East Hall under construction - 1962

The T9 Secondary Beam at CERN

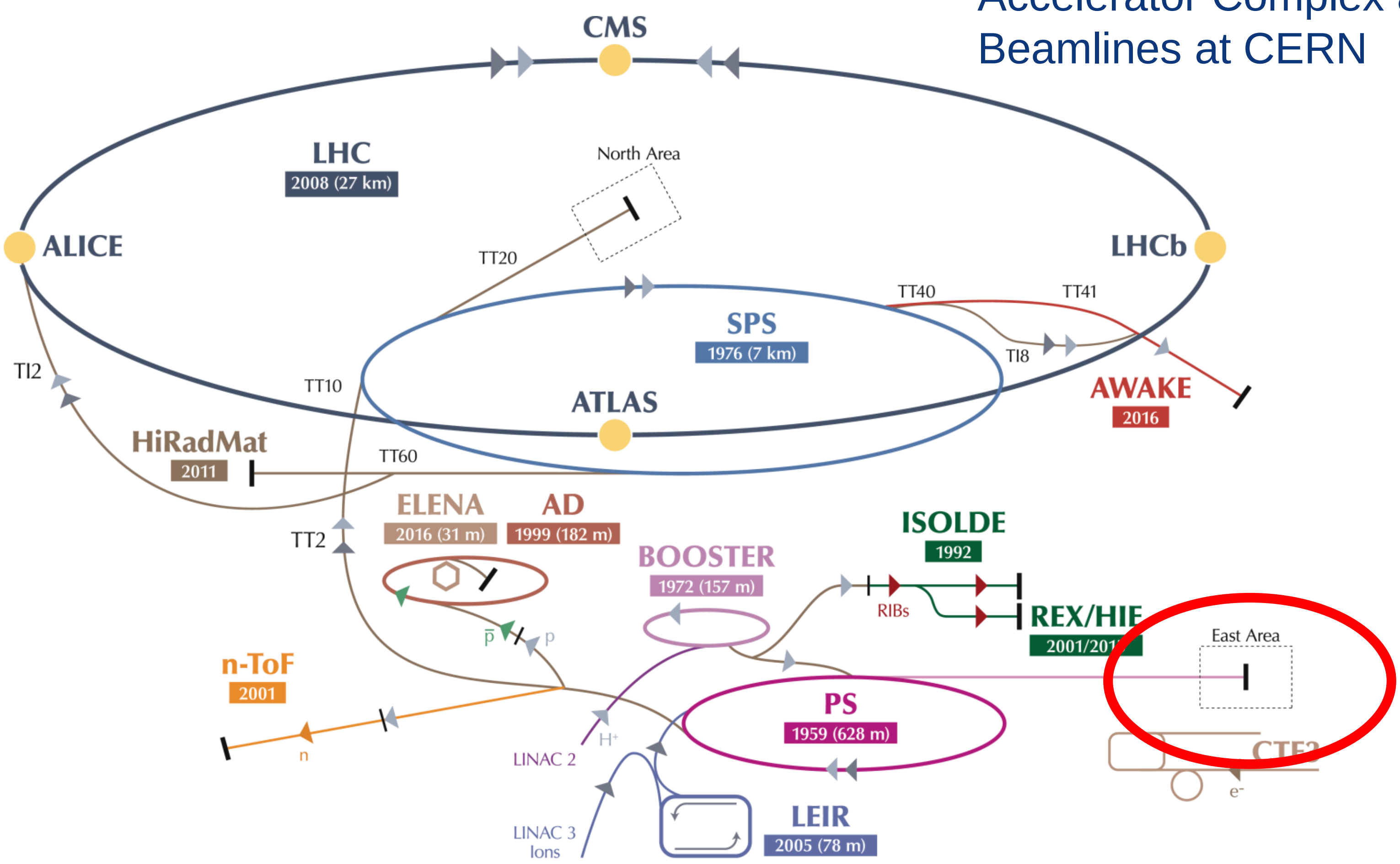
Johannes Bernhard (EN-EA)

ENGINEERING DEPARTMENT

beamline for schools

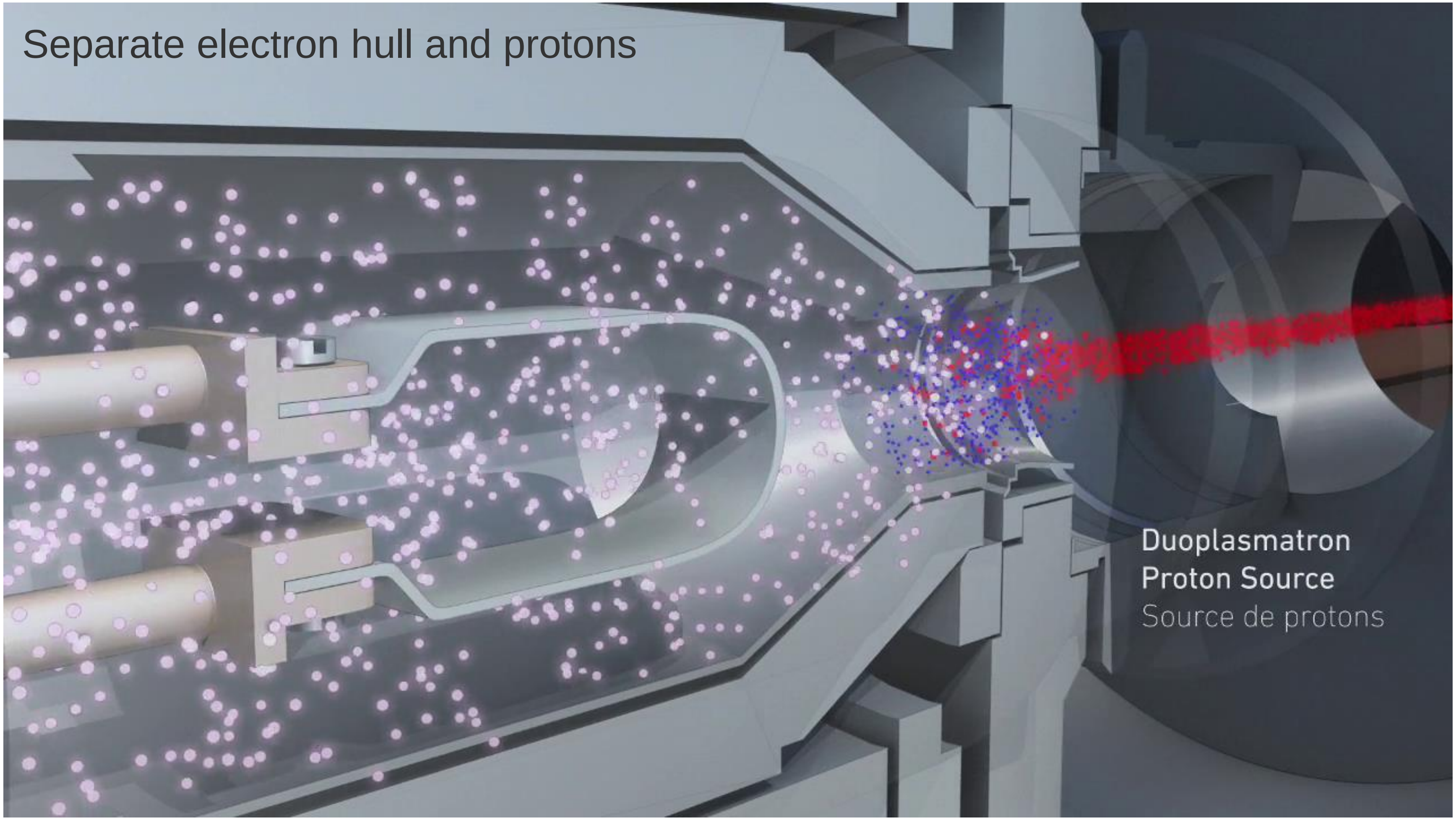
Overview

Accelerator Complex and Beamlines at CERN



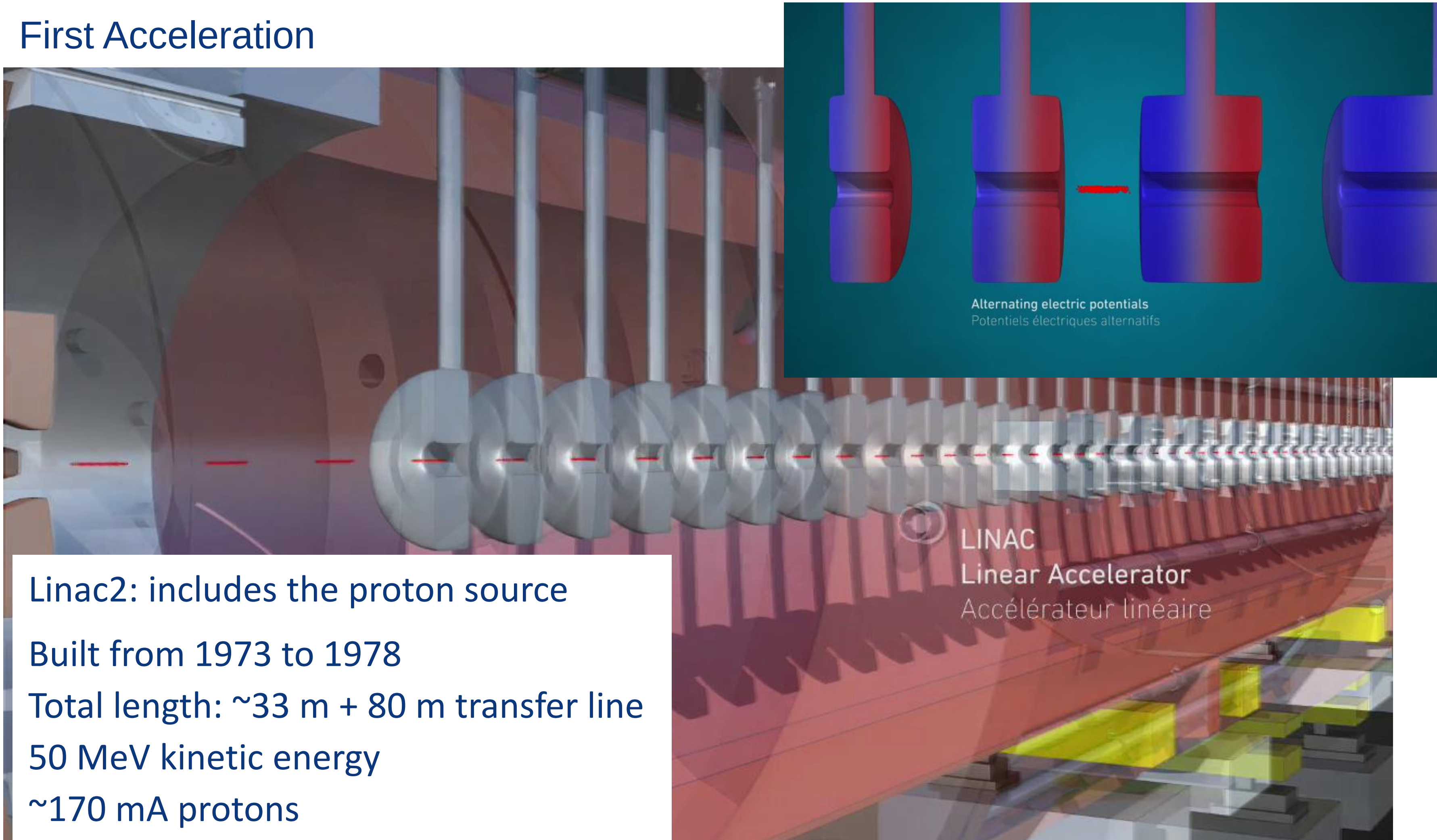
Where does the beam come from?

Where does the beam come from?



Where does the beam come from?

