0.645	4.023	0.776	4.065	-0.552	-1.605	0.000	0.000	0.000	0.000
5.580	3			1.558	8.168	0.645	4.023	0.505	3.278	-0.552	-1.605	0.000	0.000	0.000	0.000
6.820	5	QFO2	26.7793	1.784	10.059	-0.302	-1.143	-0.081	2.210	-0.445	-0.212	0.000	0.000	0.000	0.000
8.200	3			1.367	8.481	-0.302	-1.143	-0.695	1.917	-0.445	-0.212	0.000	0.000	0.000	0.000
10.800	4	BHZ1	3.6025	0.582	5.511	-0.302	-1.143	-1.849	1.361	-0.442	-0.215	-0.936	-0.720	0.000	0.000
11.230	3			0.452	5.020	-0.302	-1.143	-2.039	1.268	-0.442	-0.215	-1.245	-0.720	0.000	0.000
11.910	3	STP1		0.246	4.242	-0.302	-1.143	-2.340	1.122	-0.442	-0.215	-1.735	-0.720	0.000	0.000
13.531	3			-0.243	2.389	-0.302	-1.143	-3.057	0.773	-0.442	-0.215	-2.903	-0.720	0.000	0.000
14.211	3	STP2		-0.449	1.611	-0.302	-1.143	-3.357	0.626	-0.442	-0.215	-3.393	-0.720	0.000	0.000
14.928	3			-0.665	0.792	-0.302	-1.143	-3.674	0.472	-0.442	-0.215	-3.909	-0.720	0.000	0.000
15.828	3	MCH1		-0.937	-0.237	-0.302	-1.143	-4.072	0.278	-0.442	-0.215	-4.557	-0.720	0.000	0.000
16.164	3			-1.039	-0.622	-0.302	-1.143	-4.221	0.206	-0.442	-0.215	-4.799	-0.720	0.000	0.000
17.004	5	QFO3	15.1471	-1.153	-1.464	0.037	-0.821	-5.157	0.044	-1.832	-0.178	-4.782	0.761	0.000	0.000
17.843	3			-1.122	-2.153	0.037	-0.821	-6.694	-0.106	-1.832	-0.178	-4.143	0.761	0.000	0.000
20.443	4	BHZ2	3.0571	-1.026	-4.286	0.037	-0.821	-11.446	-0.570	-1.820	-0.178	-2.958	0.150	0.000	0.000
21.636	3			-0.982	-5.265	0.037	-0.821	-13.617	-0.782	-1.820	-0.178	-2.779	0.150	0.000	0.000
25.861	3			-0.827	-8.732	0.037	-0.821	-21.305	-1.534	-1.820	-0.178	-2.144	0.150	0.000	0.000
27.101	5	QFO4	11.8194	-0.665	-8.453	0.217	1.260	-26.870	-1.996	-7.375	-0.585	-1.660	0.611	0.000	0.000
27.461	3			-0.587	-7.999	0.217	1.260	-29.525	-2.206	-7.375	-0.585	-1.440	0.611	0.000	0.000
28.041	3	MCV1		-0.461	-7.268	0.217	1.260	-33.803	-2.546	-7.375	-0.585	-1.086	0.611	0.000	0.000
28.521	3			-0.356	-6.664	0.217	1.260	-37.343	-2.827	-7.375	-0.585	-0.793	0.611	0.000	0.000
31.121	4	BHZ3	3.0571	0.209	-3.389	0.217	1.260	-56.450	-4.342	-7.310	-0.580	0.001	0.000	0.000	0.000
31.721	3			0.339	-2.633	0.217	1.260	-60.836	-4.690	-7.310	-0.580	0.000	0.000	0.000	0.000
32.961	5	QDE5	-20.3271	0.721	-1.628	0.424	0.429	-54.467	-4.218	17.147	1.310	0.000	0.000	0.000	0.000
35.959	3			1.993	-0.341	0.424	0.429	-3.059	-0.292	17.147	1.310	0.000	0.000	0.000	0.000
36.363	3	MWPC		2.164	-0.168	0.424	0.429	3.868	0.237	17.147	1.310	0.000	0.000	0.000	0.000
38.541	3			3.088	0.767	0.424	0.429	41.215	3.089	17.147	1.310	-0.001	0.000	0.000	0.000
39.721	4	BVT1	1.4728	3.588	1.273	0.422	0.428	61.445	4.634	17.147	1.310	-0.002	-0.002	0.174	0.294
43.051	3			4.993	2.699	0.422	0.428	118.545	8.995	17.147	1.310	-0.008	-0.002	1.154	0.294
45.211	5	QDE6	-20.5147	8.424	5.054	2.986	1.910	101.625	7.727	-31.640	-2.396	-0.009	0.001	1.226	-0.233
45.651	3			9.738	5.894	2.986	1.910	87.704	6.673	-31.640	-2.396	-0.009	0.001	1.123	-0.233
47.811	5	QFO7	19.8024	11.433	7.112	-1.530	-0.864	49.427	3.789	-6.292	-0.462	-0.009	-0.001	1.060	0.171
48.631	3	CH1		10.179	6.403	-1.530	-0.864	44.268	3.410	-6.292	-0.462	-0.009	-0.001	1.200	0.171
53.661	3	CH2		2.484	2.057	-1.530	-0.864	12.621	1.086	-6.292	-0.462	-0.013	-0.001	2.059	0.171
56.013	3	MWPC		-1.114	0.024	-1.530	-0.864	-2.177	-0.001	-6.292	-0.462	-0.014	-0.001	2.461	0.171
55.811	3			-0.805	0.199	-1.530	-0.864	-0.906	0.092	-6.292	-0.462	-0.014	-0.001	2.427	0.171
55.811	3	Foc		-0.805	0.199	-1.530	-0.864	-0.906	0.092	-6.292	-0.462	-0.014	-0.001	2.427	0.171
61.811	3	ENDP		-9.984	-4.986	-1.530	-0.864	-38.657	-2.680	-6.292	-0.462	-0.018	-0.001	3.451	0.171



T9 test beam optics



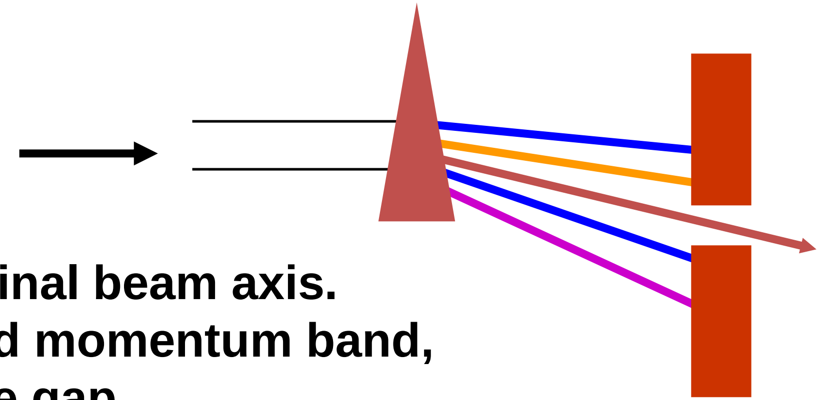
COLLIMATION

- **Collimation is as important for beam quality as optics**
- **Optics and collimation are very much correlated**

In T9 we consider 2 different types of collimators:

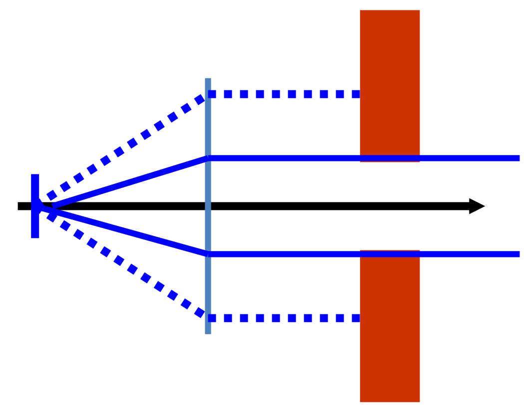
1. **Momentum slits**
2. **Acceptance collimators**

1. Momentum slit



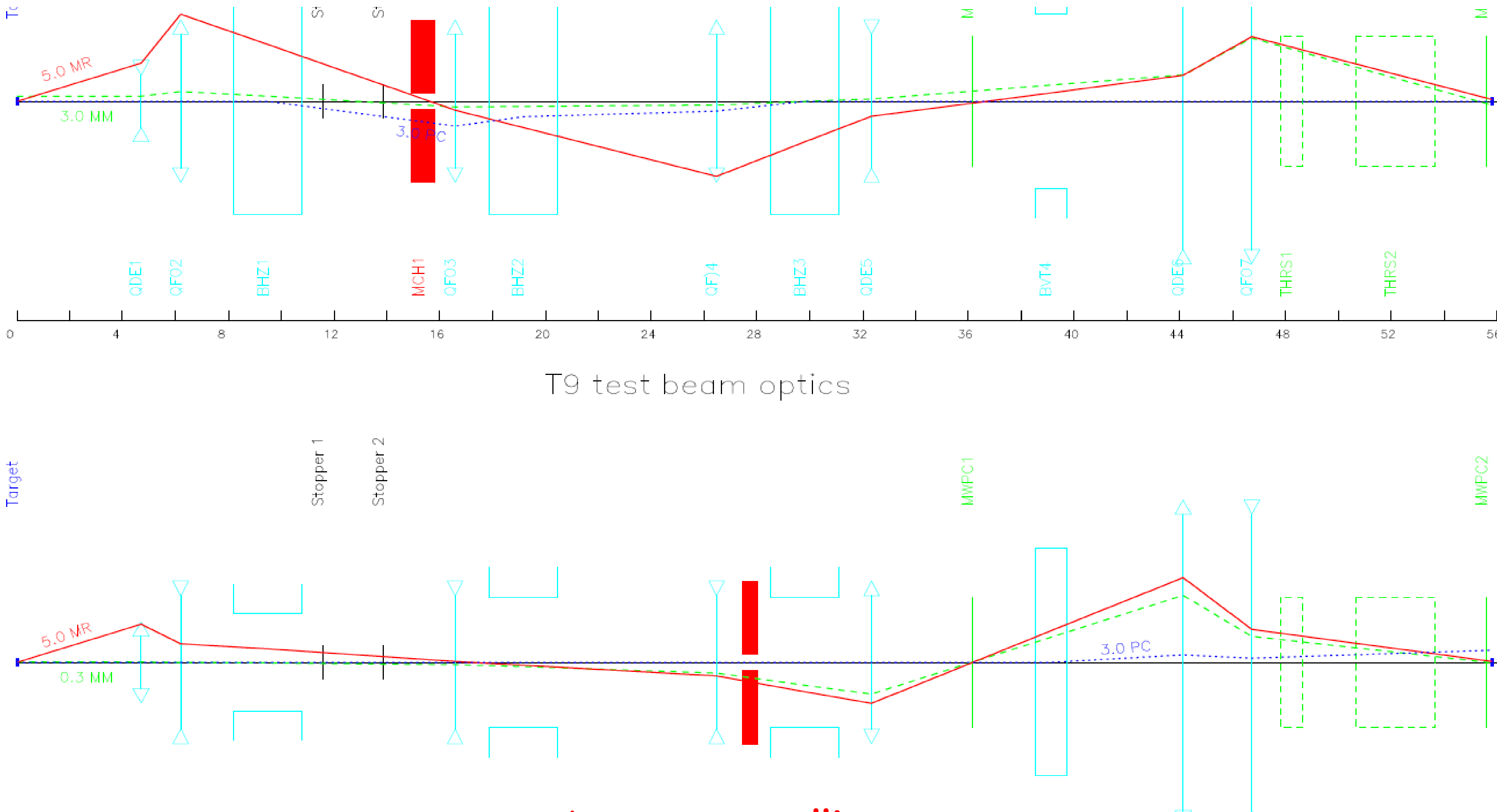
Normally located at a dispersive focus.
The center of the gap should be at the nominal beam axis.
The aperture is proportional to the accepted momentum band,
The rate is normally also proportional to the gap.
However, the ΔP/p cannot be smaller than the intrinsic resolution.
Hence the need (in general) to have a rather sharp focus.

2. Acceptance collimator



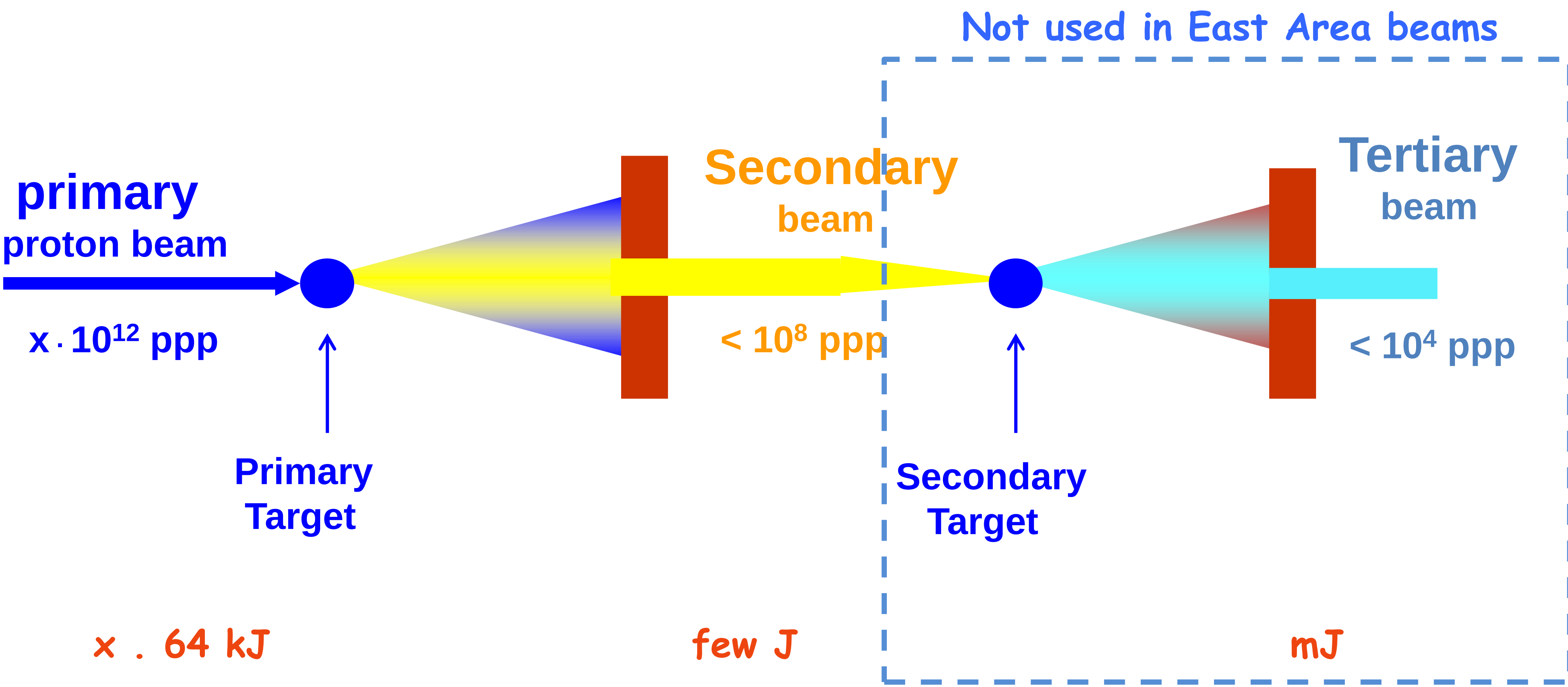
Located where the beam is large (ideally even parallel),
Allows to define the angular aperture of the beam,
Affects therefore the rate as well, however non-linearly.

Momentum slit



Acceptance collimator

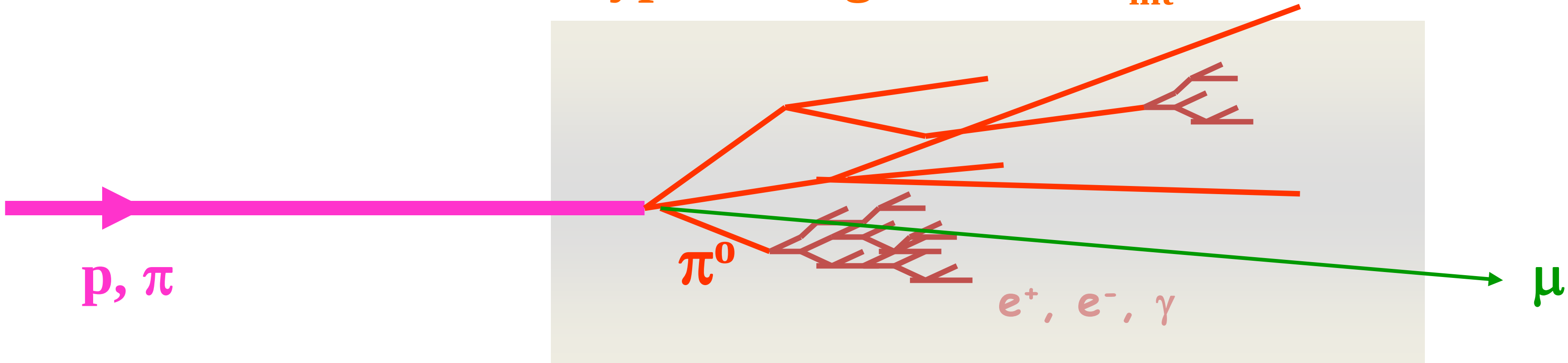
Intensities in a secondary beam



WHAT HAPPENS TO PARTICLES IN MATTER ?

Hadronic showers (p, n, K, π, Λ, …)

Typical length scale: L_{int}



$\pi^0 \rightarrow \gamma + \gamma$

γ□ $e^+ + e-$

Electromagnetic showers (γ, e^+, e^-)

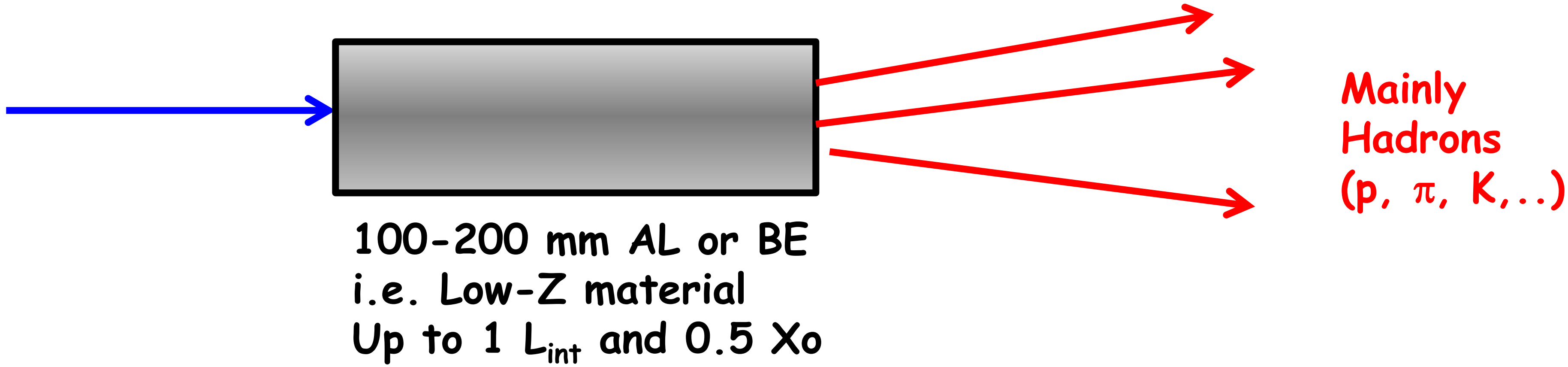
Typical length scale: X_o

Muons are produced mainly via pion decay.

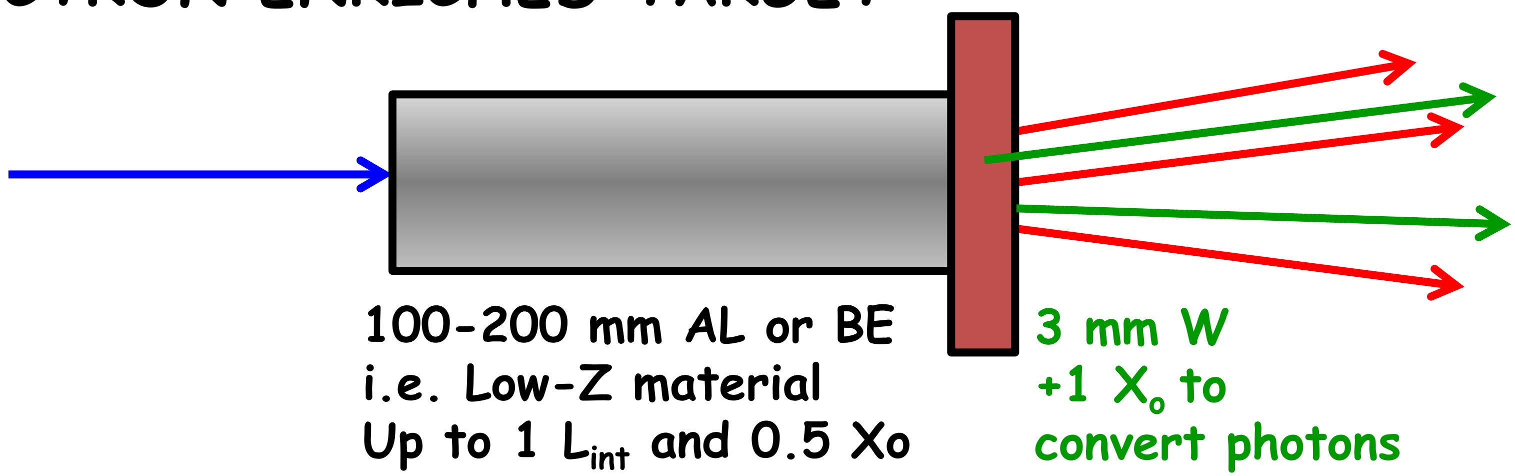
They traverse many metres of material with minimum energy loss: 2 GeV / m Iron)

Material	X_o	L_{int}	X_o/L_{int}
Beryllium	35.3 cm	40.7 cm	0.87
Copper	1.50 cm	15.0 cm	0.10
Lead	0.56 cm	17.1 cm	0.03