First Acceleration



Linac2: includes the proton source

Built from 1973 to 1978

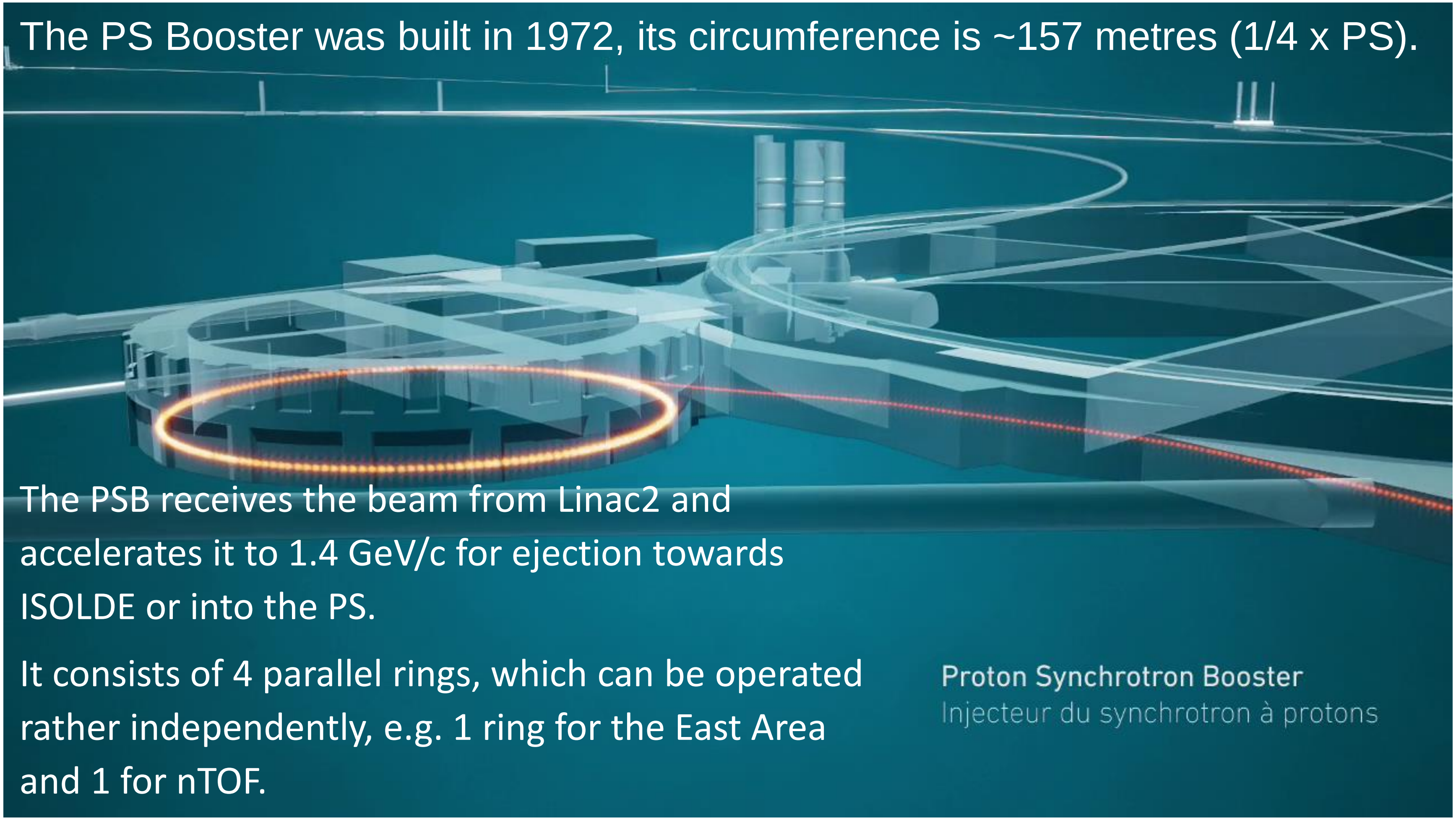
Total length: ~33 m + 80 m transfer line

50 MeV kinetic energy

~170 mA protons

Where does the beam come from?

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

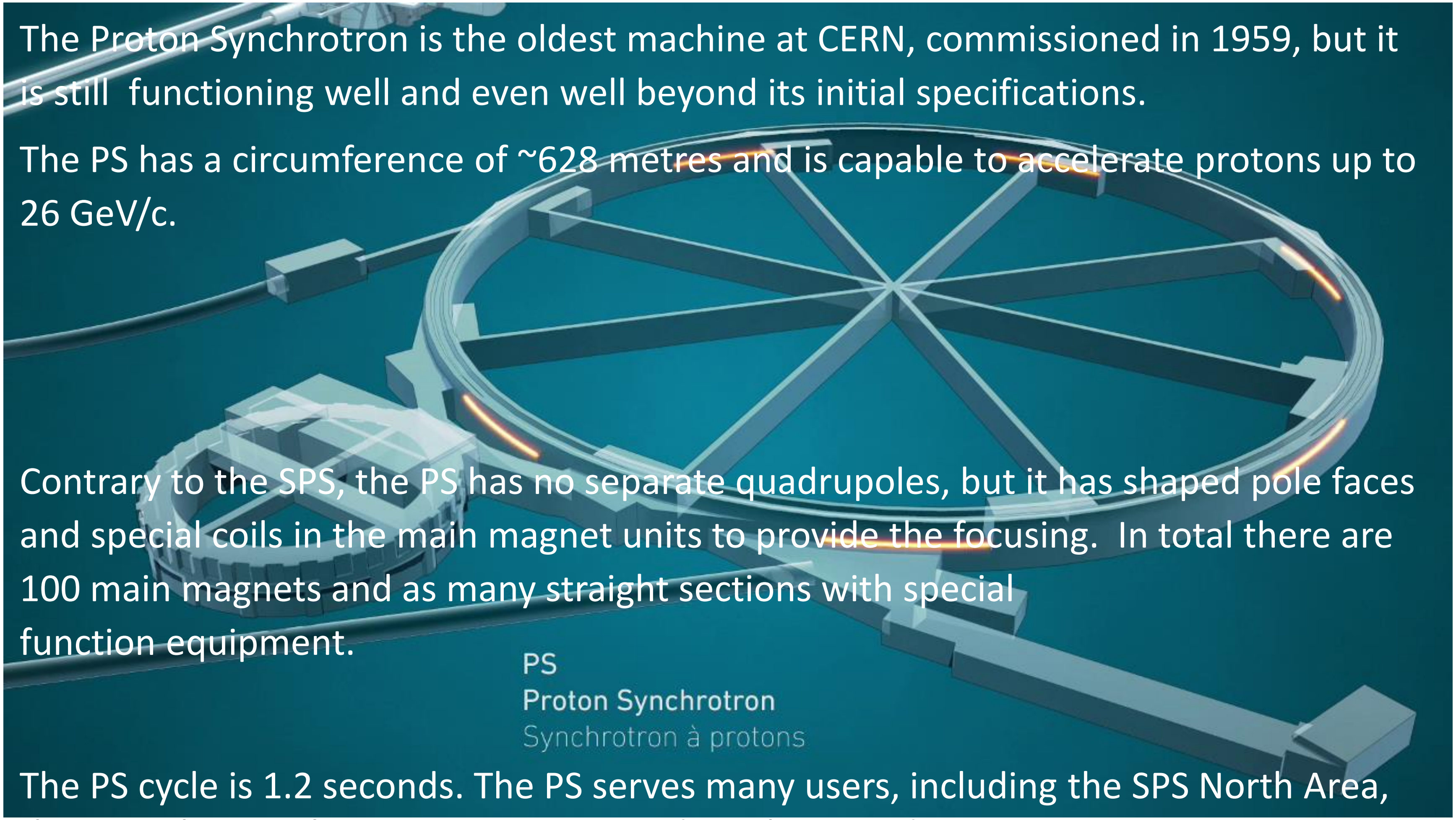


The PSB receives the beam from Linac2 and accelerates it to 1.4 GeV/c for ejection towards ISOLDE or into the PS.

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}.

Where does the beam come from?



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.

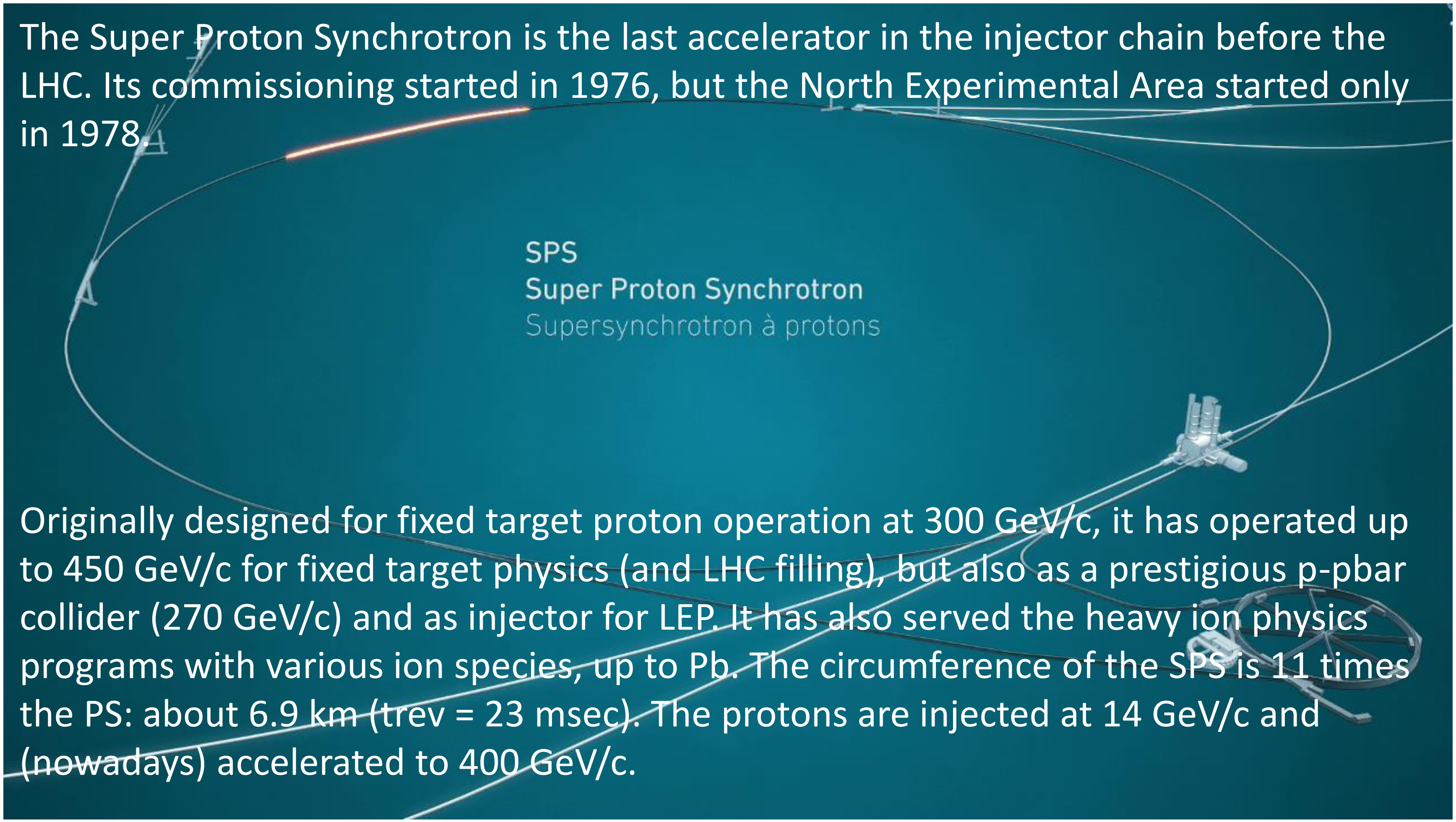
The PS has a circumference of ~628 metres and is capable to accelerate protons up to 26 GeV/c.

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 cycle is 1.2 seconds. The PS serves many users, including the SPS North Area, the LHC, the AD, the East Area, nTOF and machine studies.

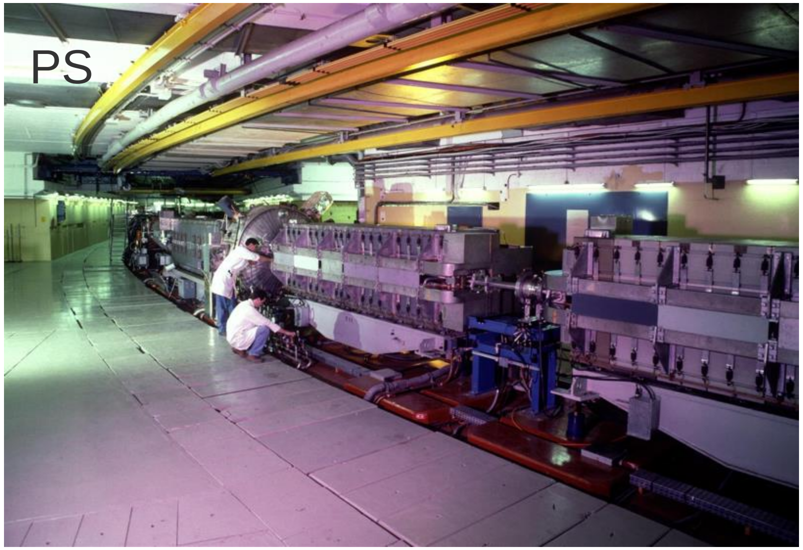
Where does the beam come from?

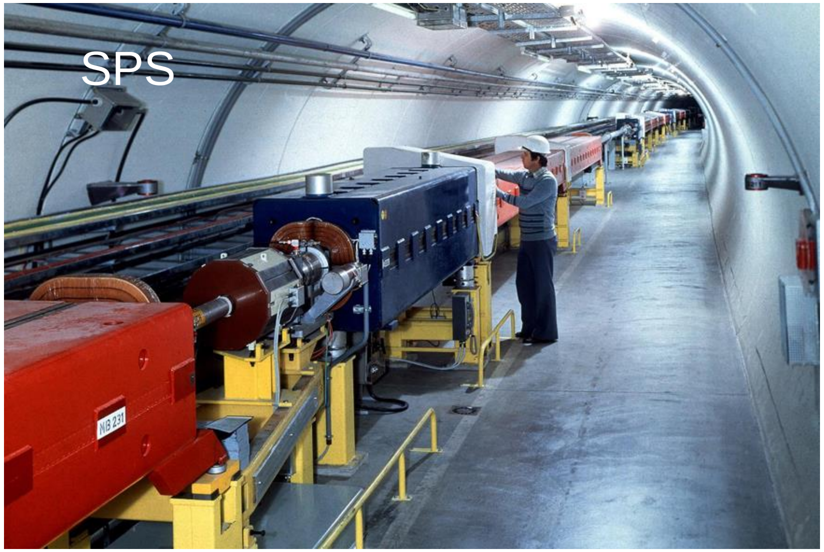
The Super Proton Synchrotron is the last accelerator in the injector chain before the LHC. Its commissioning started in 1976, but the North Experimental Area started only in 1978.