HADRON TARGET

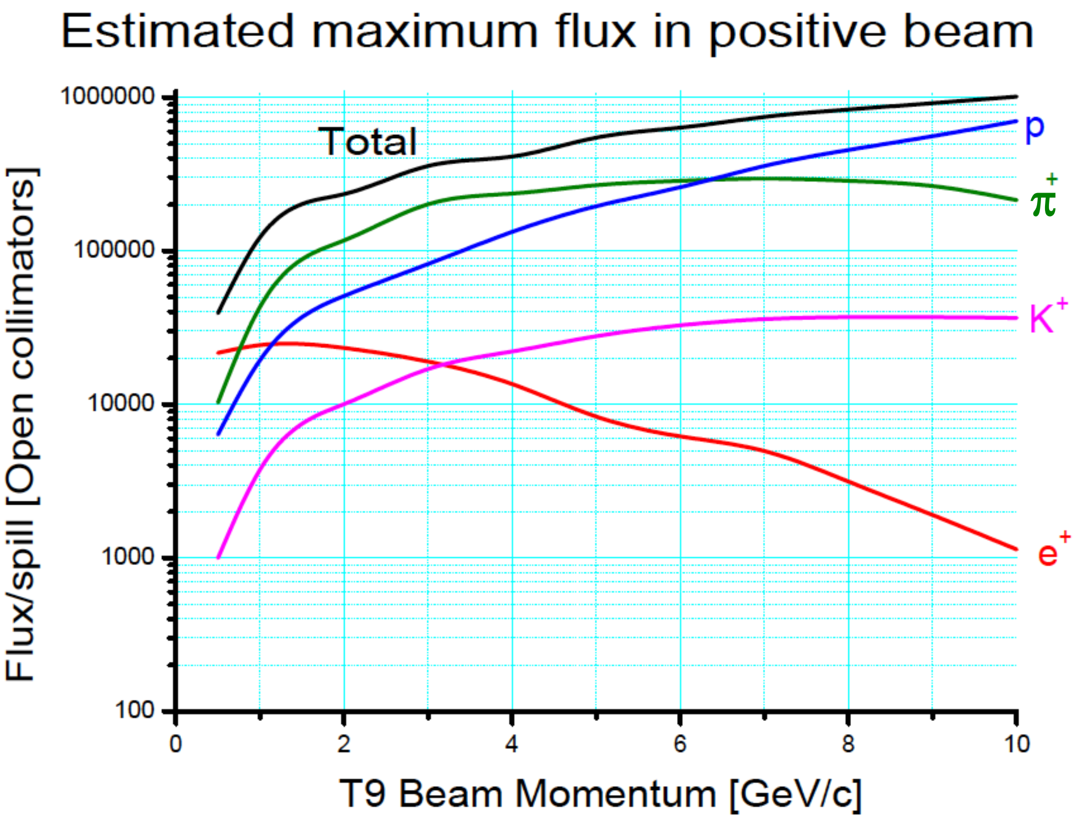


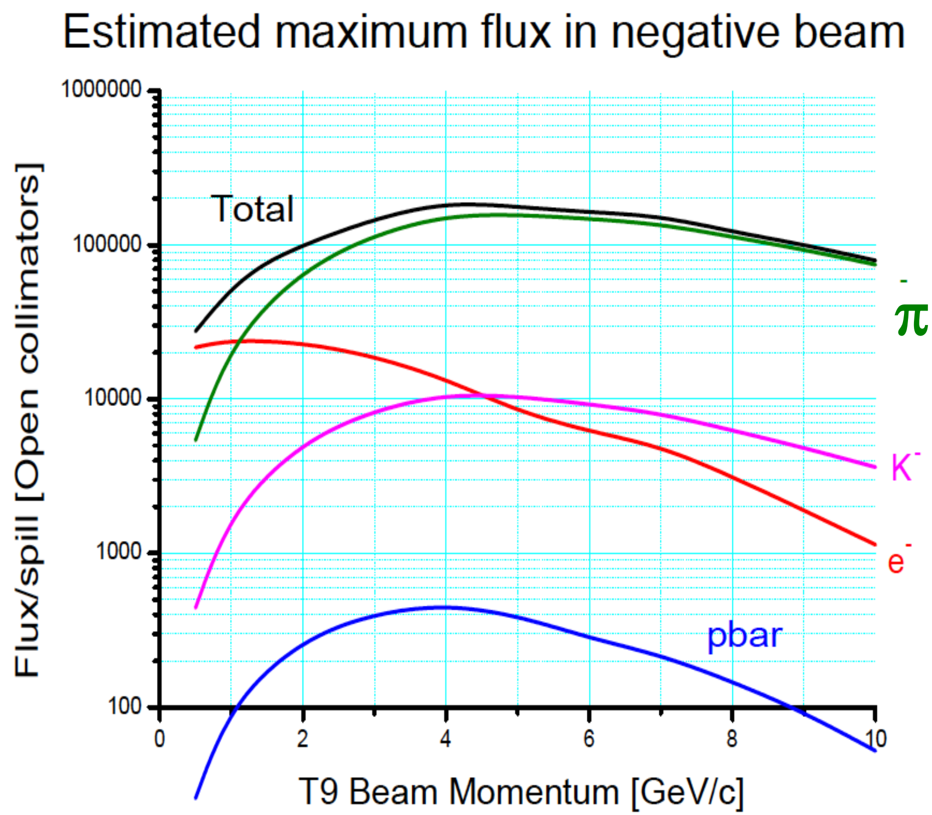
ELECTRON ENRICHED TARGET



$$\pi^+, \pi^-, \pi^o \rightarrow \gamma + \gamma \rightarrow e^+ + e^-$$

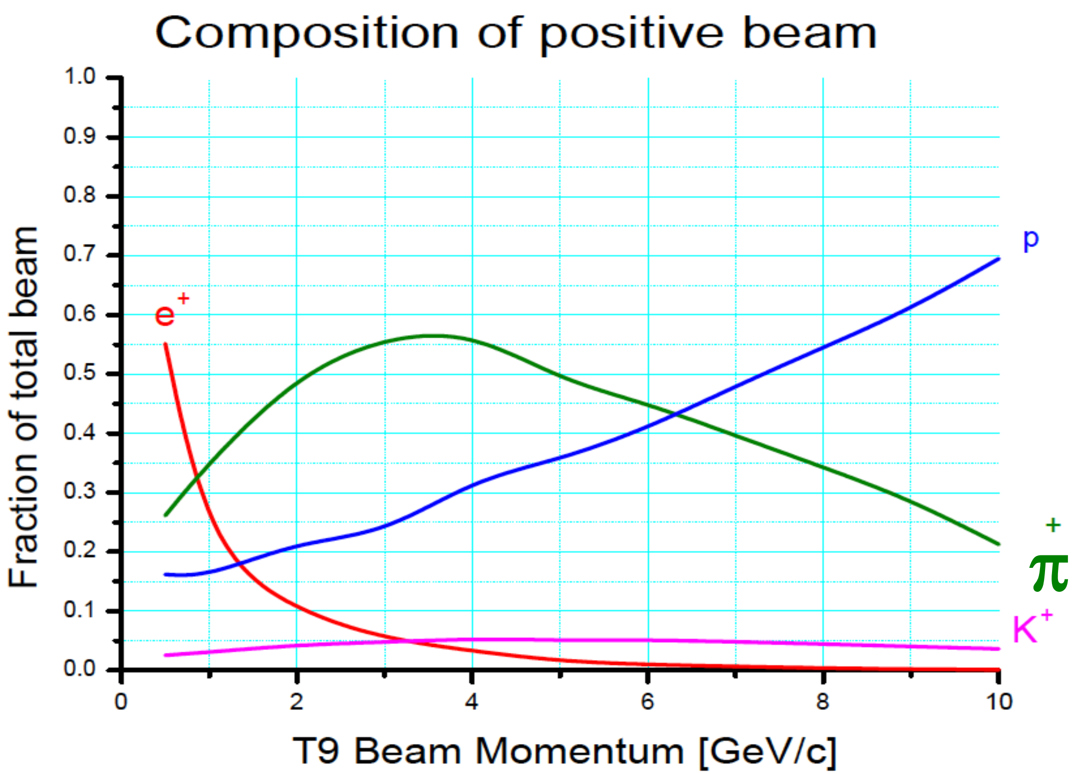
Beam rates

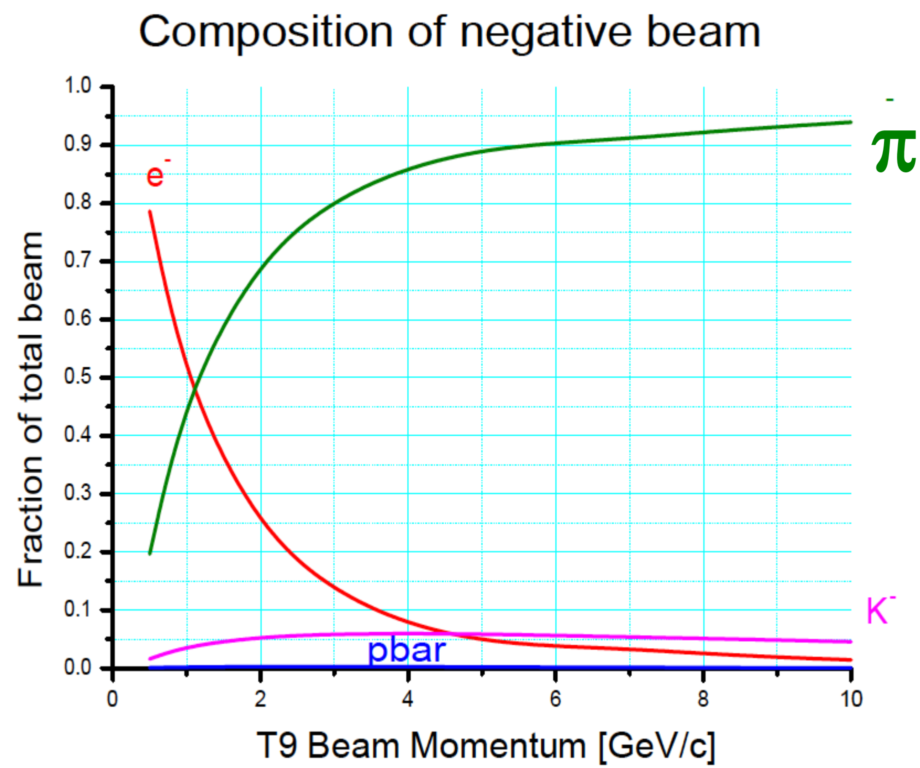




For wide open collimators, i.e. $\Delta p/p \approx \pm 7.5\%$

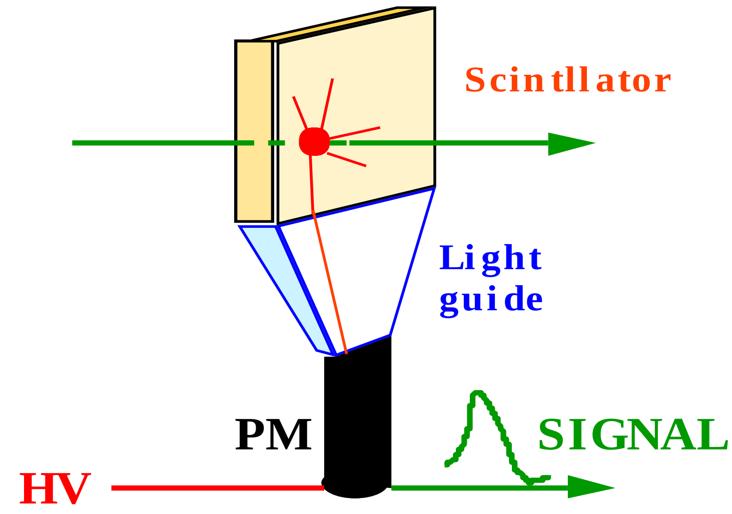
Beam Composition





With electron enriched target (otherwise $e^{\pm}$ strongly reduced)

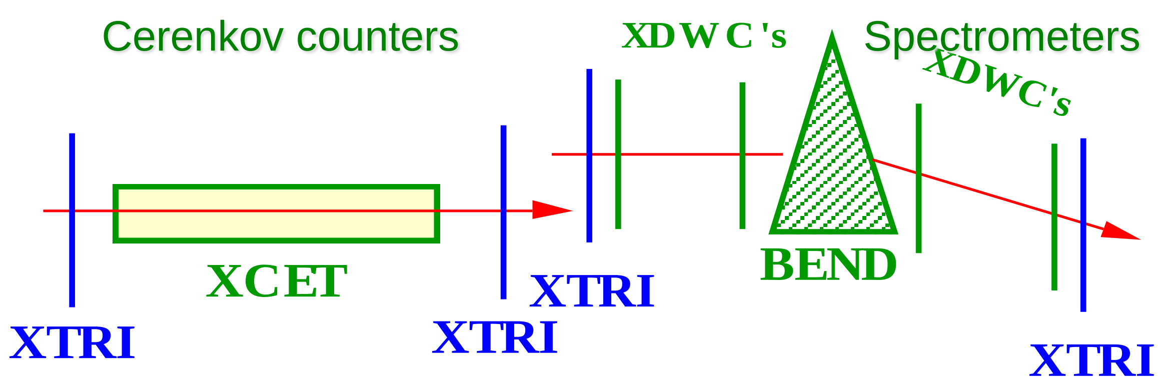
SCINTILLATORS



Scintillating material (some plastics) produce light when traversed by charged particles.
Light is transmitted to photomultiplier by light guide.
In the photomultiplier the light is converted into an electrical pulse.
After discrimination these pulses are counted by scalers and the count rates are transmitted to the control system.

Individual particles are counted as a function of beam conditions. Useful for monitoring, beam tuning and as a timing signal (T0) for more complicated detectors (XCET, Cedar, XDWC).

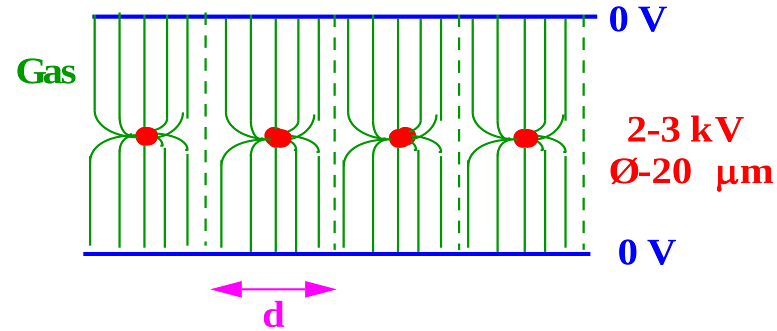
Strobing of complicated detectors:



Limited to ≈ 10^7 particles per second.

Examples:	**XTRI,XTRS**	**Big scintillators to count full beam**
	FISCS	**Narrow, mobile scintillators to scan through beam**

WIRE CHAMBERS



Charged particles ionise the gas.
The electrons drift to the anode wire, where the field increases, due the extremely small radius → Gas amplification.
An electrical pulse is produced, discriminated and sent to DAQ.

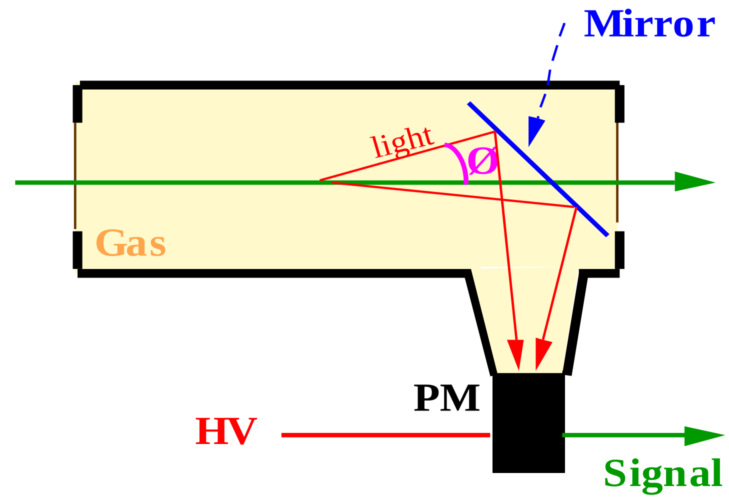
The positive ions drift slowly to the cathode plane → slow detectors.

Due to well chosen geometry each wire corresponds to a cell, electrically insulated from its neighbour.
The wire hit gives an indication about the position of the particle, resolution ±0.5 d.

Examples:

Wire chamber	**Each hit gives x±d/2 for the particle measured, limited to ≈ 107 particles per burst.**
XWCA	**Integrate charge deposited on each wire over the burst. Depends on HV!**
	No information about individual particles, but profiles for 10^4 to 10^{10} ppp.
XWCD	**The time between the signal on the wire and the time of particle**
	passage (XTRI, XTRS) measures the distance between particle and wire.
	Improves the resolution to about 100 μm. Rates ≤ 10^7 ppp.

Threshold Cerenkov counters



In a medium (e.g. He or N2 gas):

particle: $v/c = p/\sqrt{(p^2+m^2)}$

light: $v/c = 1/n$

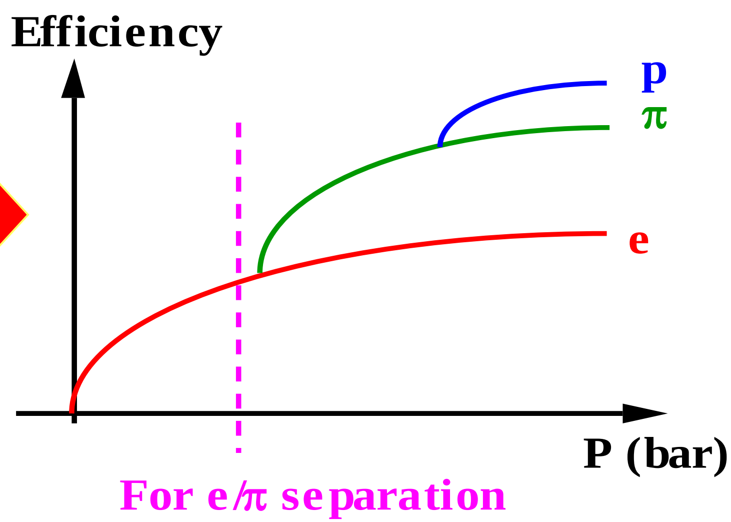
If a charged particle goes faster than light in a medium,
it emits Cerenkov light in a cone with half-opening angle ϕ:

$$\phi^2 = 2kP - m^2/p^2$$

where k depends on the gas, P=pressure.

Light is thus only emitted when $Ø^2 \geq 0$!!!

The # γ' s ~ $Ø^2$ and increases from 0 at threshold to ≈ 100% at very high pressures.



By selecting the right operating pressure, one type of particle has good efficiency and the other gives no signal.
By making a coincidence with scintillator signals, particle identification can be made.
XCET counters are better at low momenta, CEDARS allow good separation at high momenta (300 GeV/c), but are more complicated and need careful tuning.

XCET's are usually operated with Helium or Nitrogen at pressures between 20 mbar and 3 bar.

CALORIMETER

Principle:

Particles shower in the lead-glass block. At the end of the shower, the small energy quanta remaining deposit their energy in the form of light.
The light is captured by a photomultiplier that transforms it into an electrical pulse.
The amount of light (thus the electrical signal) is proportional to the deposited energy.

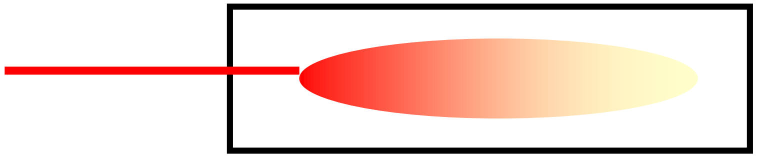
As the energy is deposited in N quanta, the relative precision of the measurement is limited by statistical fluctuations on N, i.e. :

$$\sigma(E)/E \sim 1/\sqrt{E}$$

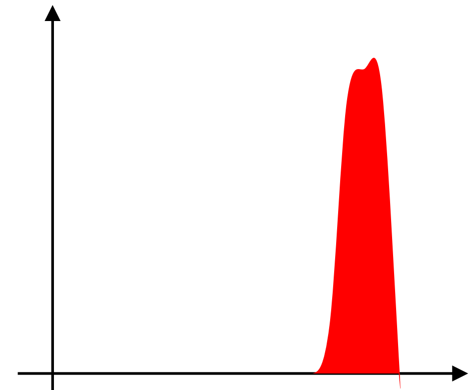
Normally a calorimeter is used for energy measurements,

But in our case its main use is for particle identification.

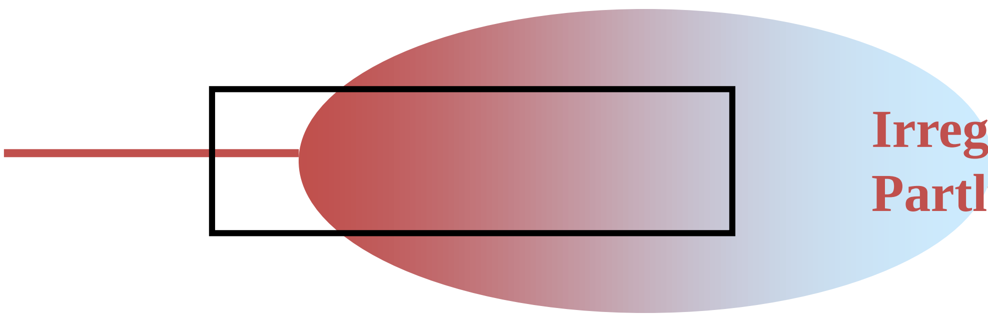
Electron shower:



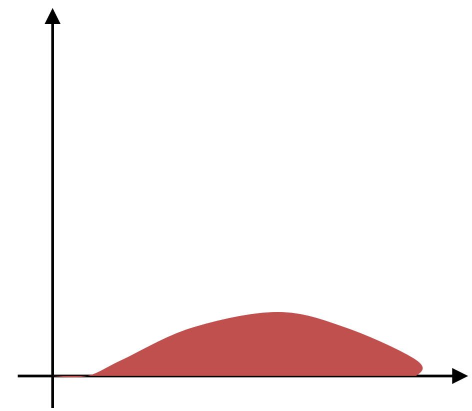
Regular
Fully contained:



Hadron shower:

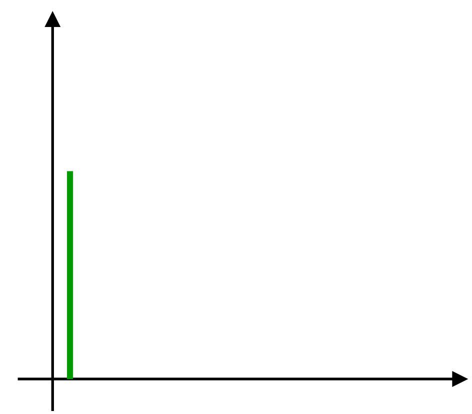


Irregular,
Partly contained:

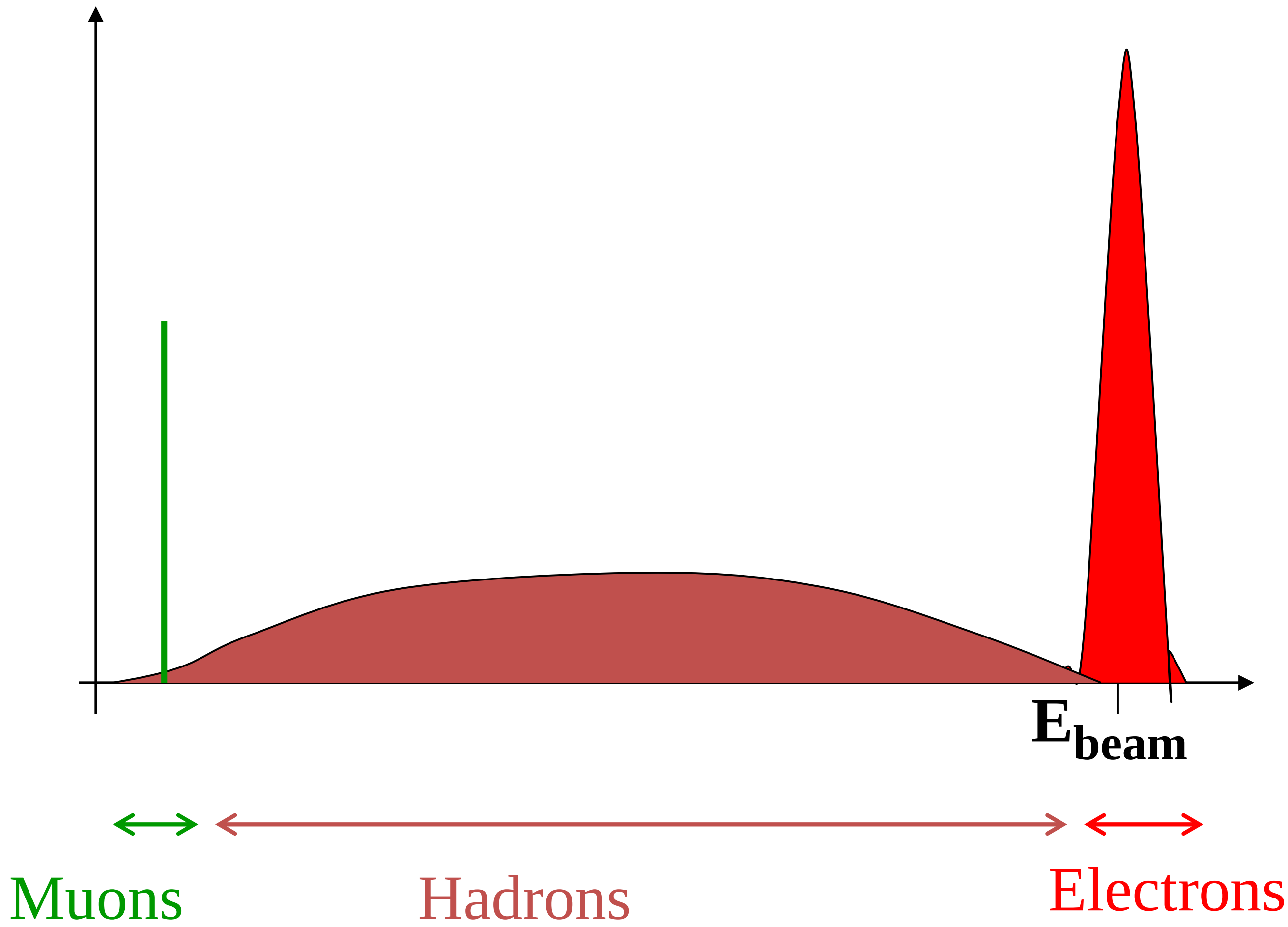


Muon shower:

Only dE/dx
Constant, small

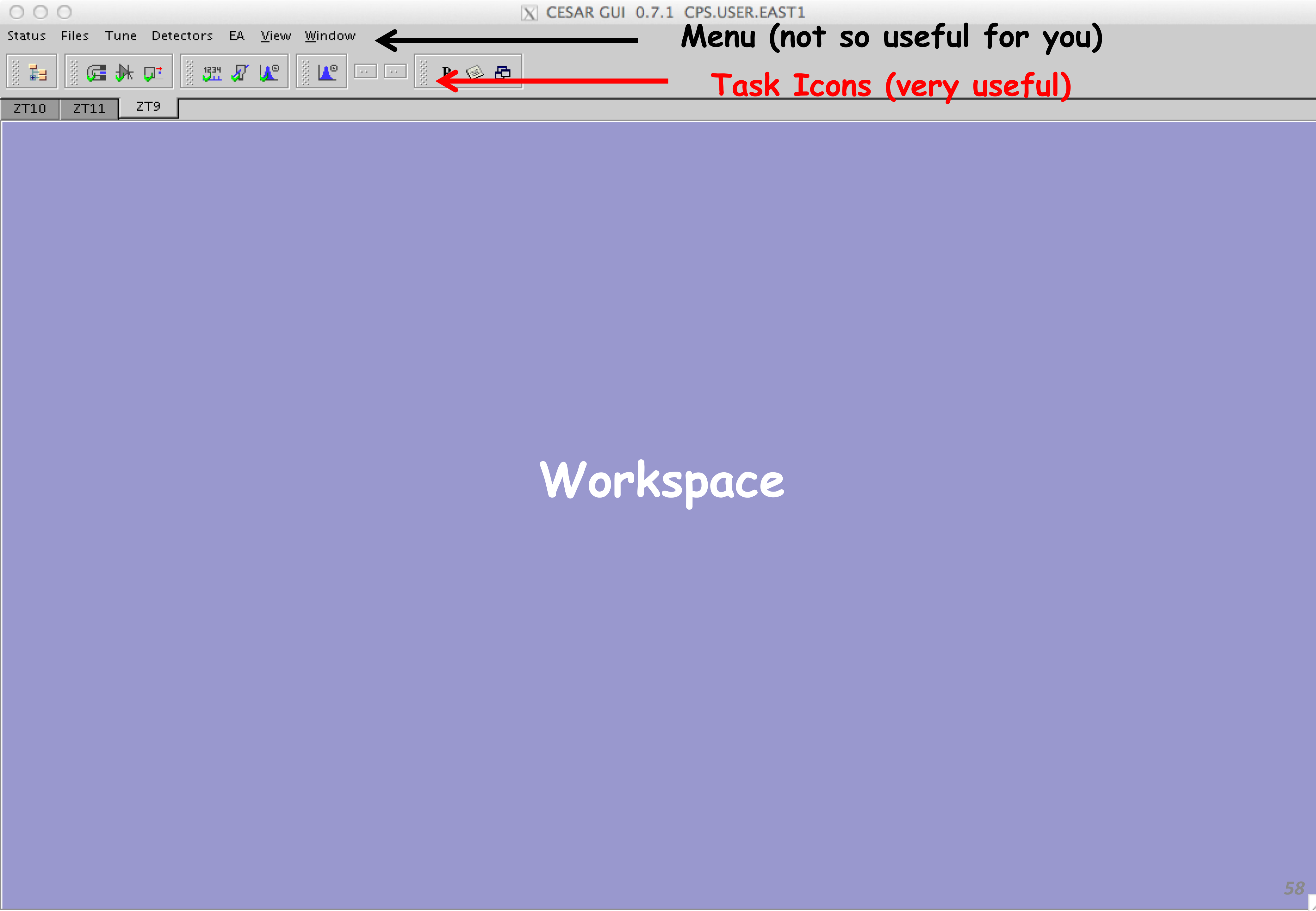


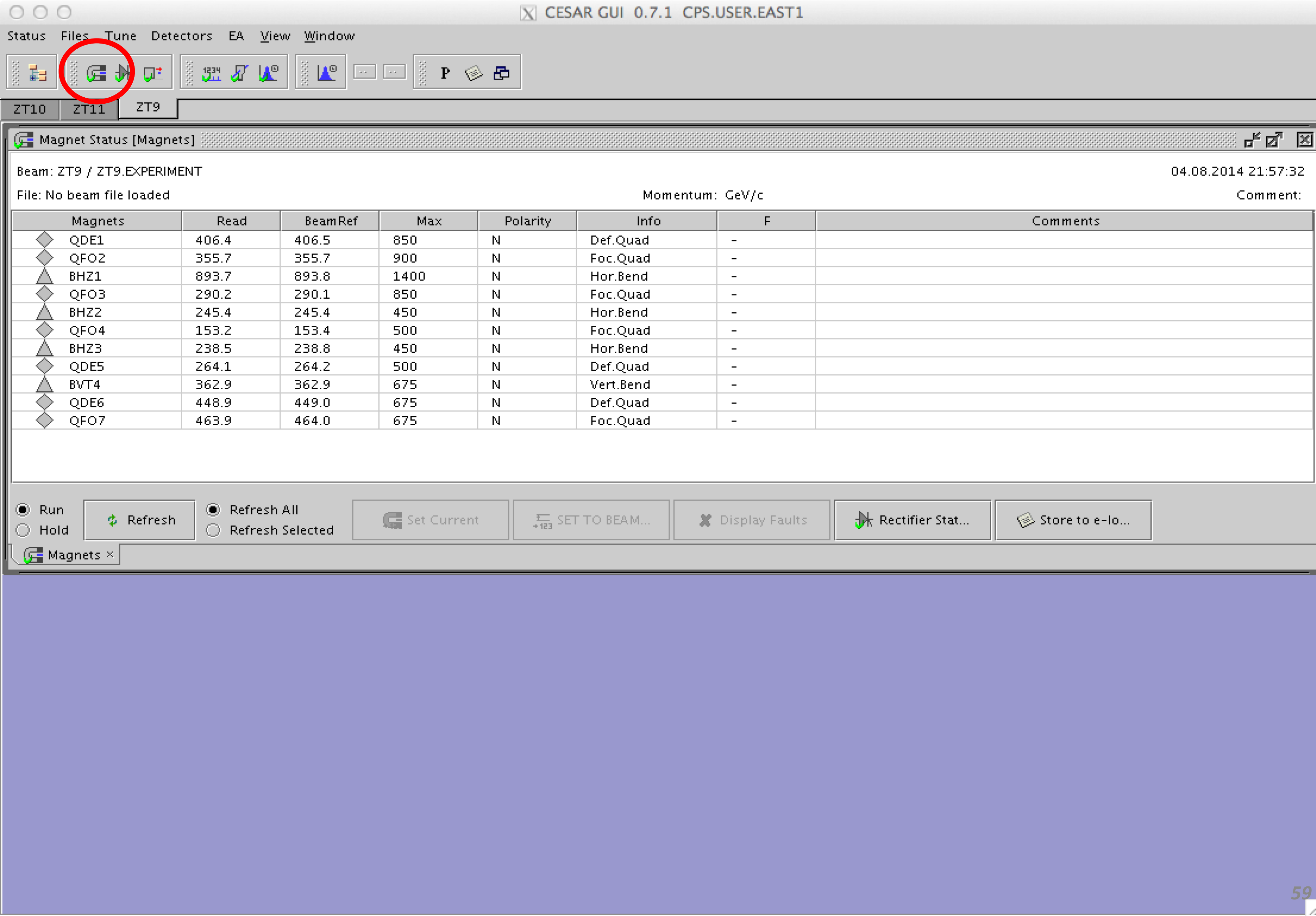
Particle identification via:



HOW TO CONTROL THE T9 BEAM?