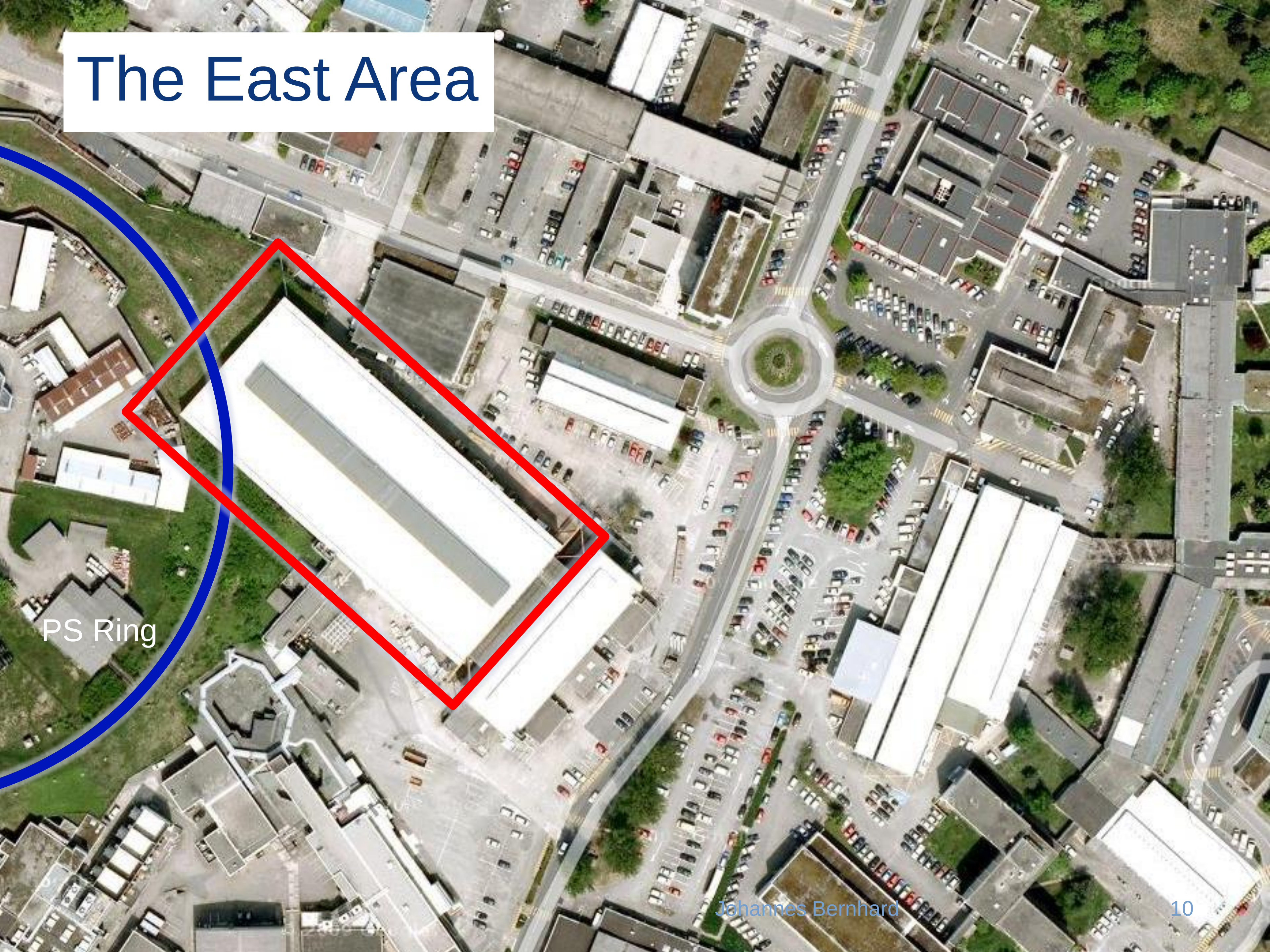
Originally designed for fixed target proton operation at 300 GeV/c, it has operated up to 450 GeV/c for fixed target physics (and LHC filling), but also as a prestigious p-pbar collider (270 GeV/c) and as injector for LEP. It has also served the heavy ion physics programs with various ion species, up to Pb. The circumference of the SPS is 11 times the PS: about 6.9 km (trev = 23 msec). The protons are injected at 14 GeV/c and (nowadays) accelerated to 400 GeV/c.

Some pictures…

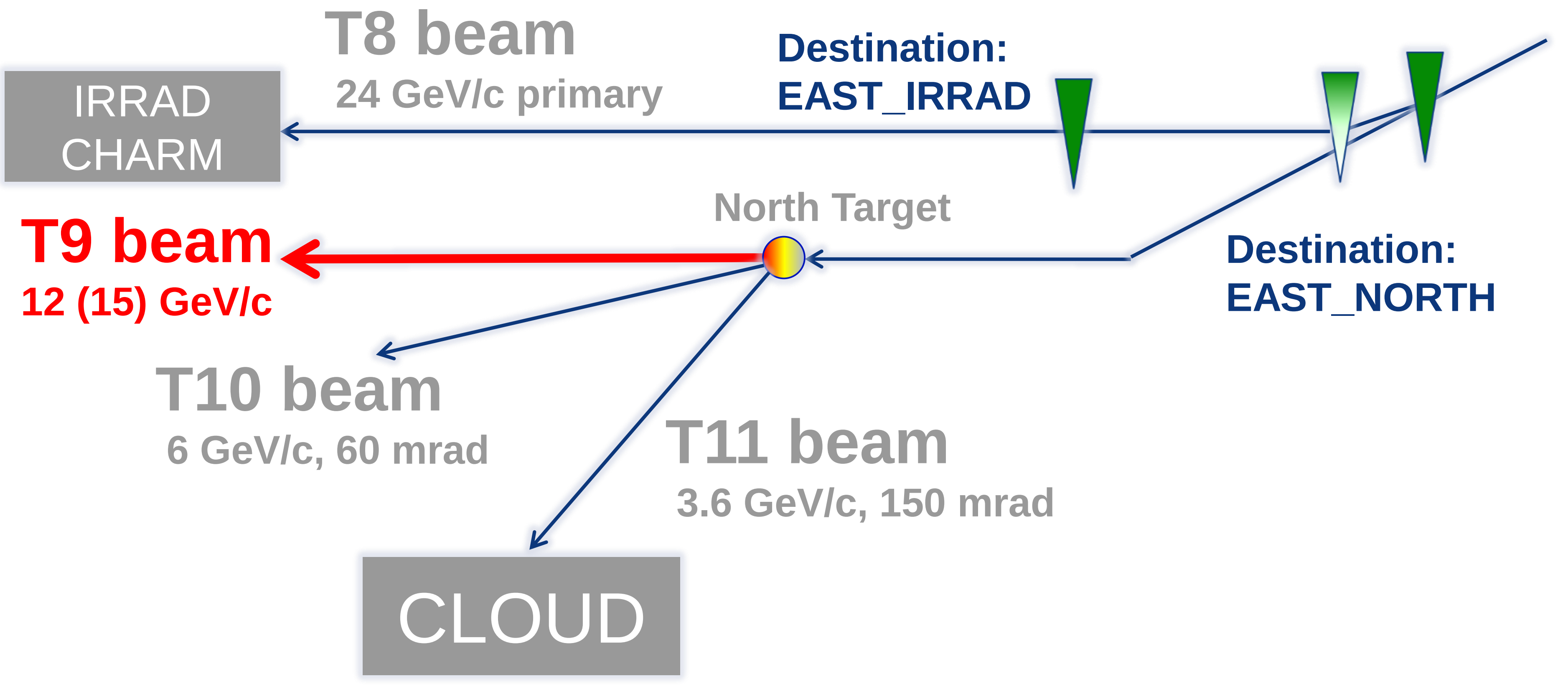




The East Area

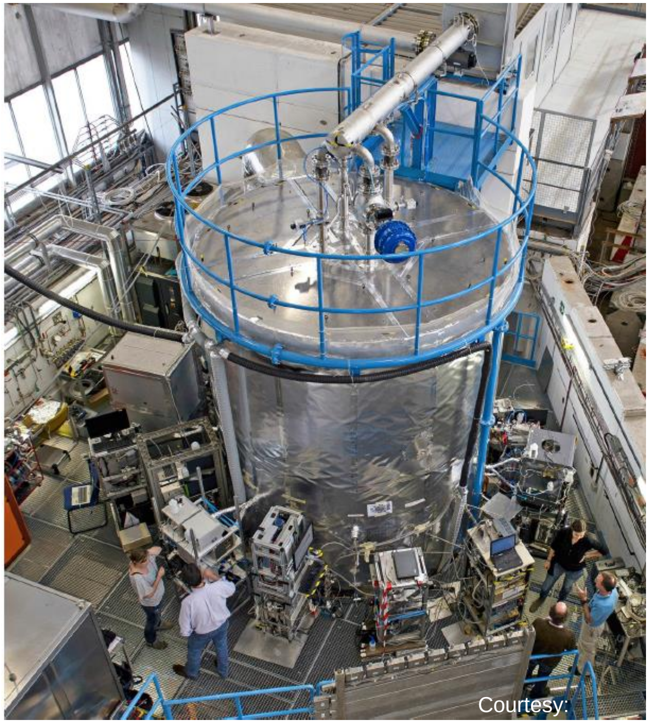


The East Area Beams



Experiments: cloud

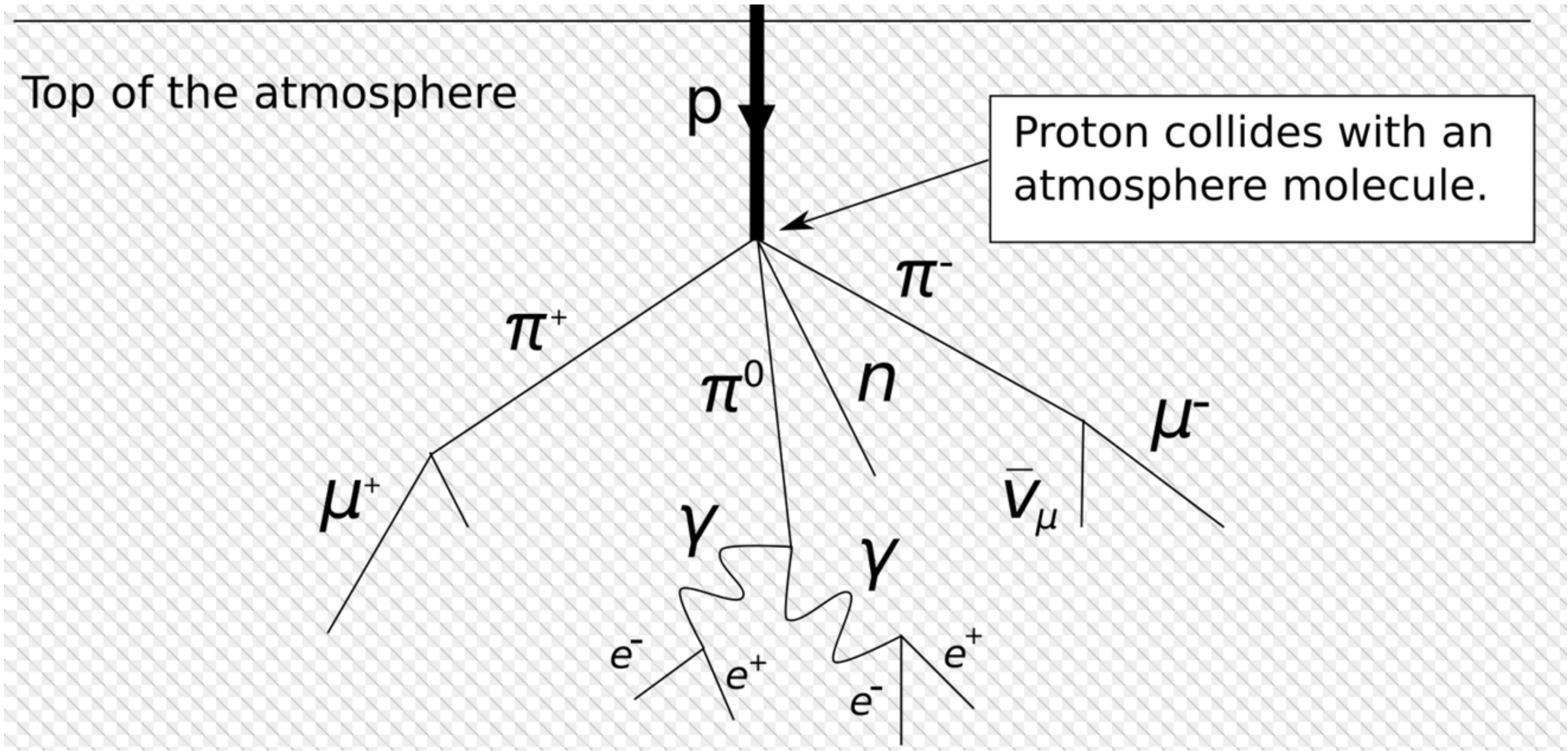
- Studies the influence of cosmic rays to cloud formation
- Cloud expansion chamber set-up with extensive instrumentation (mass spectrometers, particle counters, etc.)
- Uses PS beam as first and only particle beam experiment to study atmospheric and climate science
- Spectacular results achieved (several publications in Nature and Science)



How do we produce a secondary beam?