Using the CESAR software !!!


CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
Menu (not so useful for you)
Task Icons (very useful)
ZT10
ZT11
ZT9
Workspace


CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
ZT10 ZT11 ZT9
Magnet Status [Magnets]
Beam: ZT9 / ZT9.EXPERIMENT
04.08.2014 21:57:32
File: No beam file loaded
Momentum: GeV/c
Comment:
Magnets Read BeamRef Max Polarity Info F Comments
QDE1 406.4 406.5 850 N Def.Quad -
QFO2 355.7 355.7 900 N Foc.Quad -
BHZ1 893.7 893.8 1400 N Hor.Bend -
QFO3 290.2 290.1 850 N Foc.Quad -
BHZ2 245.4 245.4 450 N Hor.Bend -
QFO4 153.2 153.4 500 N Foc.Quad -
BHZ3 238.5 238.8 450 N Hor.Bend -
QDE5 264.1 264.2 500 N Def.Quad -
BVT4 362.9 362.9 675 N Vert.Bend -
QDE6 448.9 449.0 675 N Def.Quad -
QFO7 463.9 464.0 675 N Foc.Quad -
Run
Hold
Refresh
Refresh All
Refresh Selected
Set Current
SET TO BEAM...
Display Faults
Rectifier Stat...
Store to e-lo...
Magnets

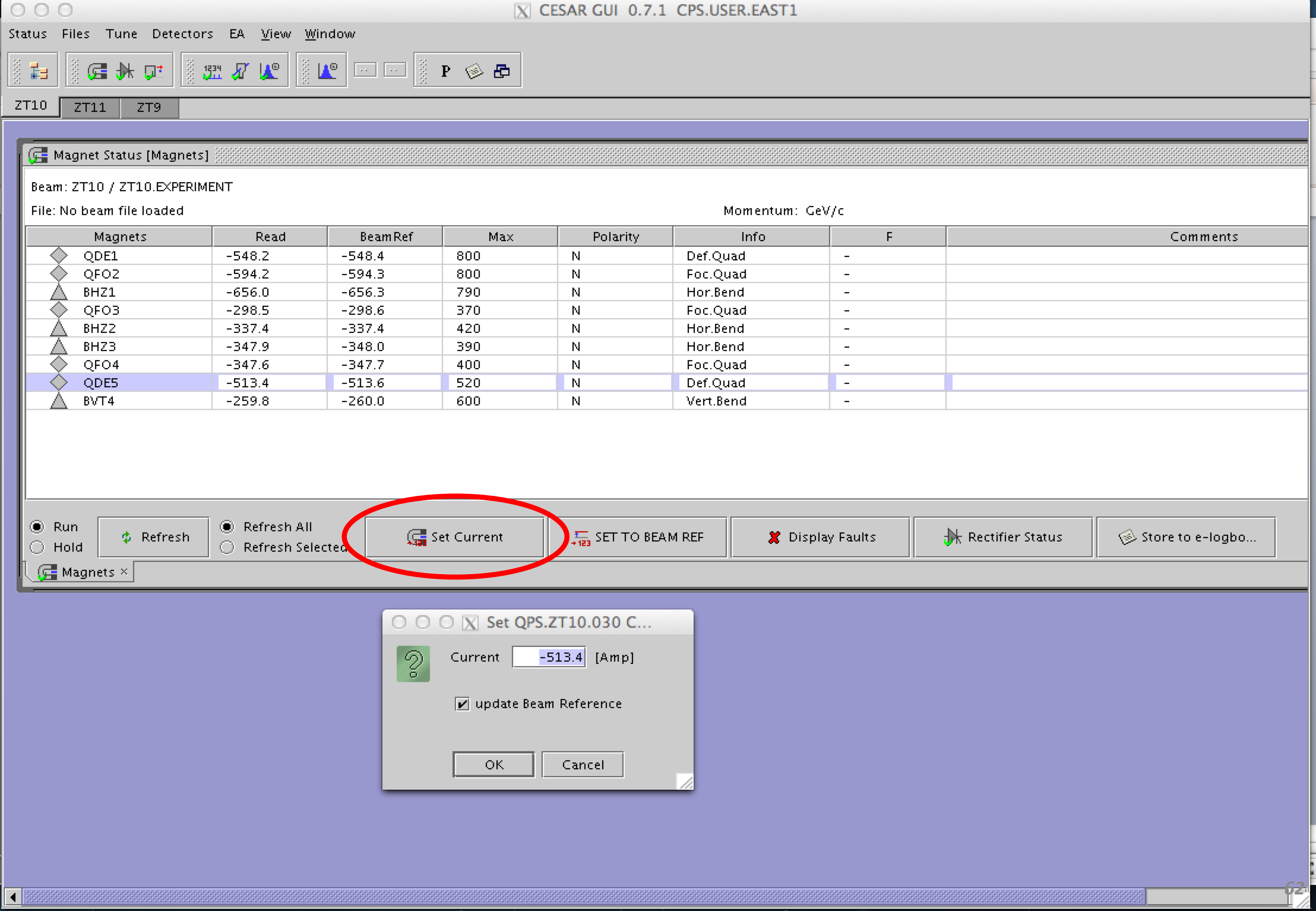
CURRENTS FOR T9 TEST BEAM, TUNED 28-07-2014

Focus 1 m behind XDWC

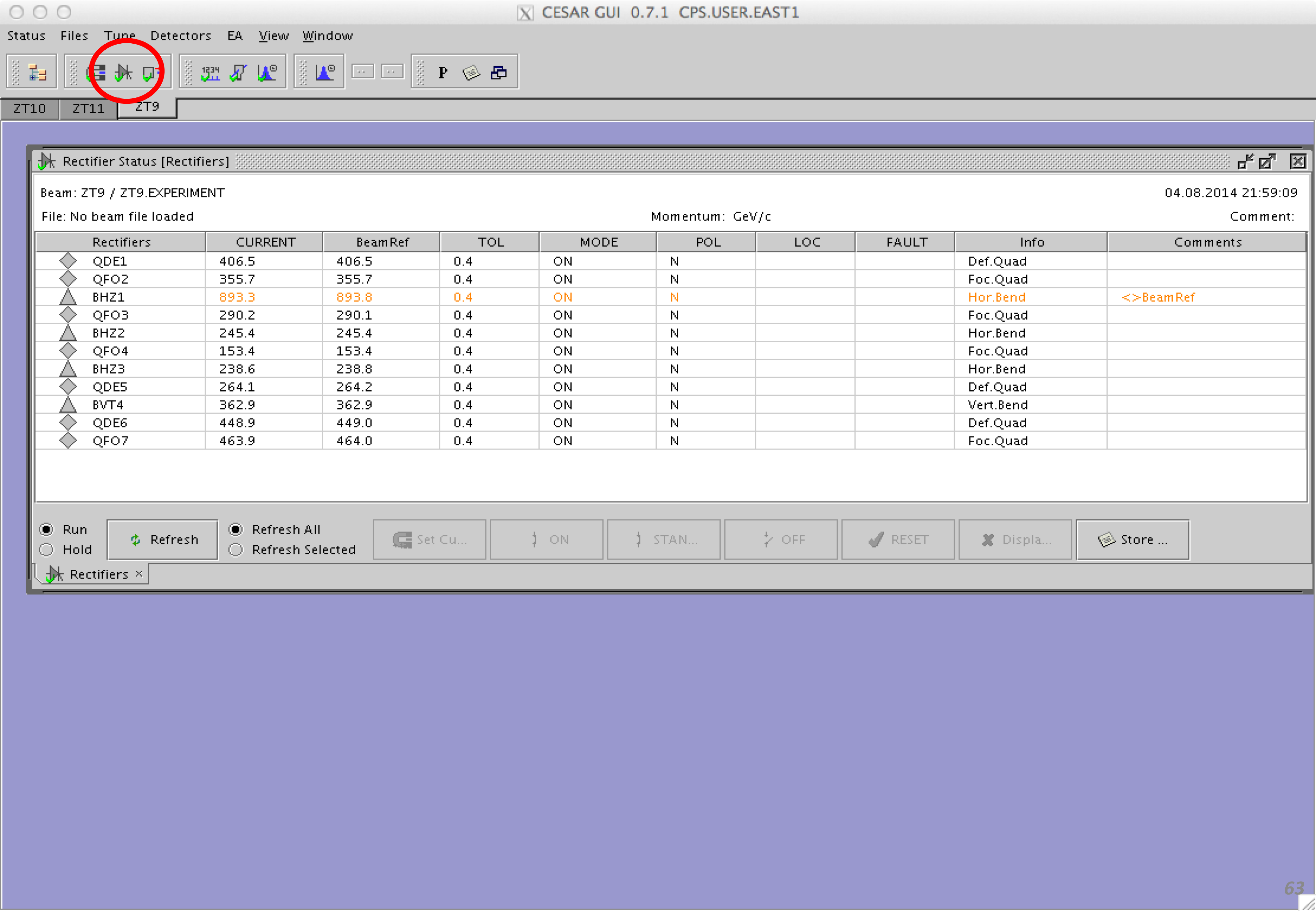
Momentum	QDE1	QFO2	BHZ1	QFO3	BHZ2	QFO4	BHZ3	QDE5	BVT1	QDE6	QFO7
1.00	40.66	38.07	89.28	29.01	24.54	15.36	23.91	26.42	35.83	44.74	46.12
1.50	60.99	55.22	133.92	43.52	36.82	23.04	35.86	39.62	53.76	67.12	69.18
2.00	81.32	72.00	178.56	58.03	49.09	30.72	47.81	52.83	71.69	89.49	92.24
2.50	101.65	88.77	223.21	72.53	61.36	38.40	59.76	66.04	89.64	111.86	115.30
3.00	121.96	105.71	267.86	87.04	73.63	46.08	71.72	79.25	107.61	134.23	138.36
3.50	142.28	122.94	312.52	101.55	85.91	53.76	83.67	92.46	125.59	156.61	161.41
4.00	162.59	140.50	357.18	116.06	98.18	61.44	95.62	105.66	143.60	178.98	184.47
4.50	182.89	158.35	401.85	130.56	110.45	69.12	107.58	118.87	161.64	201.35	207.53
5.00	203.20	176.44	446.52	145.07	122.72	76.80	119.53	132.08	179.71	223.72	230.59
6.00	243.79	212.95	535.90	174.08	147.27	92.16	143.43	158.49	215.96	268.47	276.71
7.00	284.38	249.29	625.31	203.10	171.81	107.52	167.34	184.91	252.38	313.21	322.83
8.00	325.00	285.10	714.76	232.11	196.36	122.88	191.25	211.33	289.00	357.96	368.95
9.00	365.68	320.43	804.27	261.13	220.90	138.24	215.15	237.74	325.86	402.70	415.16
10.00	406.49	355.66	893.84	290.14	245.45	153.60	239.06	264.16	363.00	449.01	463.98
11.00	447.53	391.39	983.47	319.41	269.99	168.96	262.96	290.57	400.44	499.26	517.31
12.00	488.94	428.37	1073.17	350.88	294.54	184.32	286.87	317.19	438.24	554.65	576.72