Targets and particle production

- Principle taken from cosmic radiation
  - Primary proton beam initiating hadronic shower
  - Always followed by an electro-magnetic shower
  - Particles are produced at once in a large momentum range



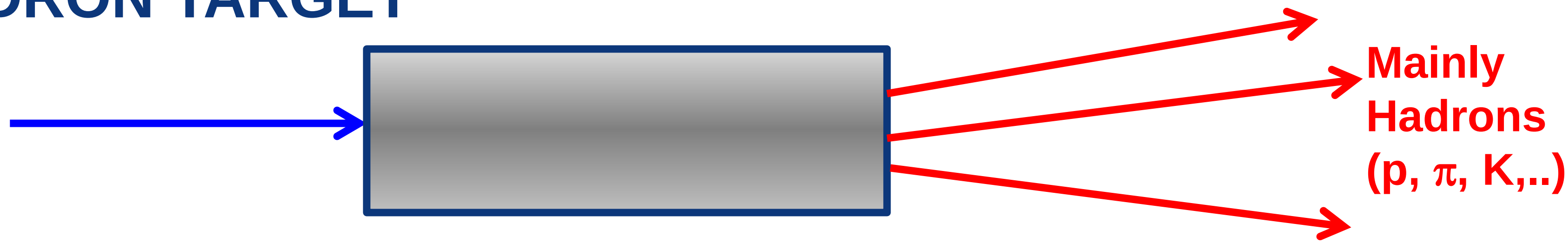
Targets and particle production

Category	Name	Symbol	Q	Mass [MeV/c²]	Mean life (τ) [s]	cτ [m]	Mean decay distance [m/GeV/c]	Decays
Leptons	Electron	e	$\pm e$	0.511	stable			
Leptons	Muon	μ	$\pm e$	105.6	2.2×10^{-6}	659.6	6.3×10^{3}	$\mu^+ \to e^+ \bar{\nu}_e \nu_\mu$ (100%)
Hadrons – Mesons	Pion	π	$\pm e$	139.6	2.6×10^{-8}	7.8	56.4	$\pi^+ \to \mu^+ \nu_\mu$ (100%)
Hadrons – Mesons	Kaon	K	$\pm e$	493.6	1.23×10^{-8}	3.7	8.38	$K^+ \to \mu^+ \nu_\mu$ (63%) $\pi^0 e^+ \nu_e$ (5%) $\pi^0 \mu^+ \nu_\mu$ (3%) $\pi^+ \pi^0$ (...) (28.9%)
Hadrons – Mesons	Kaon	K^0	0	497.6	K^0_S: 8.9×10^{-11}	0.02	0.060	$K^0_S \to \pi^0 \pi^0$ (30.7%) $\pi^+\pi^-$ (69.2%)
Hadrons – Mesons	Kaon	K^0	0	497.6	K^0_L: 5.12×10^{-8}	15.34	34.4	$K^0_L \to \pi^\pm e^\mp \nu_e$ (40.5%) $\pi^\pm \mu^\mp \nu_\mu$ (27.0%) $3\pi^0$ (19.5%) $\pi^+\pi^-\pi^0$ (12.5%)
Hadrons – Baryons	Proton	p	$\pm e$	938	stable			
Hadrons – Baryons	Lambda	Λ	0	1115.6	2.63×10^{-10}	0.079	0.237*	$\Lambda^0 \to p\, \pi^-$ (63.9%)
Hadrons – Baryons	Sigma Hyperons	Σ^+	$+e$	1189.3	8.02×10^{-11}	0.024	0.068*	$\Sigma^+ \to p\, \pi^0$ (51.57%)
Hadrons – Baryons	Sigma Hyperons	Σ^-	$-e$	1197.4	1.48×10^{-10}	0.044	0.125*	$\Sigma^- \to n\, \pi^-$ (99.84%)

(*) for 10 GeV/c

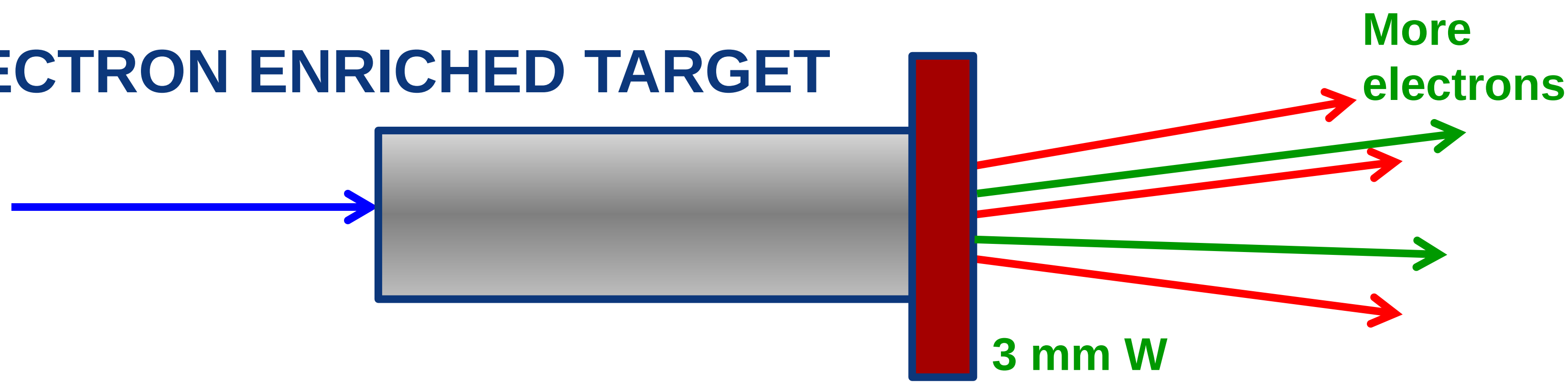
Targets and particle production

HADRON TARGET



100-200 mm AL or BE, i.e. Low-Z material
Up to 1 L_{int} and 0.5 Xo

ELECTRON ENRICHED TARGET



3 mm W
+1 X_o to convert photons

π^+, π^-, π^o □ $\gamma + \gamma$ □ $e^+ + e^-$

How do we build a beam line?

Beam lines

- Experiments and test beams require “clean” beams with high purity (one particle type) and small momentum spread
- Beam lines design (“optics”)
  1. Collect produced particles from target
  2. Select momentum
  3. Select particle type
  4. Transport beam to experiment
  5. Select beam spot size for experiment

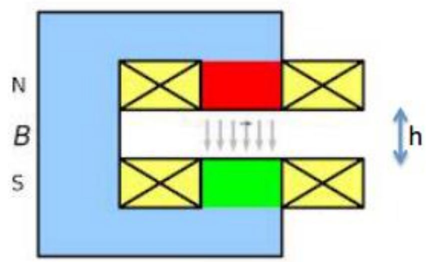
Secondary beam line - layout

Basic beam design

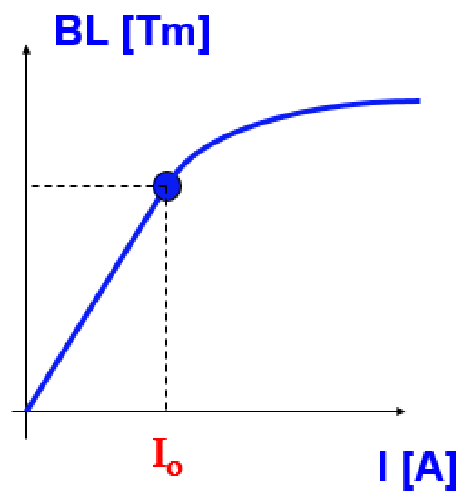
- Transport and momentum selection: bending magnets

Dipole electro-magnets:

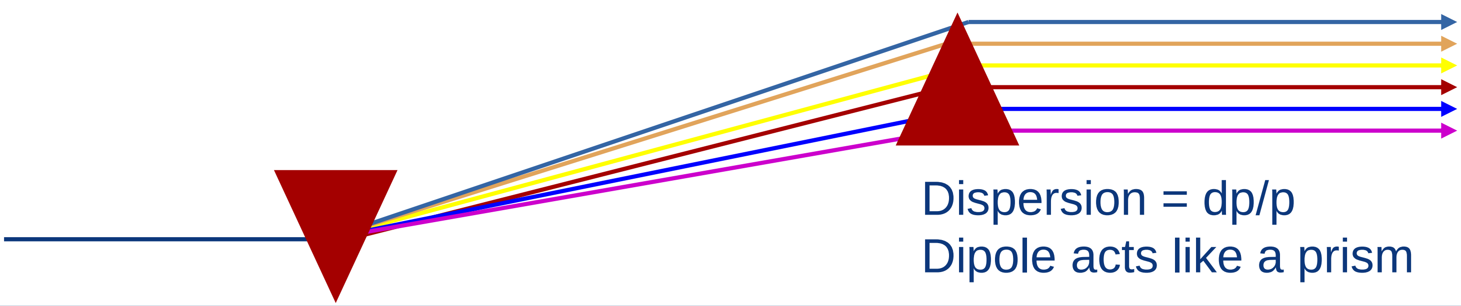
$$\boxed{\vec{F} = q \cdot \vec{v} \times \vec{B}}$$



$$B = \frac{\mu_0 n I}{h}$$



$$\theta\,[mrad] = \frac{299.79 Bl\ [T \cdot m]}{p[GeV]}$$



e.g.
1 GeV
2 GeV
3 GeV

Dispersion = dp/p
Dipole acts like a prism

Secondary beam line - layout

Basic beam design

- Transport and focus: Quadrupole Magnets

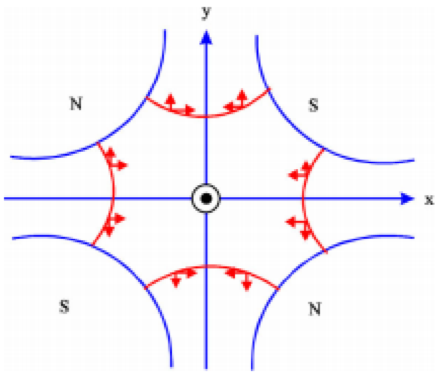
E.g. in the horizontal plane

$$F(x) = q \cdot v \cdot B(x)$$

We want a magnetic field that

$$B_y = g \cdot x \qquad B_x = g \cdot y$$

➔ Quadrupole magnet



The red arrows show the direction of the force on the particle

Gradient of quadrupole

$$g = \frac{2\mu_0 n I}{r^2} \left[\frac{T}{m}\right]$$

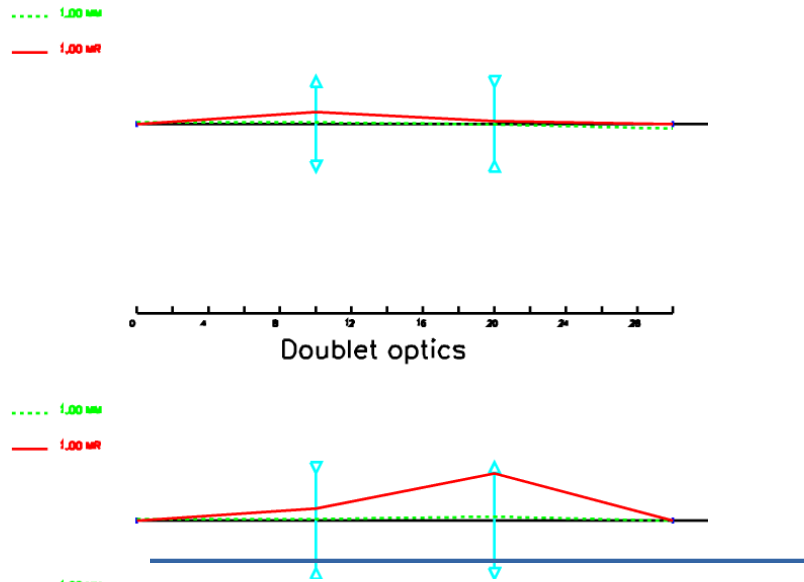
Normalized gradient, focusing strength

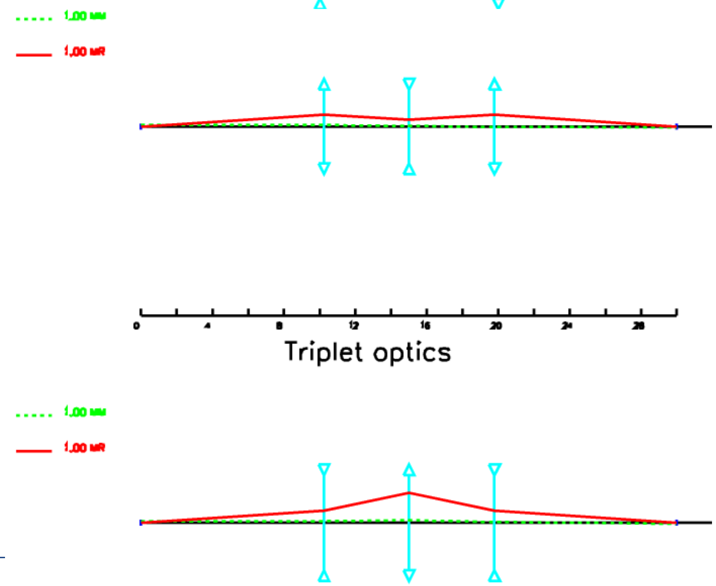
$$k = \frac{g}{p/e} [m^{-2}]$$

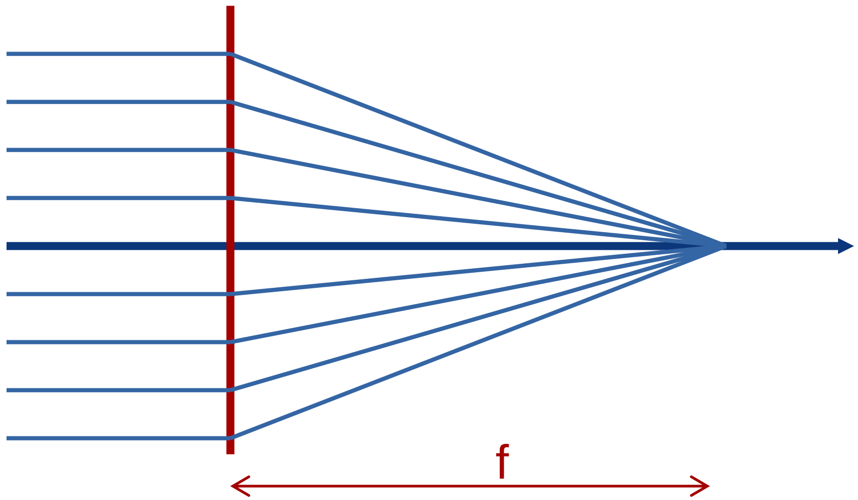
Secondary beam line - layout

Basic beam design

- Transport and focus: Quadrupoles
  - Like an optical lens
  - Difference: focusing in one plane and defocusing in the other plane at the same time
  - Use doublets or triplets for transport and focus



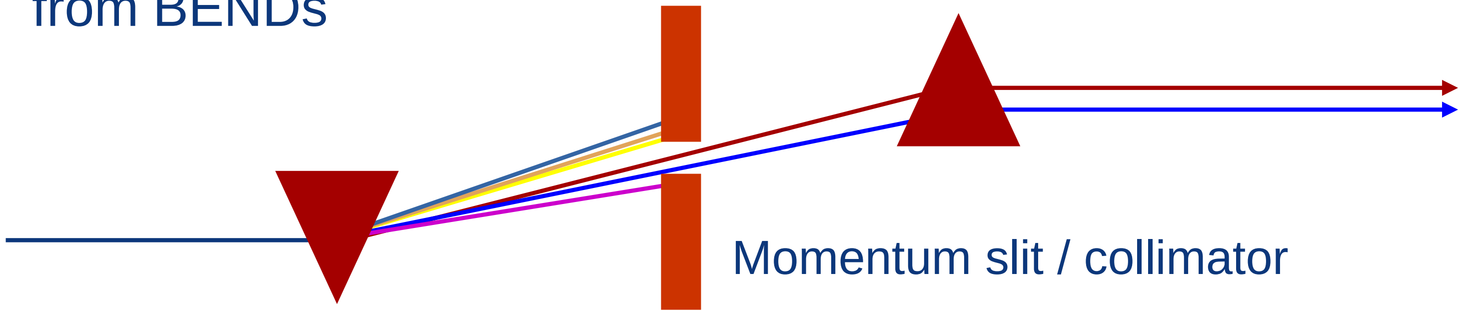




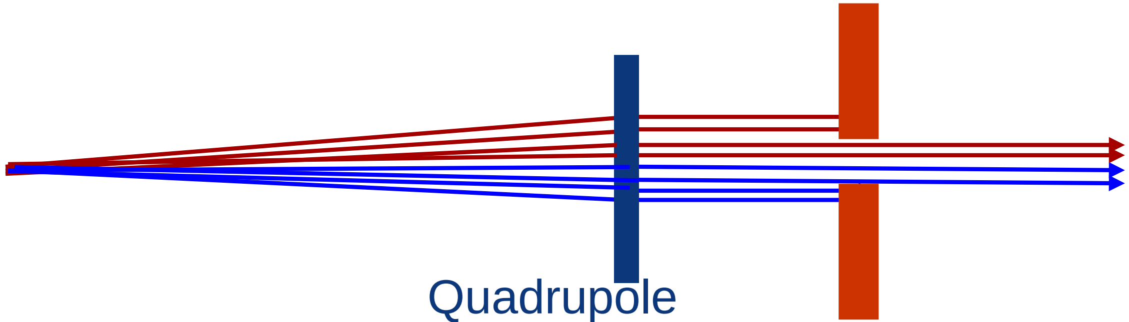
Secondary beam line - layout

Basic beam design

- Momentum selection and acceptance: collimators
  - Select small momentum band in combination with dispersion from BENDs

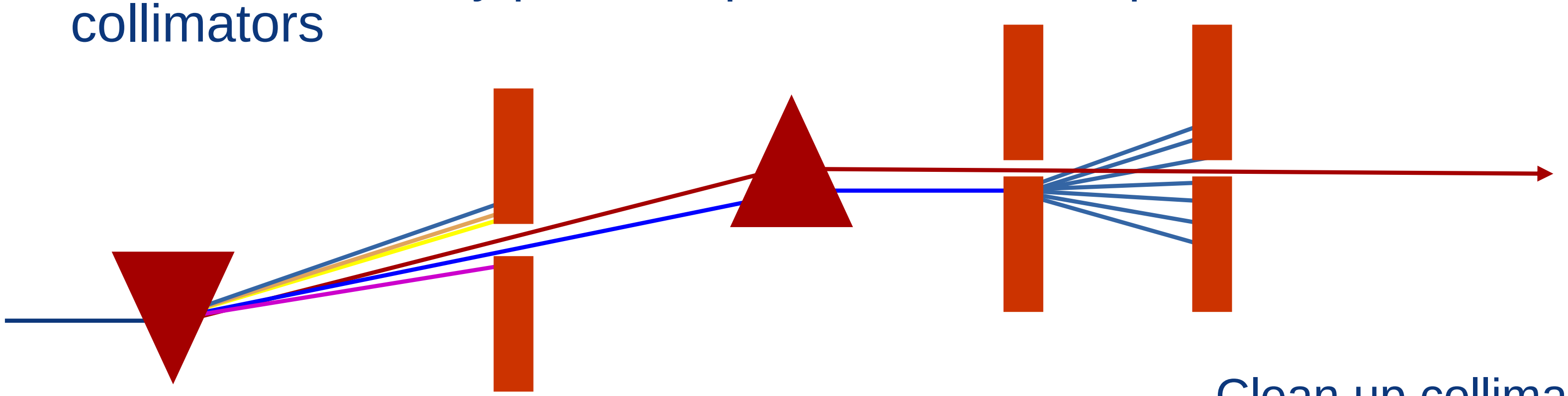


  - Acceptance collimators
    - Select beam size and beam rate



Secondary beam line - layout

- Clean up collimators
  - Absorb secondary particles produced in acceptance collimators



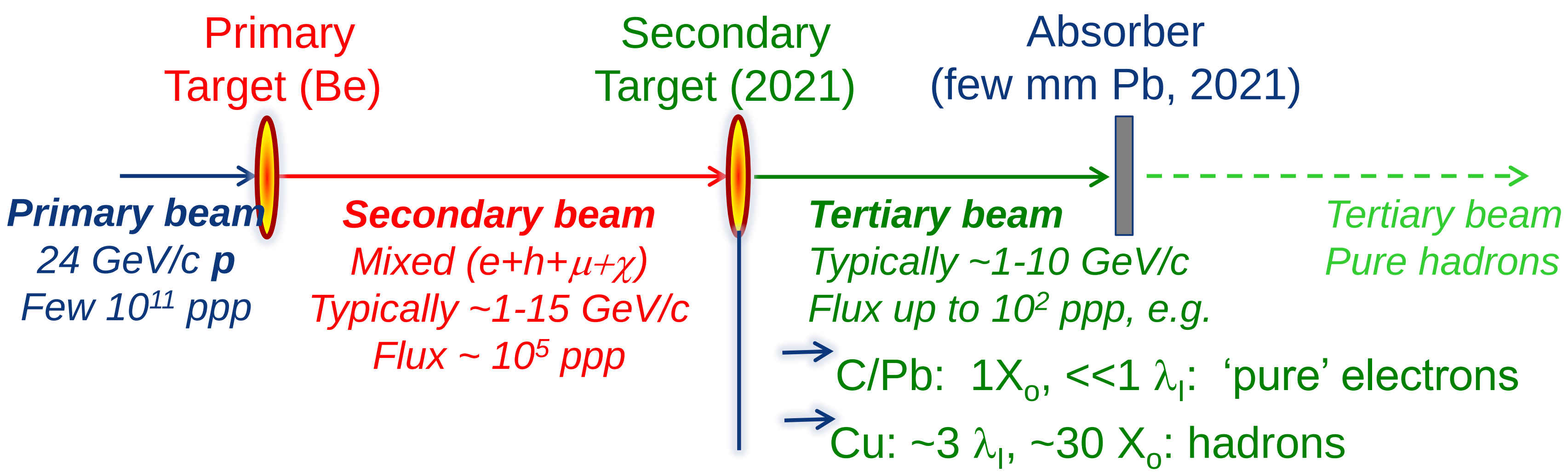
Clean up collimator

- TAX (Target attenuator, only North Area)
  - Define initial acceptance of the beam line

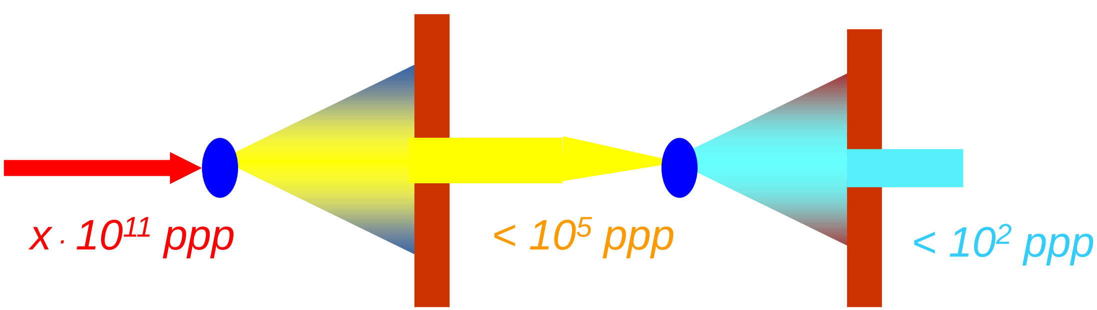
Secondary beam line - layout

Basic beam design

- Selection of particle types

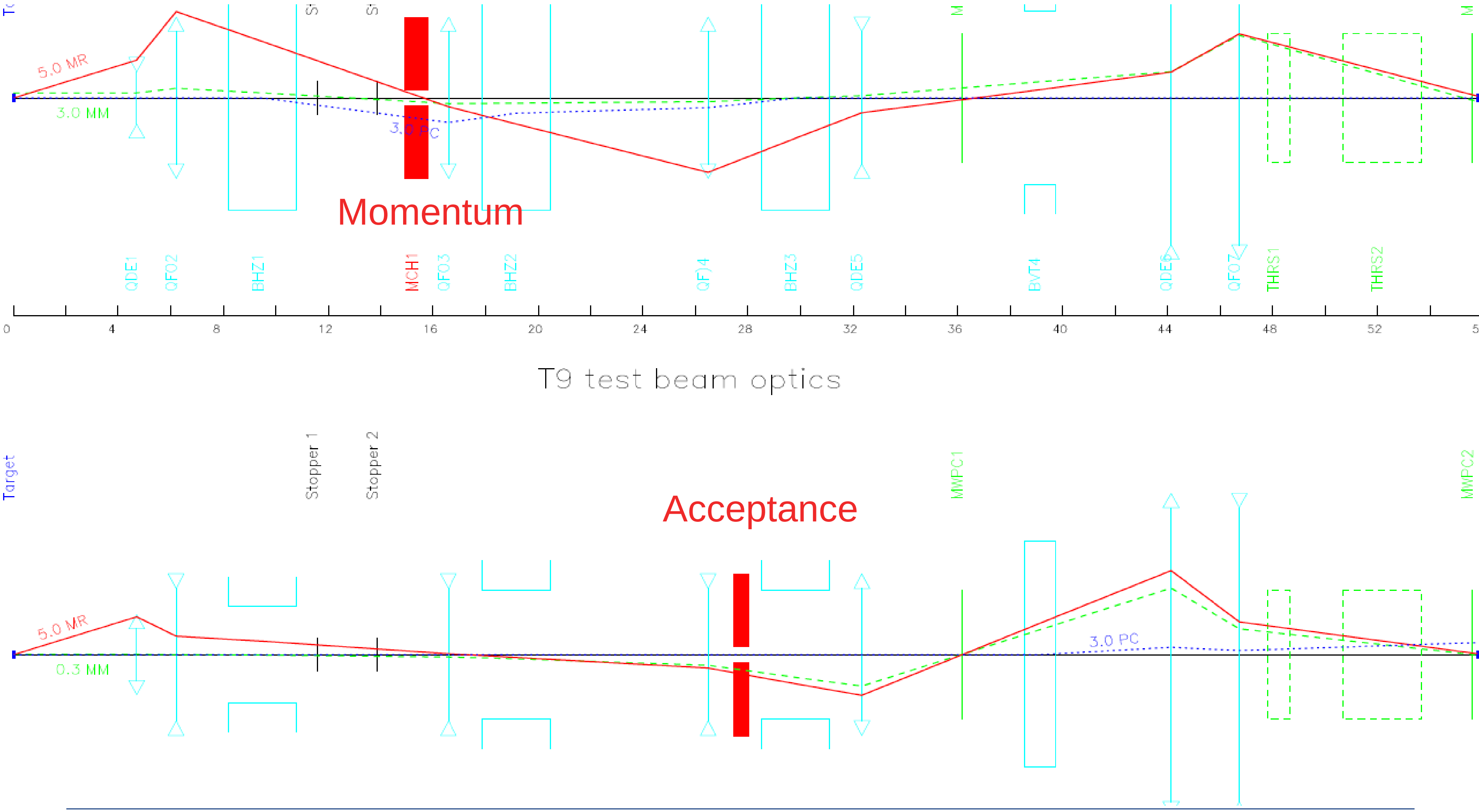


- Intensities



Secondary beam line - layout

Finalised optics of a beam line (T9)