OTHER FOCUSSING OPTIONS

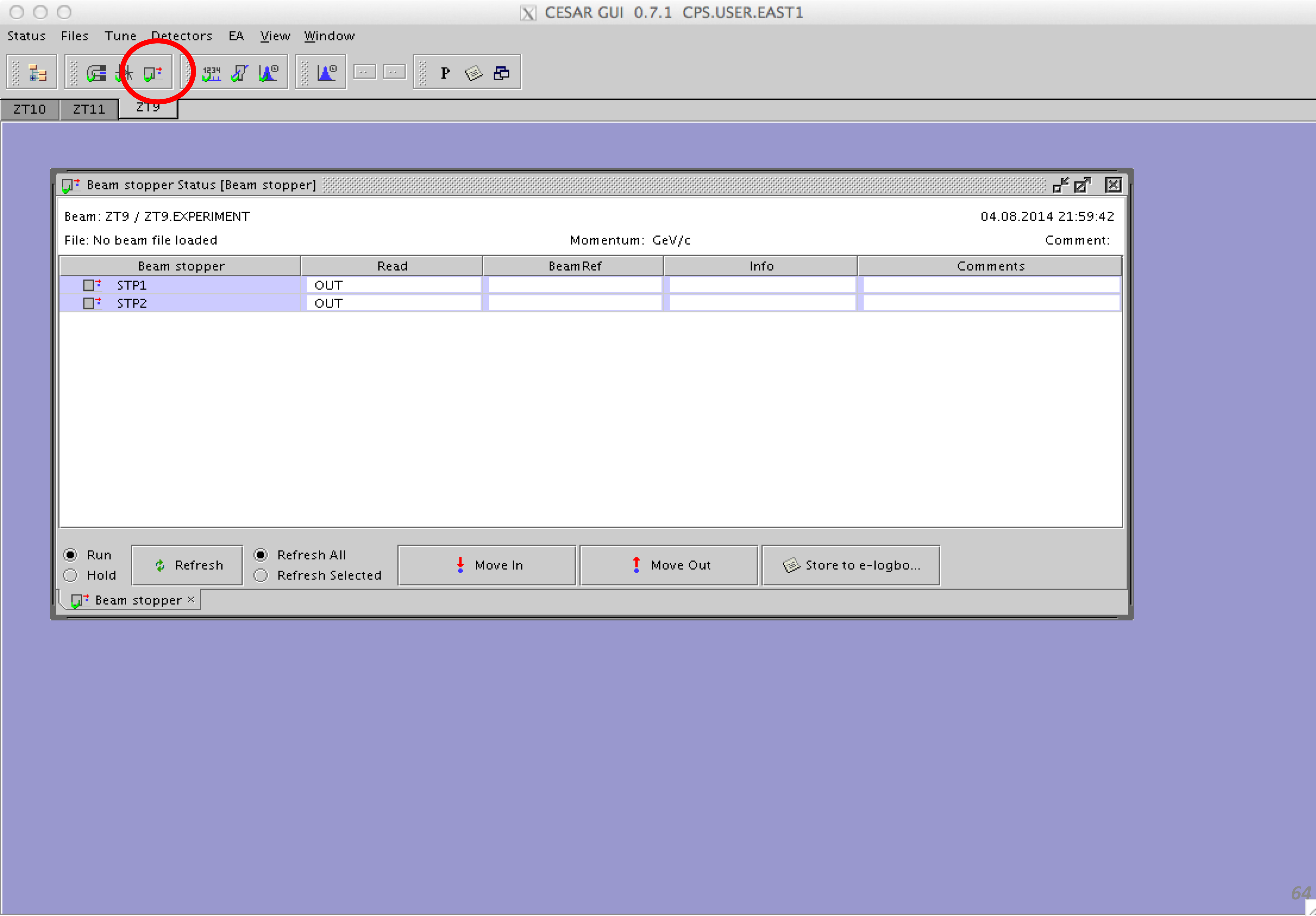
Momentum	Focus at XDWC		XDWC + 2m		XDWC + 4.5m		XDWC + 7m		XDWC + 9.5m		Parallel beam	
GeV/c	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7
1.00	45.57	47.99	44.00	44.18	42.38	40.93	41.24	38.88	40.30	37.12	36.09	32.11
1.50	68.36	71.98	65.99	66.27	63.57	61.40	61.86	58.32	60.45	55.68	54.14	48.16
2.00	91.15	95.98	87.99	88.36	84.76	81.86	82.48	77.76	80.60	74.25	72.19	64.22
2.50	113.94	119.97	109.99	110.45	105.95	102.33	103.10	97.19	100.75	92.81	90.23	80.27
3.00	136.72	143.97	131.99	132.54	127.14	122.79	123.72	116.63	120.90	111.37	108.28	96.33
3.50	159.51	167.96	153.98	154.63	148.32	143.26	144.33	136.07	141.05	129.93	126.33	112.38
4.00	182.30	191.96	175.98	176.72	169.51	163.73	164.95	155.51	161.20	148.49	144.37	128.44
4.50	205.08	215.95	197.98	198.81	190.70	184.19	185.57	174.95	181.35	167.05	162.42	144.49
5.00	227.87	239.95	219.98	220.90	211.89	204.66	206.19	194.39	201.50	185.62	180.47	160.55
6.00	273.44	287.94	263.97	265.08	254.27	245.59	247.43	233.27	241.80	222.74	216.56	192.65
7.00	319.02	335.93	307.97	309.27	296.65	286.52	288.67	272.15	282.10	259.86	252.65	224.76
8.00	364.59	383.92	351.96	353.45	339.03	327.45	329.91	311.02	322.40	296.98	288.75	256.87
9.00	410.19	432.53	395.96	397.63	381.41	368.38	371.15	349.90	362.70	334.11	324.84	288.98
10.00	458.00	485.00	441.01	442.98	424.09	409.33	412.44	388.78	403.00	371.23	360.93	321.09
11.00	510.08	542.95	489.66	492.02	469.49	452.03	455.69	428.10	444.57	408.37	397.03	353.20
12.00	567.85	608.58	543.03	545.88	518.82	498.06	502.40	469.91	489.25	446.90	433.80	385.31

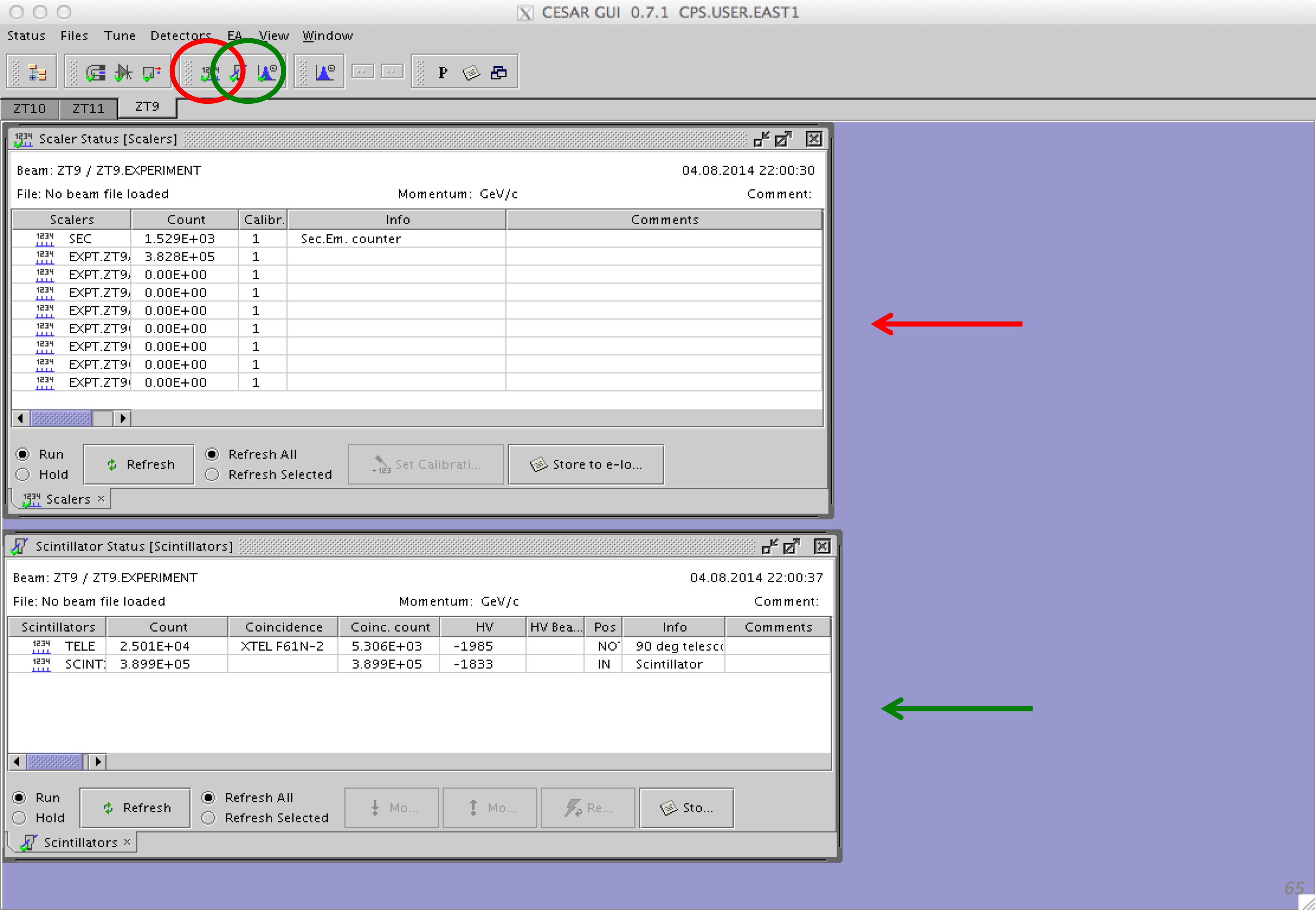


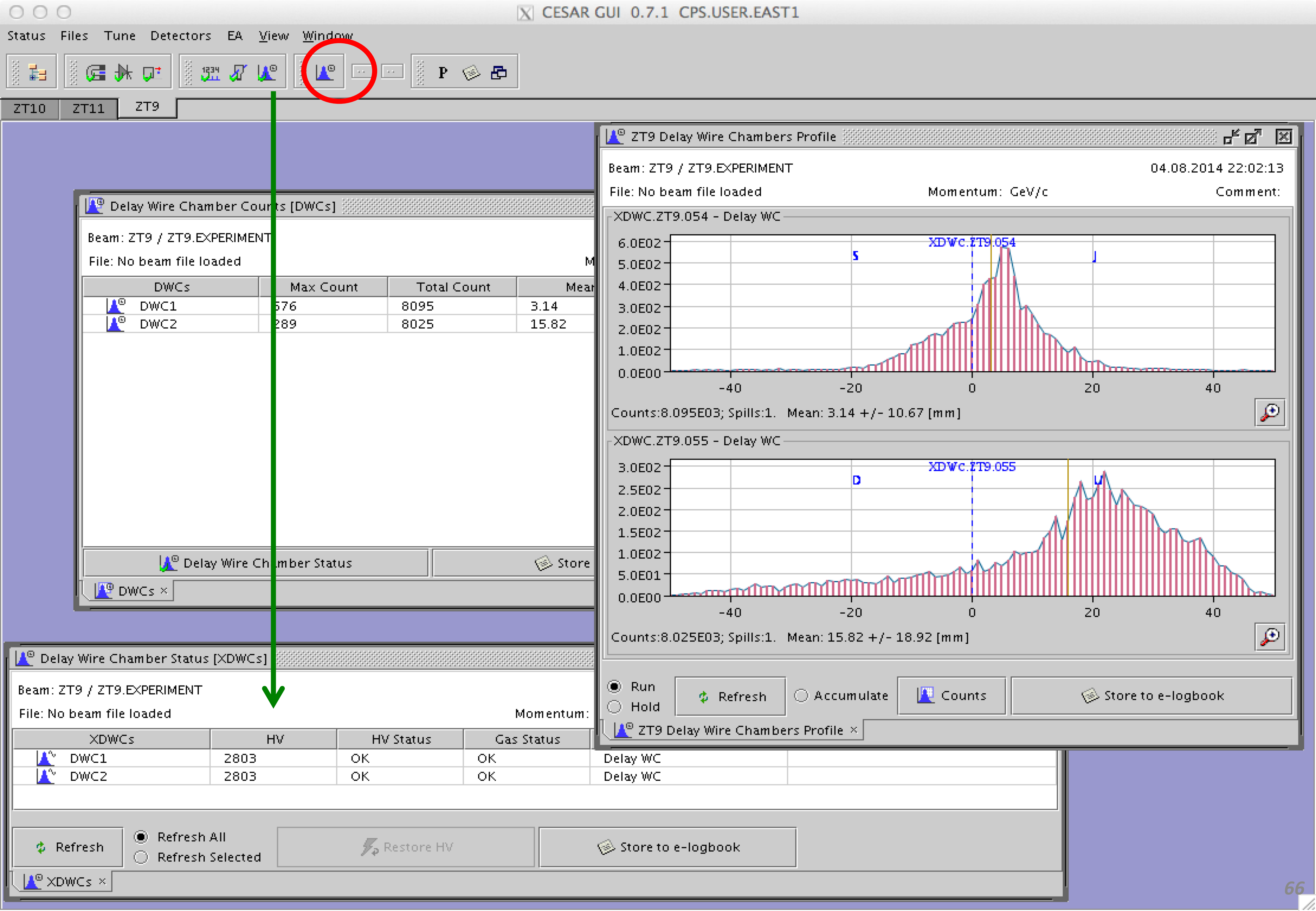
CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
ZT10 ZT11 ZT9
Magnet Status [Magnets]
Beam: ZT10 / ZT10.EXPERIMENT
File: No beam file loaded
Momentum: GeV/c
Magnets Read BeamRef Max Polarity Info F Comments
QDE1 -548.2 -548.4 800 N Def.Quad -
QFO2 -594.2 -594.3 800 N Foc.Quad -
BHZ1 -656.0 -656.3 790 N Hor.Bend -
QFO3 -298.5 -298.6 370 N Foc.Quad -
BHZ2 -337.4 -337.4 420 N Hor.Bend -
BHZ3 -347.9 -348.0 390 N Hor.Bend -
QFO4 -347.6 -347.7 400 N Foc.Quad -
QDE5 -513.4 -513.6 520 N Def.Quad -
BVT4 -259.8 -260.0 600 N Vert.Bend -
Run
Hold
Refresh
Refresh All
Refresh Selected
Set Current
SET TO BEAM REF
Display Faults
Rectifier Status
Store to e-logbo...
Magnets
Set QPS.ZT10.030 C...
Current -513.4 [Amp]
update Beam Reference
OK
Cancel

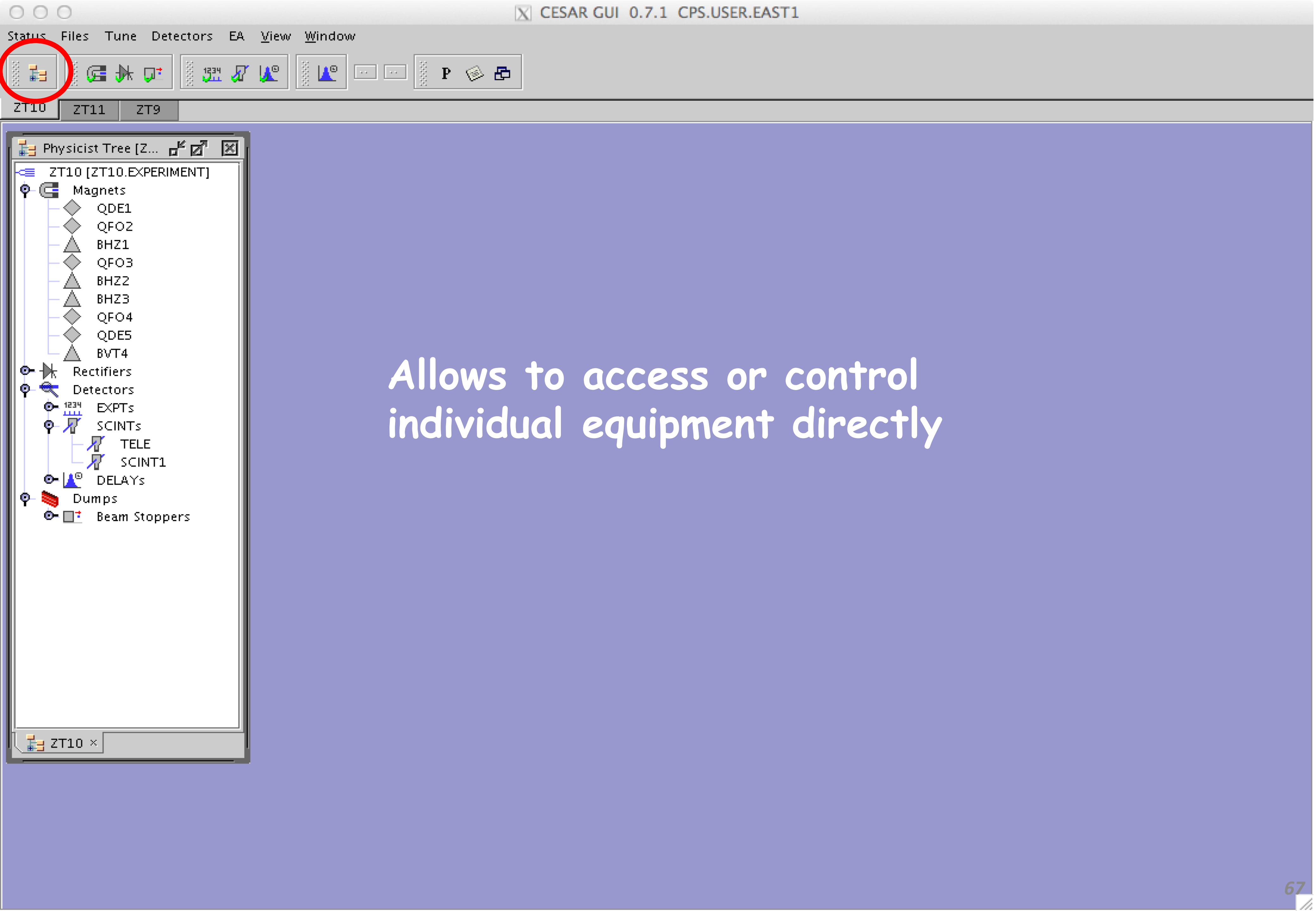


Rectifiers	CURRENT	BeamRef	TOL	MODE	POL	LOC	FAULT	Info	Comments
QDE1	406.5	406.5	0.4	ON	N			Def.Quad	
QFO2	355.7	355.7	0.4	ON	N			Foc.Quad	
BHZ1	893.3	893.8	0.4	ON	N			Hor.Bend	<>BeamRef
QFO3	290.2	290.1	0.4	ON	N			Foc.Quad	
BHZ2	245.4	245.4	0.4	ON	N			Hor.Bend	
QFO4	153.4	153.4	0.4	ON	N			Foc.Quad	
BHZ3	238.6	238.8	0.4	ON	N			Hor.Bend	
QDE5	264.1	264.2	0.4	ON	N			Def.Quad	
BVT4	362.9	362.9	0.4	ON	N			Vert.Bend	
QDE6	448.9	449.0	0.4	ON	N			Def.Quad	
QFO7	463.9	464.0	0.4	ON	N			Foc.Quad	

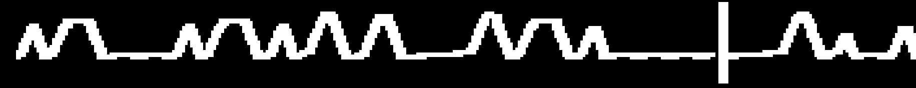

CESAR GUI 0.7.1 CPS.USER.EAST1
Status
Files
Tune
Detectors
EA
View
Window
ZT10
ZT11
ZT9
Beam stopper Status [Beam stopper]
Beam: ZT9 / ZT9.EXPERIMENT
04.08.2014 21:59:42
File: No beam file loaded
Momentum: GeV/c
Comment:
Beam stopper
Read
BeamRef
Info
Comments
STP1
OUT
STP2
OUT
Run
Hold
Refresh
Refresh All
Refresh Selected
Move In
Move Out
Store to e-logbo...
Beam stopper


CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
ZT10 ZT11 ZT9
Scaler Status [Scalers]
Beam: ZT9 / ZT9.EXPERIMENT
04.08.2014 22:00:30
File: No beam file loaded
Momentum: GeV/c
Comment:
Scalers Count Calibr. Info Comments
SEC 1.529E+03 1 Sec.Em. counter
EXPT.ZT9 3.828E+05 1
EXPT.ZT9 0.00E+00 1
EXPT.ZT9 0.00E+00 1
EXPT.ZT9 0.00E+00 1
EXPT.ZT9 0.00E+00 1
EXPT.ZT9 0.00E+00 1
EXPT.ZT9 0.00E+00 1
EXPT.ZT9 0.00E+00 1
Run
Hold
Refresh
Refresh All
Refresh Selected
Set Calibrati...
Store to e-lo...
Scalers
Scintillator Status [Scintillators]
Beam: ZT9 / ZT9.EXPERIMENT
04.08.2014 22:00:37
File: No beam file loaded
Momentum: GeV/c
Comment:
Scintillators Count Coincidence Coinc. count HV HV Bea... Pos Info Comments
TELE 2.501E+04 XTEL F61N-2 5.306E+03 -1985 NOT 90 deg telesc
SCINT 3.899E+05 3.899E+05 -1833 IN Scintillator
Run
Hold
Refresh
Refresh All
Refresh Selected
Mo...
Mo...
Re...
Sto...
Scintillators

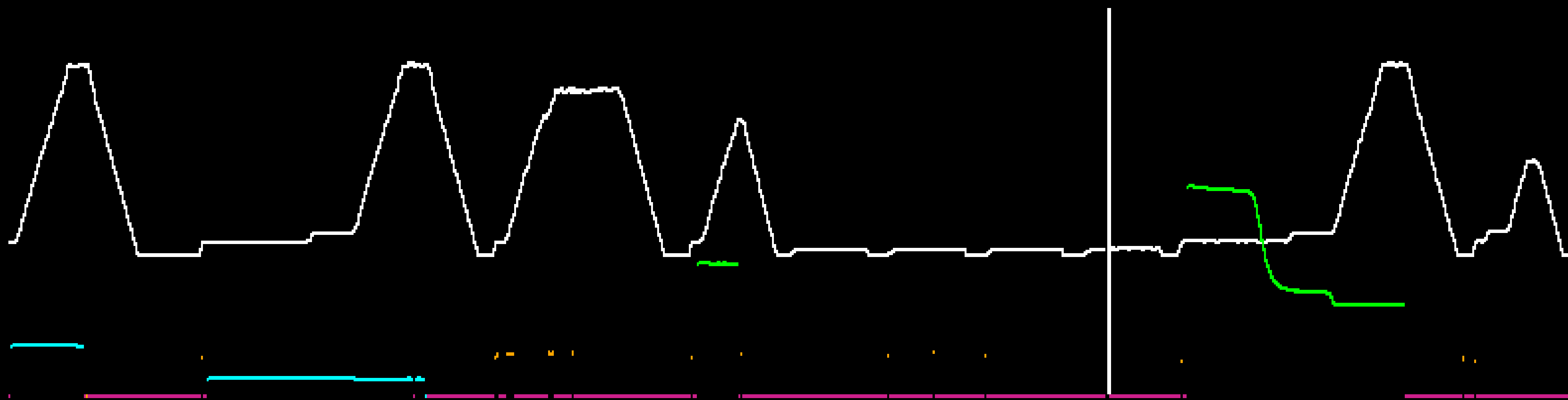

CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
ZT10 ZT11 ZT9
Delay Wire Chamber Counts [DWCs]
Beam: ZT9 / ZT9.EXPERIMENT
File: No beam file loaded
DWCs | Max Count | Total Count | Mean
DWC1 | 576 | 8095 | 3.14
DWC2 | 289 | 8025 | 15.82
Delay Wire Chamber Status
Store
DWCs
ZT9 Delay Wire Chambers Profile
Beam: ZT9 / ZT9.EXPERIMENT
04.08.2014 22:02:13
File: No beam file loaded
Momentum: GeV/c
Comment:
XDWC.ZT9.054 - Delay WC
XDWC.ZT9.054
Counts:8.095E03; Spills:1. Mean: 3.14 +/- 10.67 [mm]
XDWC.ZT9.055 - Delay WC
XDWC.ZT9.055
Counts:8.025E03; Spills:1. Mean: 15.82 +/- 18.92 [mm]
Run
Hold
Refresh
Accumulate
Counts
Store to e-logbook
ZT9 Delay Wire Chambers Profile
Delay Wire Chamber Status [XDWCs]
Beam: ZT9 / ZT9.EXPERIMENT
File: No beam file loaded
Momentum:
XDWCs | HV | HV Status | Gas Status
DWC1 | 2803 | OK | OK | Delay WC
DWC2 | 2803 | OK | OK | Delay WC
Refresh
Refresh All
Refresh Selected
Restore HV
Store to e-logbook
XDWCs


CESAR GUI 0.7.1 CPS.USER.EAST1
Status
Files
Tune
Detectors
EA
View
Window
ZT10
ZT11
ZT9
Physicist Tree [Z...
ZT10 [ZT10.EXPERIMENT]
Magnets
QDE1
QFO2
BHZ1
QFO3
BHZ2
BHZ3
QFO4
QDE5
BVT4
Rectifiers
Detectors
EXPTs
SCINTs
TELE
SCINT1
DELAYs
Dumps
Beam Stoppers
ZT10
Allows to access or control individual equipment directly

CPS Tel:76677-W 35



27 Aug 14 09:38:45



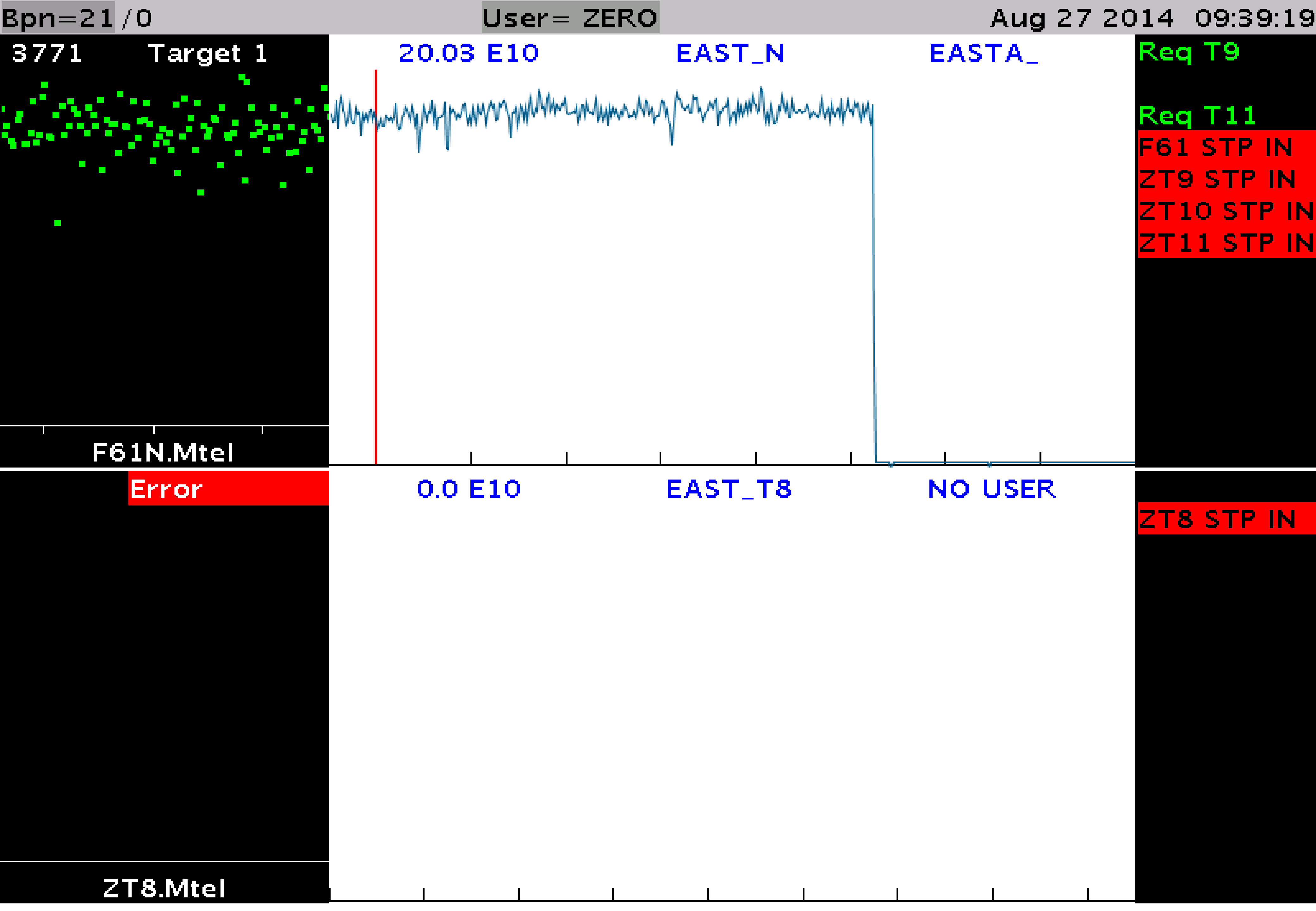
4 Colour range scales: 0.1 - 0.49 0.49 - 9 9 - 225 225 - 4500 E10 Charges

7	EASTA_	2	0.21	P+	EAST_N
9	TOF_	23	107	P+	NTOF
10	LHC_ION_2BP_Ea	4	0.47	AR11	PS_DUMP
12	AD_	1	861	P+	TT2_D3
14	LHC_DB_50ns	9	280	P+	TT2_D3
17	EASTA_	2	0.19	P+	EAST_N
19	TOF_	23	108	P+	NTOF
20	~~~zero~~~	24		–	
21	~~~zero~~~	24		–	
23	~~~zero~~~	24		–	PS_DUMP
/0	LHC_DB_50ns	9		–	TT2_D3