The East Area Beams

The T9, T10 and T11 beam lines are mixed beams.

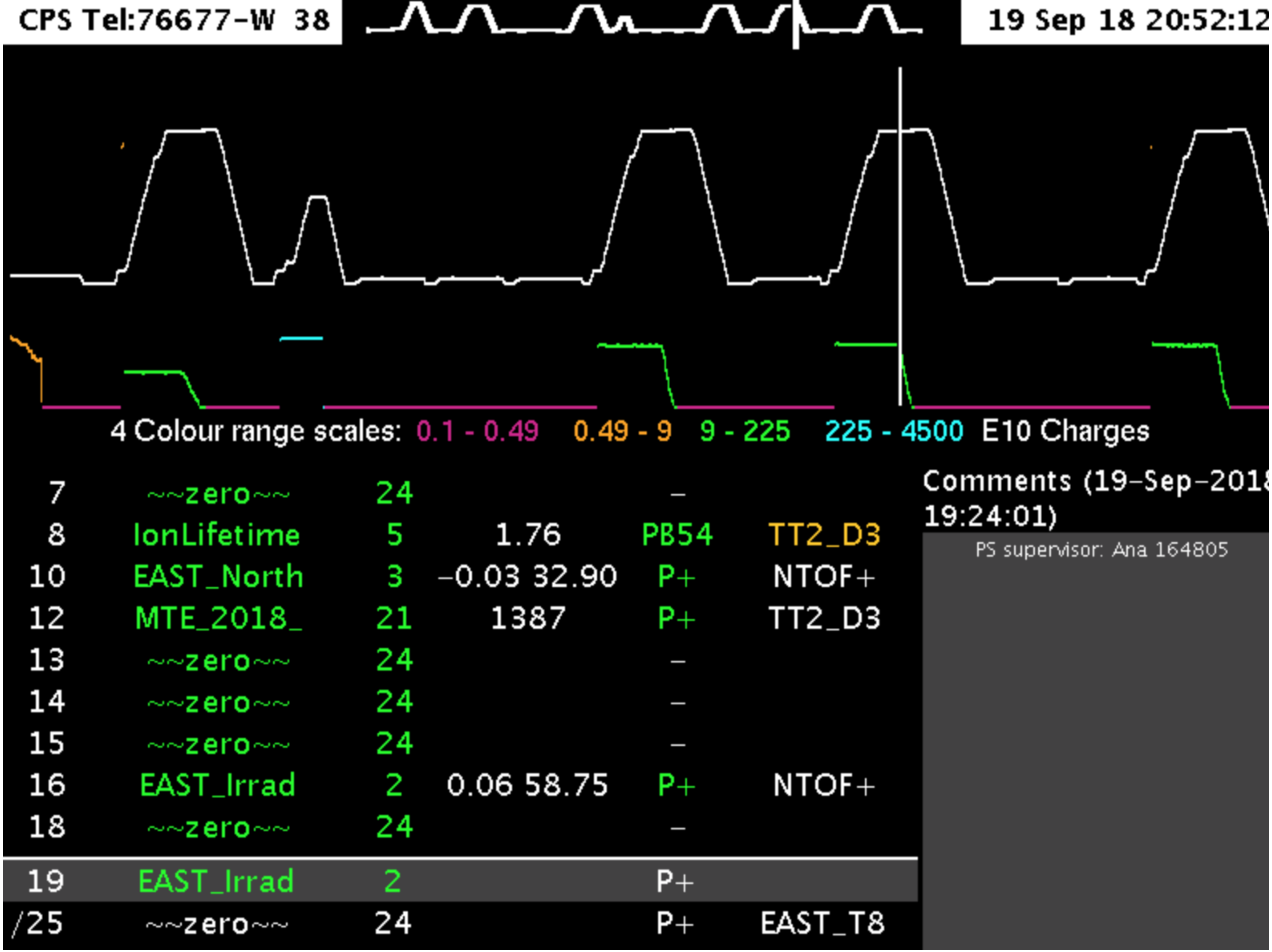
Their maximum intensity is 10^6 per EAST_NORTH cycle.

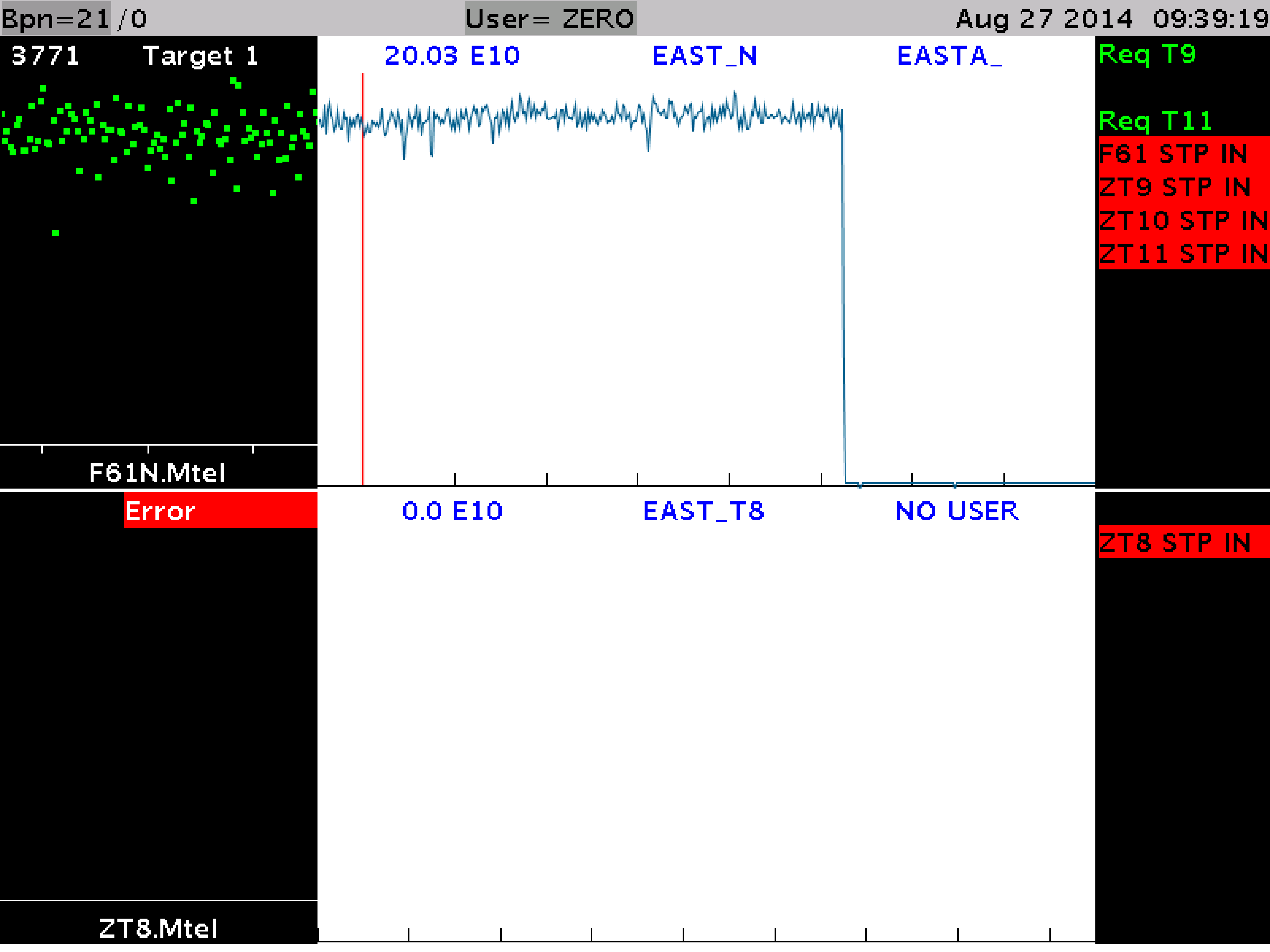
Both T9 and T10 beams are served from a common target, together also with the T11 beam for CLOUD.

The flat top is 0.4 seconds.

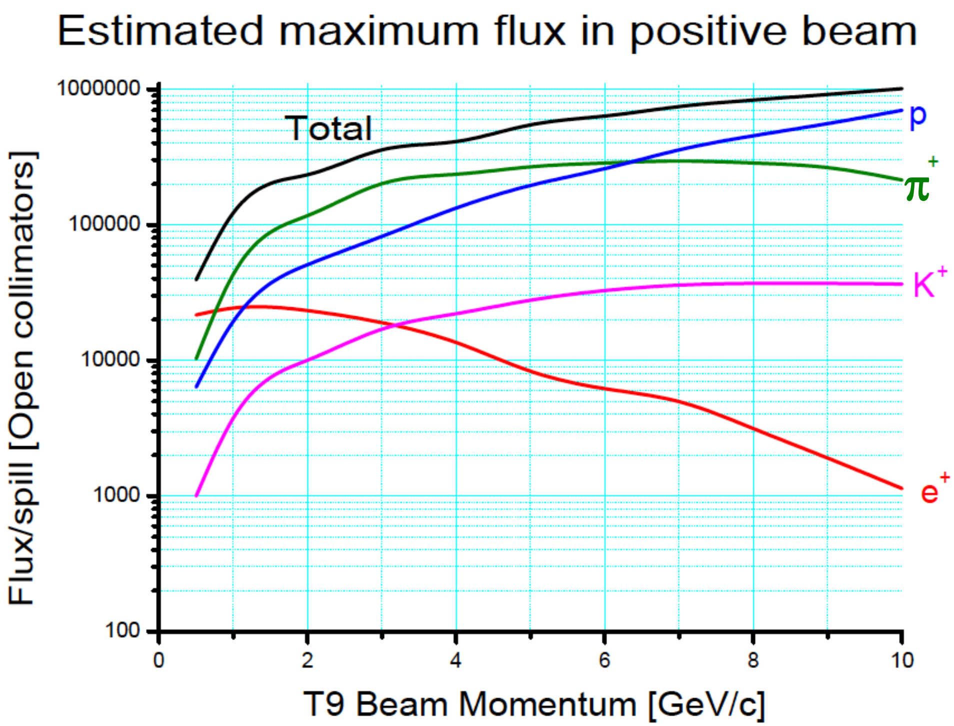
The number of EAST_NORTH cycles is normally 3 per super-cycle of 21.6 seconds.

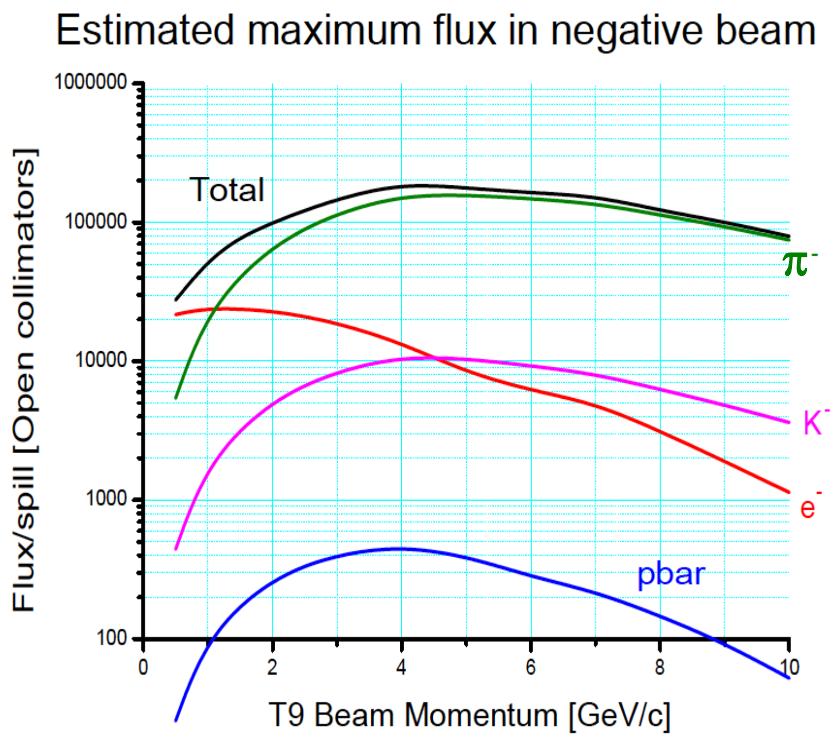
Parameter	T9
Maximum momentum (GeV/c)	12
Production angle (mrad)	0
Beam length to ref. focus (m)	55.8
Beam height above floor (m)	2.50
Ang.acceptance Horizotal (mrad) Vertical (mrad)	±4.8 ±5.8
Acc. Solid angle (μsterad)	87
Theor. momentum resol. (%)	0.24
Max. momentum band (%)	±10
Magnification at reference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


CPS Tel:76677-W 38
19 Sep 18 20:52:12
4 Colour range scales: 0.1 - 0.49 0.49 - 9 9 - 225 225 - 4500 E10 Charges
7 ~~zero~~ 24 -
8 IonLifetime 5 1.76 PB54 TT2_D3
10 EAST_North 3 -0.03 32.90 P+ NTOF+
12 MTE_2018_ 21 1387 P+ TT2_D3
13 ~~zero~~ 24 -
14 ~~zero~~ 24 -
15 ~~zero~~ 24 -
16 EAST_Irrad 2 0.06 58.75 P+ NTOF+
18 ~~zero~~ 24 -
19 EAST_Irrad 2 P+
/25 ~~zero~~ 24 P+ EAST_T8
Comments (19-Sep-2018
19:24:01)
PS supervisor: Ana 164805


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

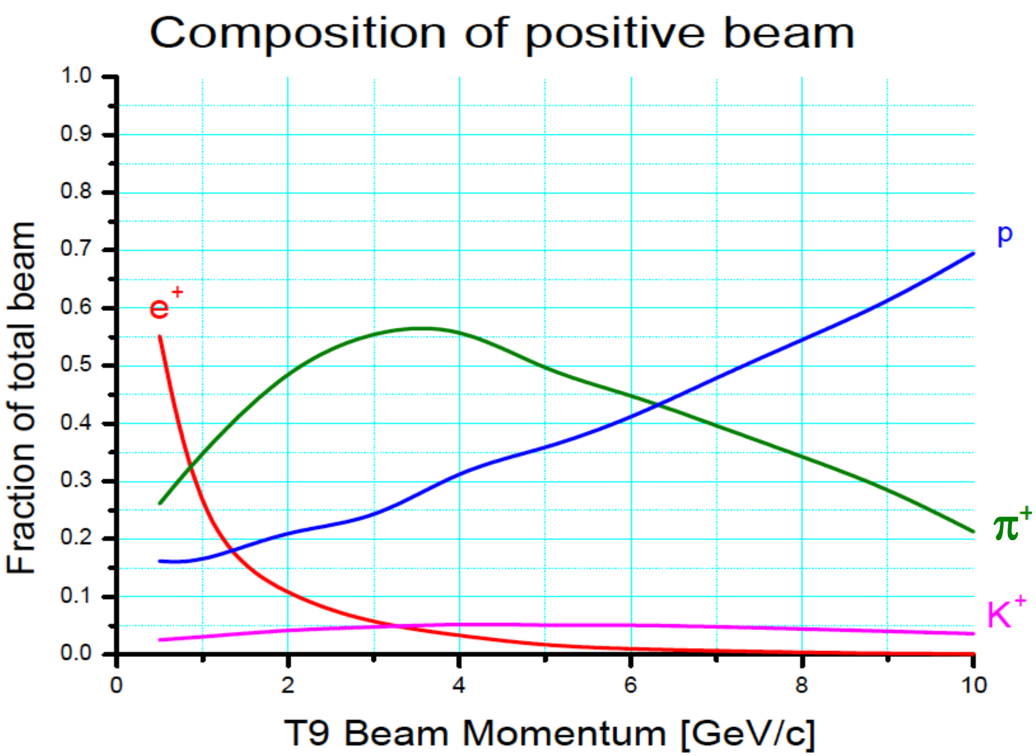
Beam rates

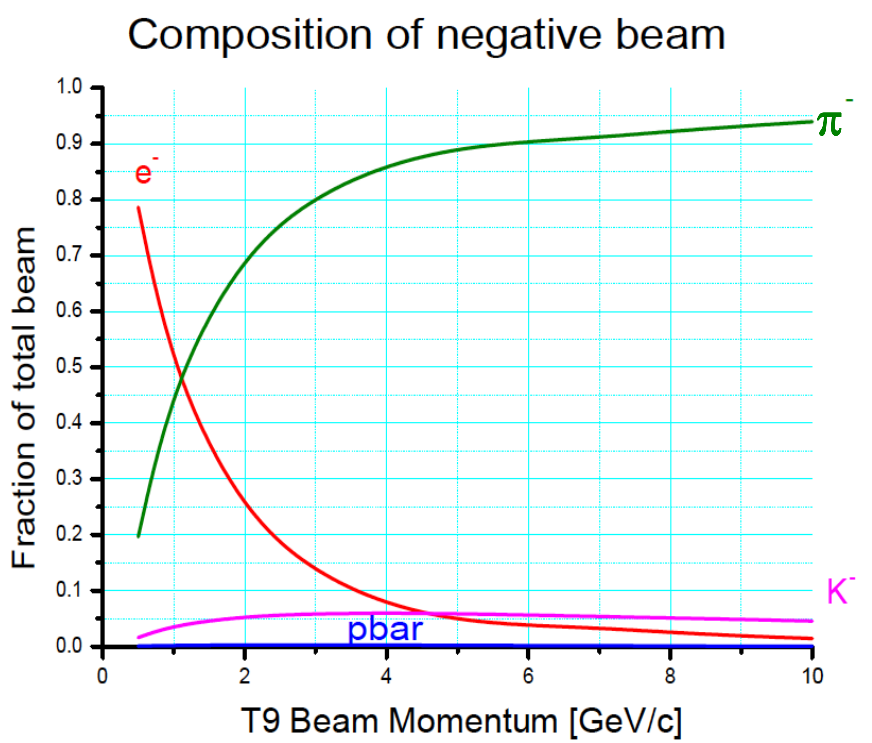




For wide open collimators, i.e. $dp/p \approx \pm 7.5\%$

Beam composition



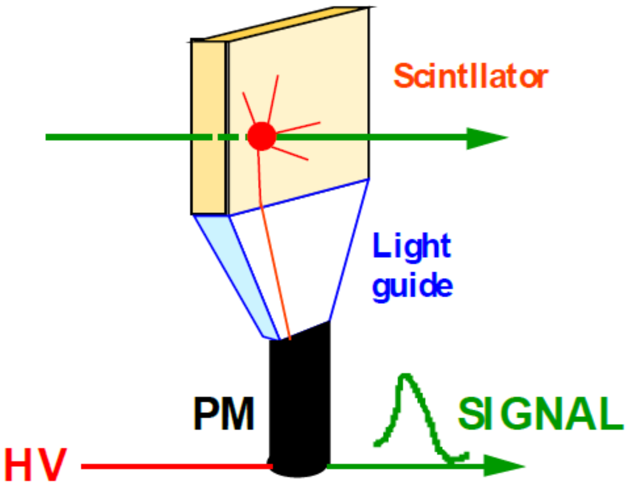


With electron enriched target (otherwise $e^{\pm}$ strongly reduced)

How do we see the beam?

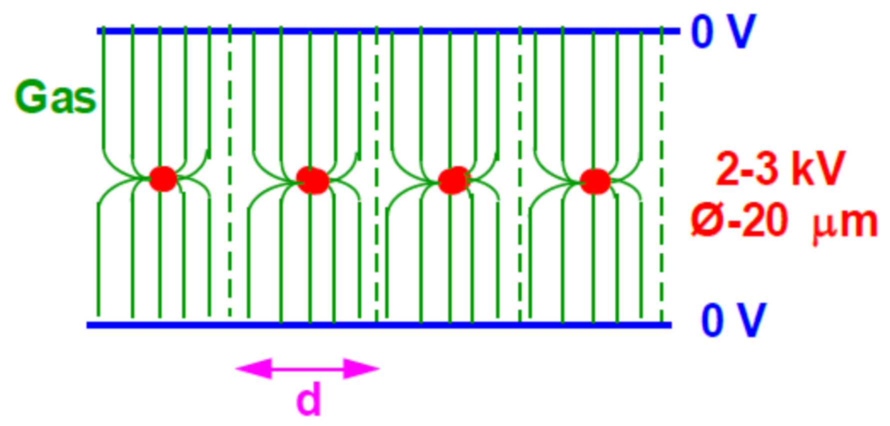
Secondary beam line - Instrumentation

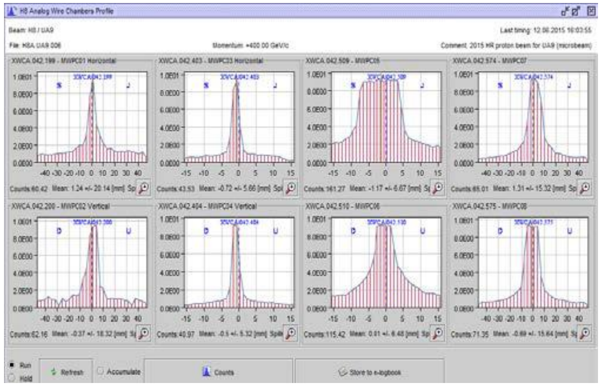
- Scintillating Counter
  - Charged particles produce light in scintillator
  - Light collected and transported by light guide
  - Coupled to photo multiplier tube (PM), light hits photocathode and produces electrons
  - Electrons are amplified within a high voltage cascade
  - Used to count particles in a range from a few particles up to rates of MHz
  - Different shapes and sizes: Some can scan through a beam, other count the total rate

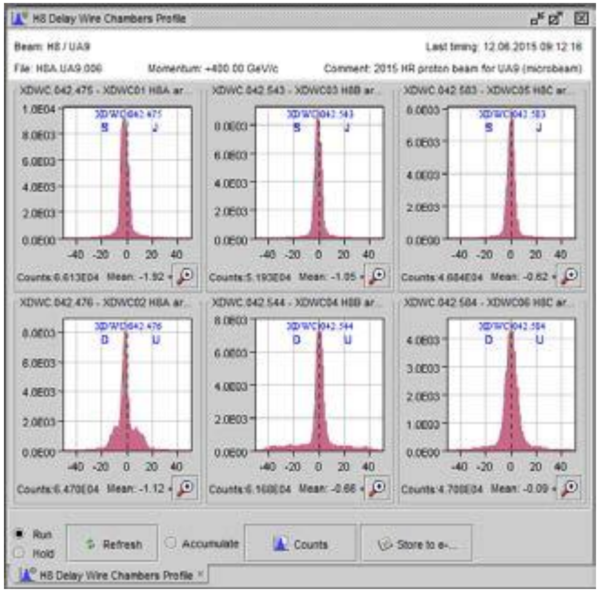


Secondary beam line - Instrumentation

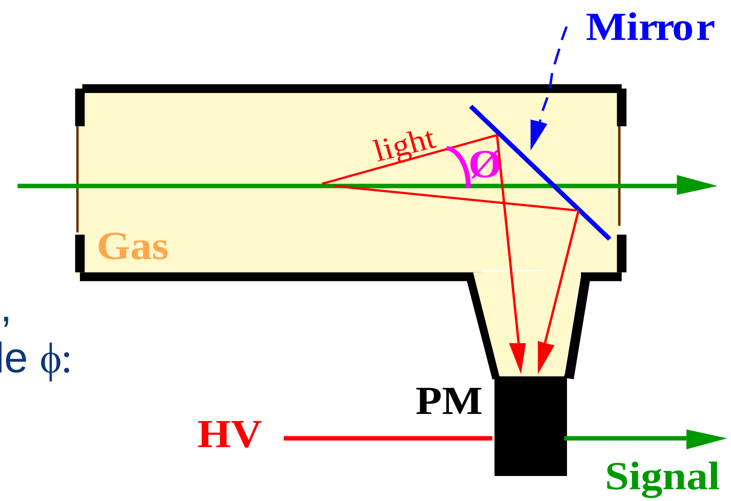
- Wire Chambers
  - Ionisation in gas from passing charged particles
  - Gas electron amplification and drift towards positively charged wires
  - Two types used in beam lines
    - Analogue MWPC (integrating charges)
    - Delay MWPC (add information of scintillator for better resolution)







Secondary beam line - Instrumentation



- Threshold Cerenkov counters

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

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

light: $v/c = 1/n$

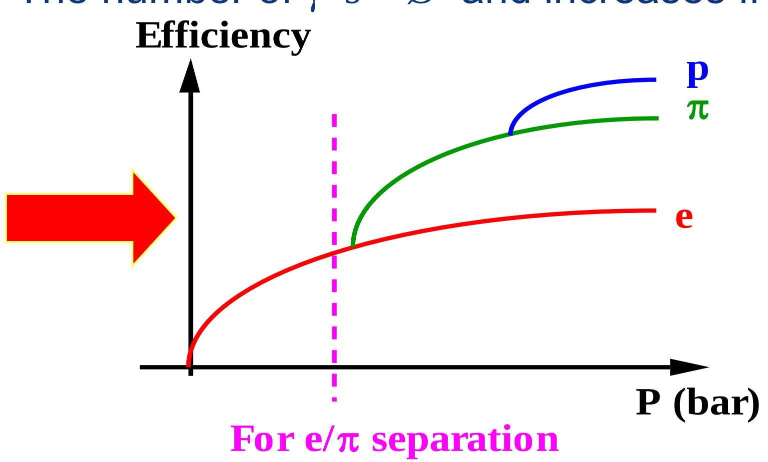
If a charged particle goes faster than light in a medium, it emits Cerenkov light in a cone with half-opening angle ϕ:

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

where k depends on the gas, P=pressure.