Comments
(27-Aug-2014 07:21:20)

Extraction kicker 21 down. Rolled back to extraction without TPS15

No beam for EAST HALL. Access today

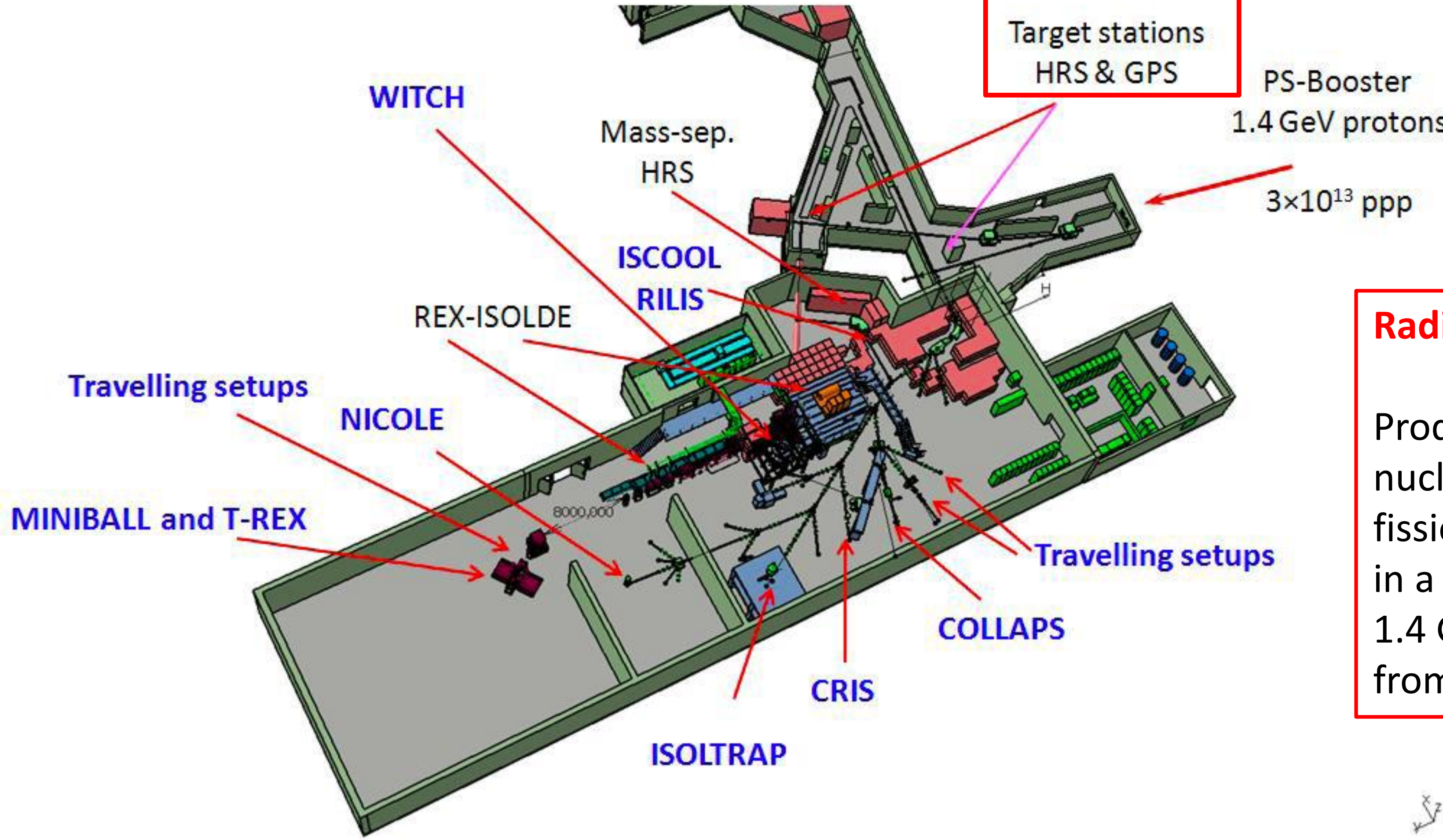

Bpn=21 /0
User= ZERO
Aug 27 2014 09:39:19
3771 Target 1
20.03 E10
EAST_N
EASTA_
Req T9
Req T11
F61 STP IN
ZT9 STP IN
ZT10 STP IN
ZT11 STP IN
F61N.Mtel
Error
0.0 E10
EAST_T8
NO USER
ZT8 STP IN
ZT8.Mtel

Congratulations for having won this competition !

Good luck for a successful experiment !

And have a wonderful time at CERN !!!

THE ISOLDE COMPLEX



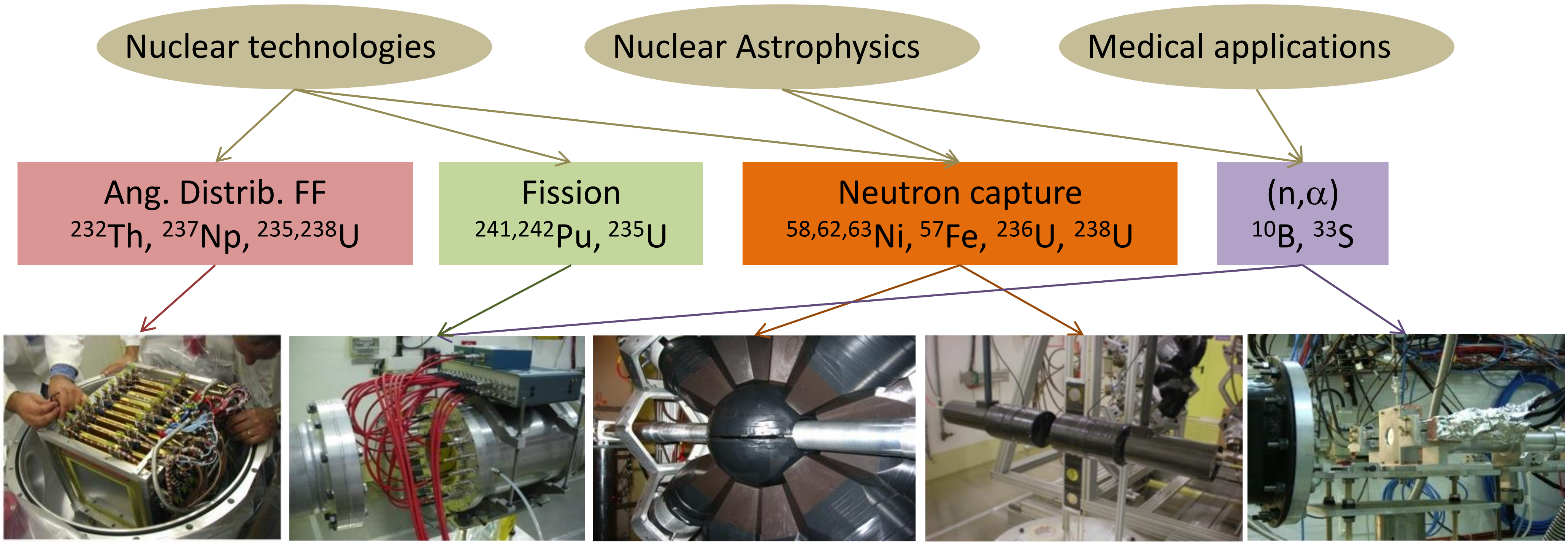
Radioactive Ion Beams

Produce radioactive nuclides via spallation, fission or fragmentation in a thick target via a 1.4 GeV/c proton beam from the PSB.

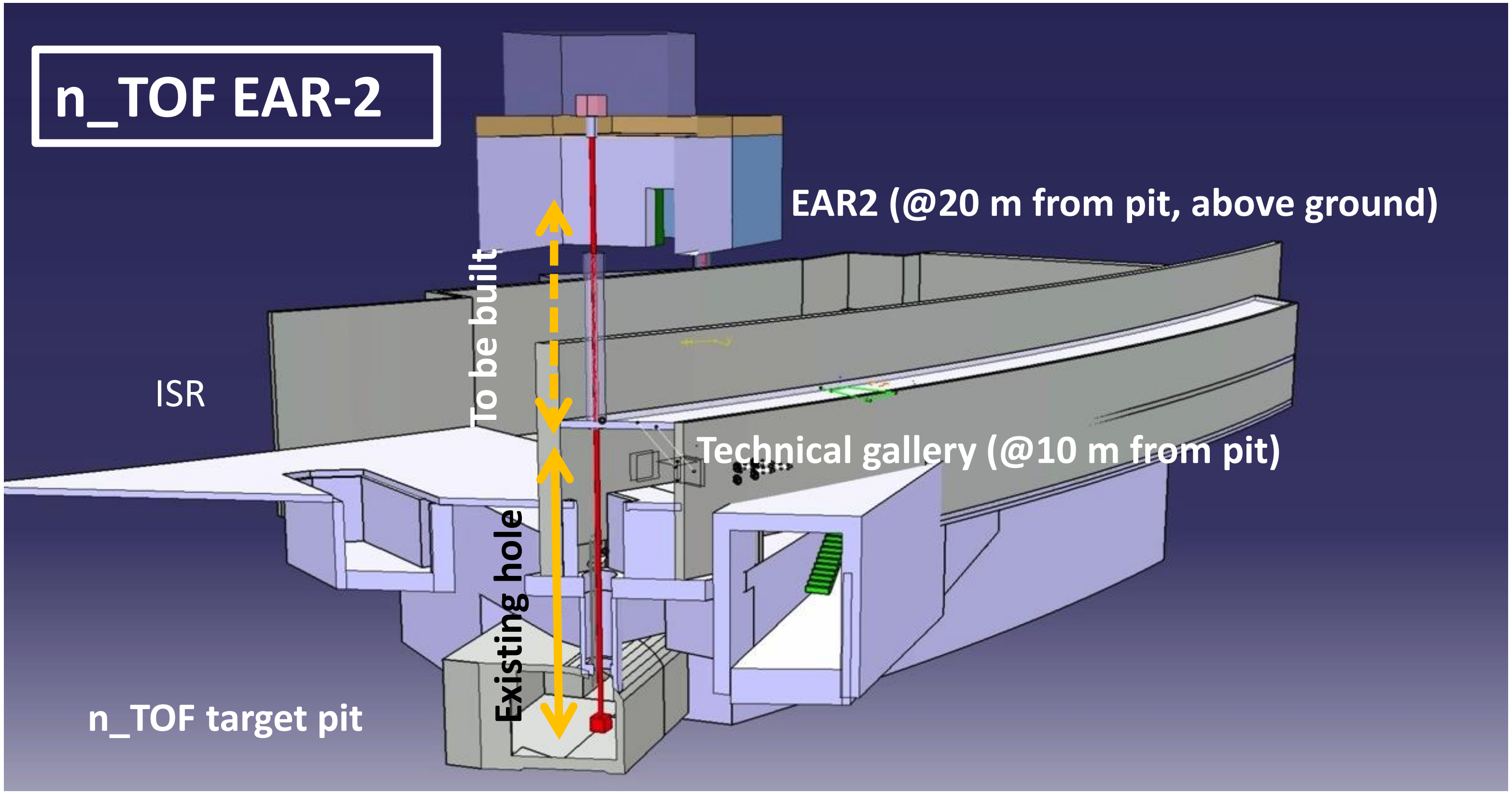
The HRS (High-Resolution Spectrometer) and General Purpose Spectrometer (GPS) are two isotope separators that deliver 60 keV mass separated radioactive ion beams.
They are used for nuclear physics, medical physics, astrophysics, etc

nTOF PHYSICS MOTIVATIONS

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

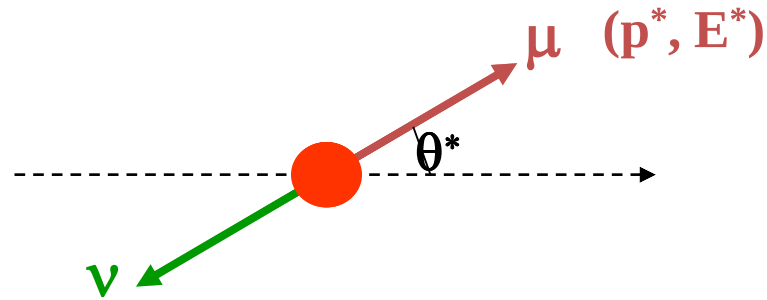


nTOF EAR2 : AN UPGRADE OF THE EXISTING FACILITY



Muons from pion decay

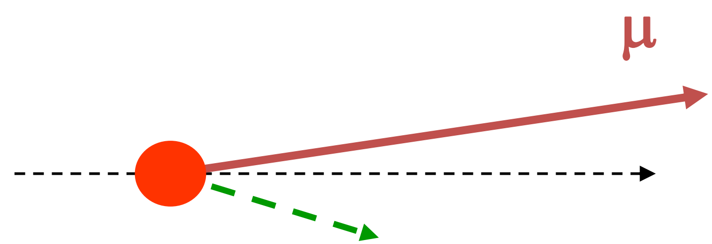
- **Pion decay in π center of mass:**



$$p^* = \frac{m_\pi^2 - m_\mu^2}{2\, m_\pi} = 30\ \text{MeV/c}$$

$$E^* = \frac{m_\pi^2 + m_\mu^2}{2\, m_\pi} = 110\ \text{MeV/c}$$

- **Boost to laboratory frame:**



$$E_\mu = \gamma_\pi \left(E^* + \beta_\pi\, p^* \cos\theta^*\right) \quad \text{with } \beta_\pi \approx 1$$

- **Limiting cases:**

$$\cos\theta = +1 \rightarrow E_{max} = 1.0\, E_\pi$$

$$\cos\theta = -1 \rightarrow E_{min} = 0.57\, E_\pi$$

$$\Rightarrow \quad 0.57 < E_\mu / E_\pi < 1$$