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

The number of γ's $\sim Ø^2$ 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.

Congratulations for having won this competition and good luck for a successful experiment!

Have a wonderful time at CERN !

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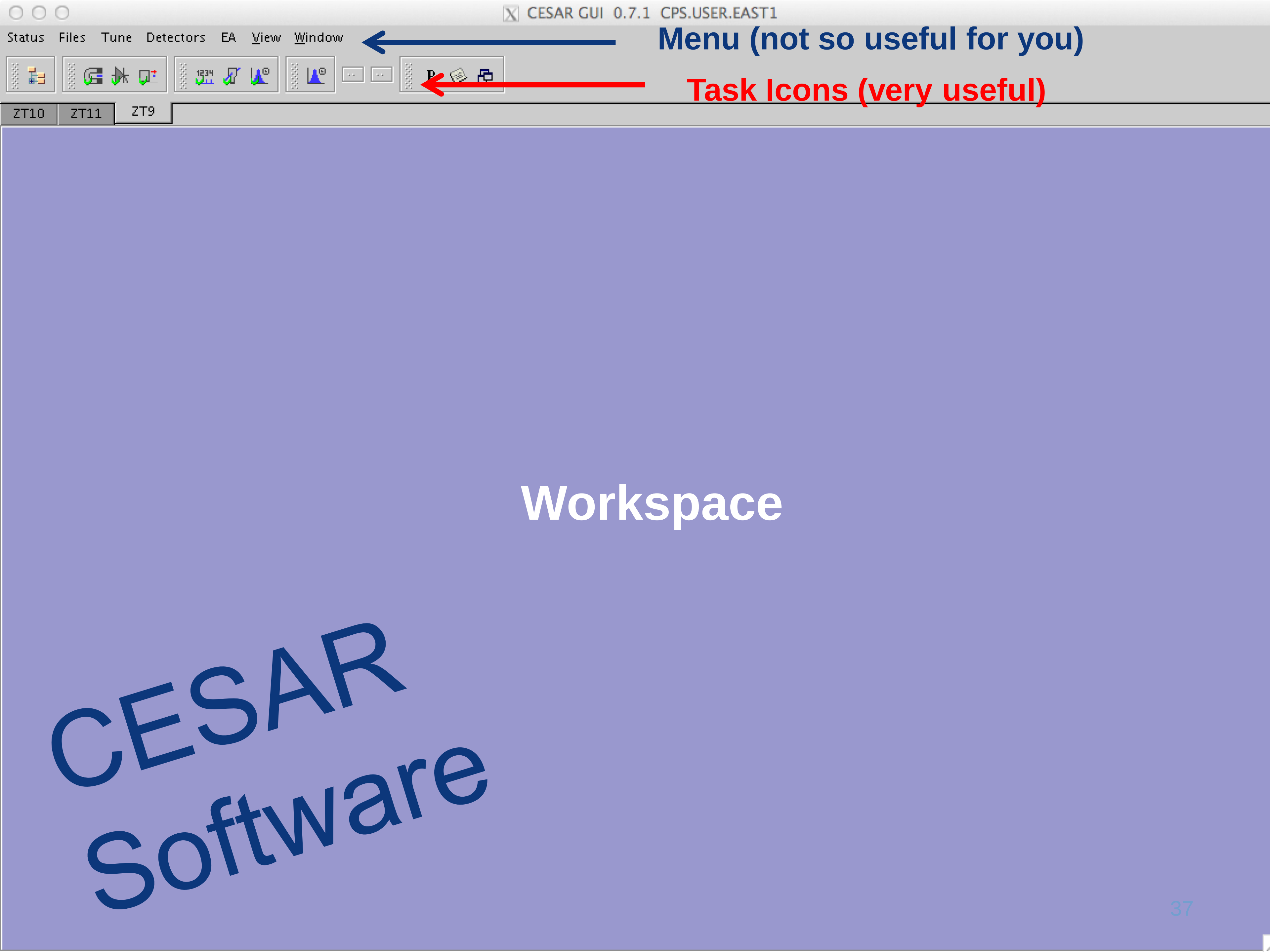
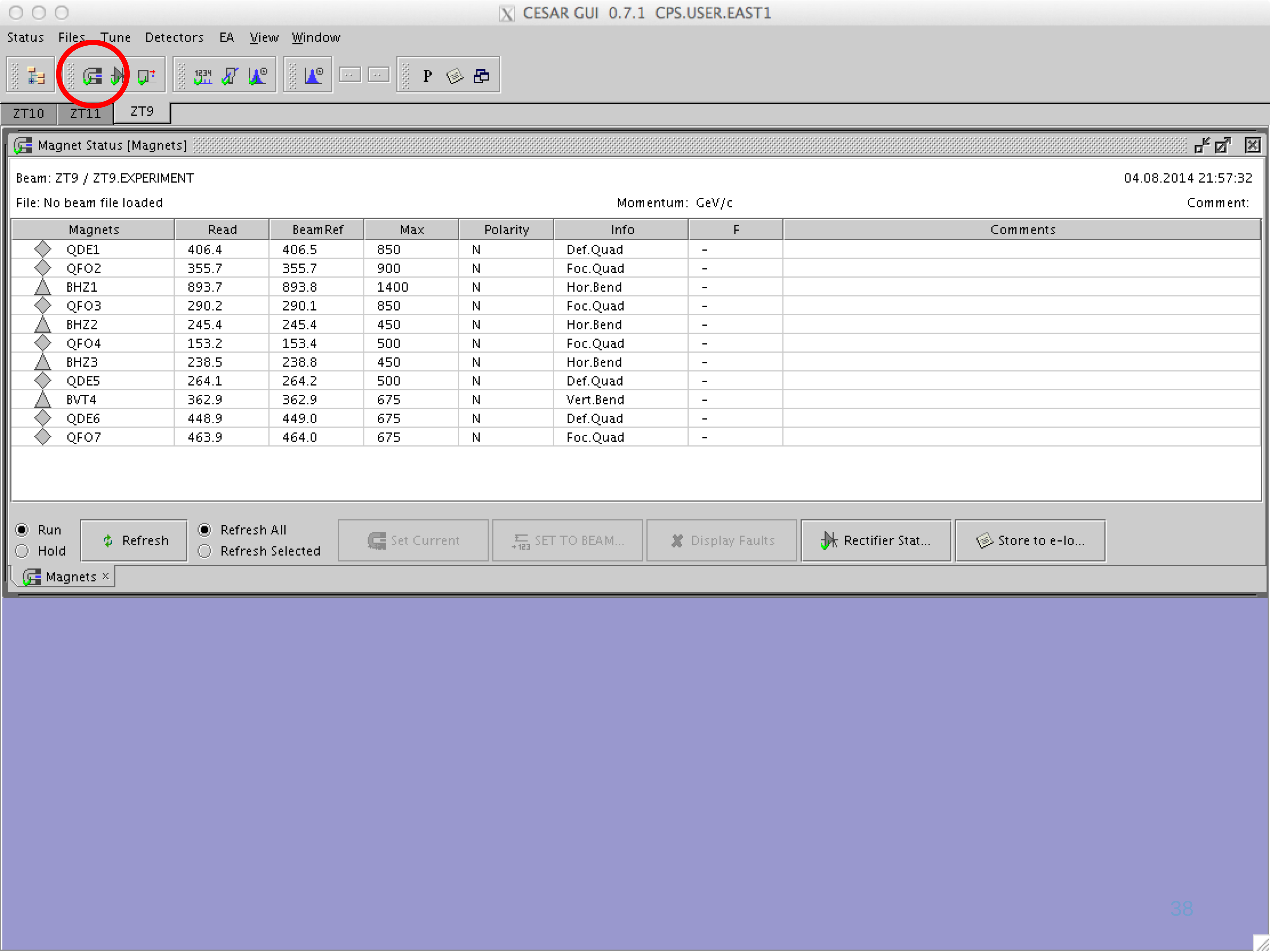
How do we control a beam line?


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 Software


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

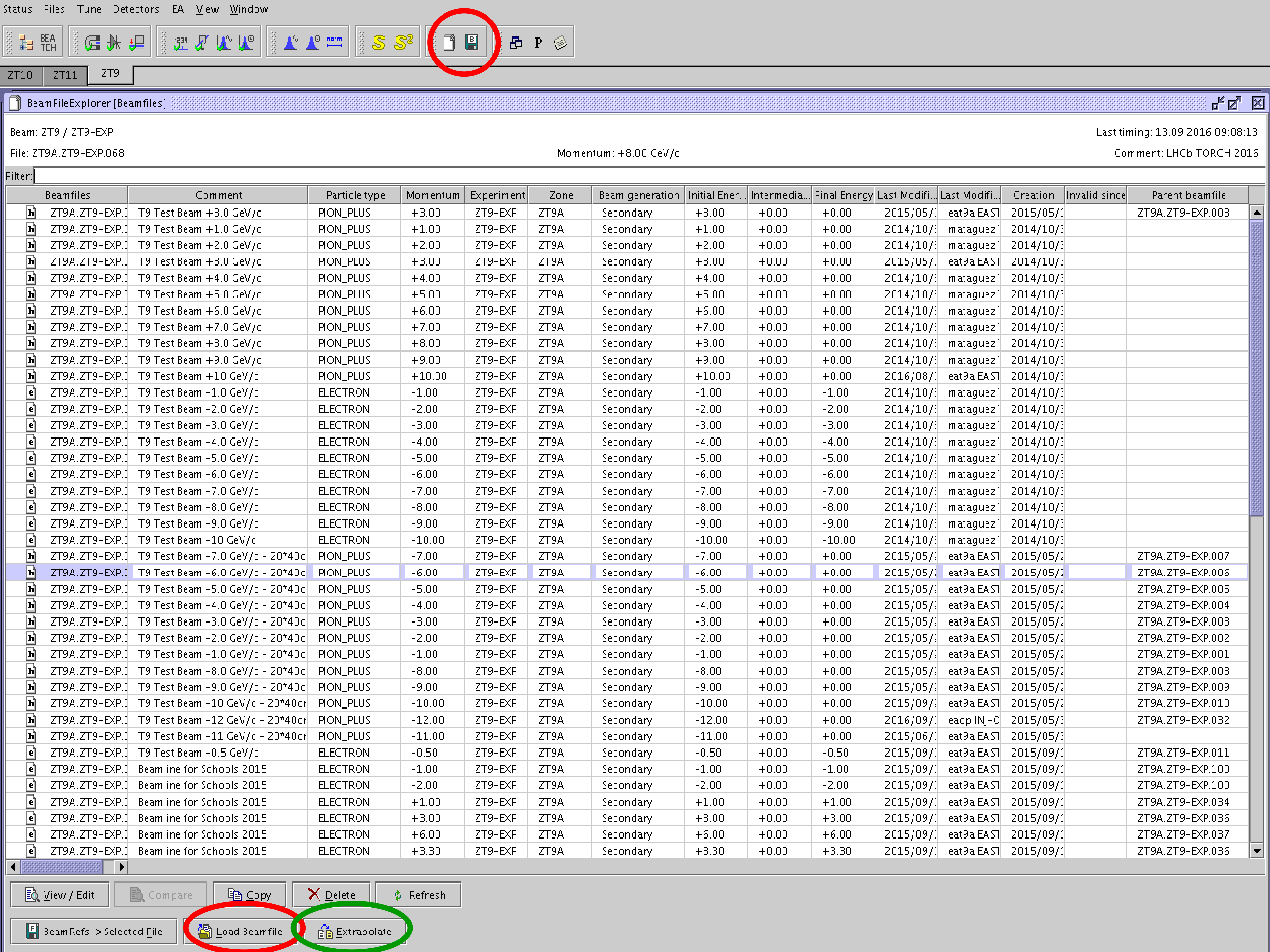
CURRENTS FOR T9 TEST BEAM, TUNED 28-07-2014

Focus 1 m behind XDWC

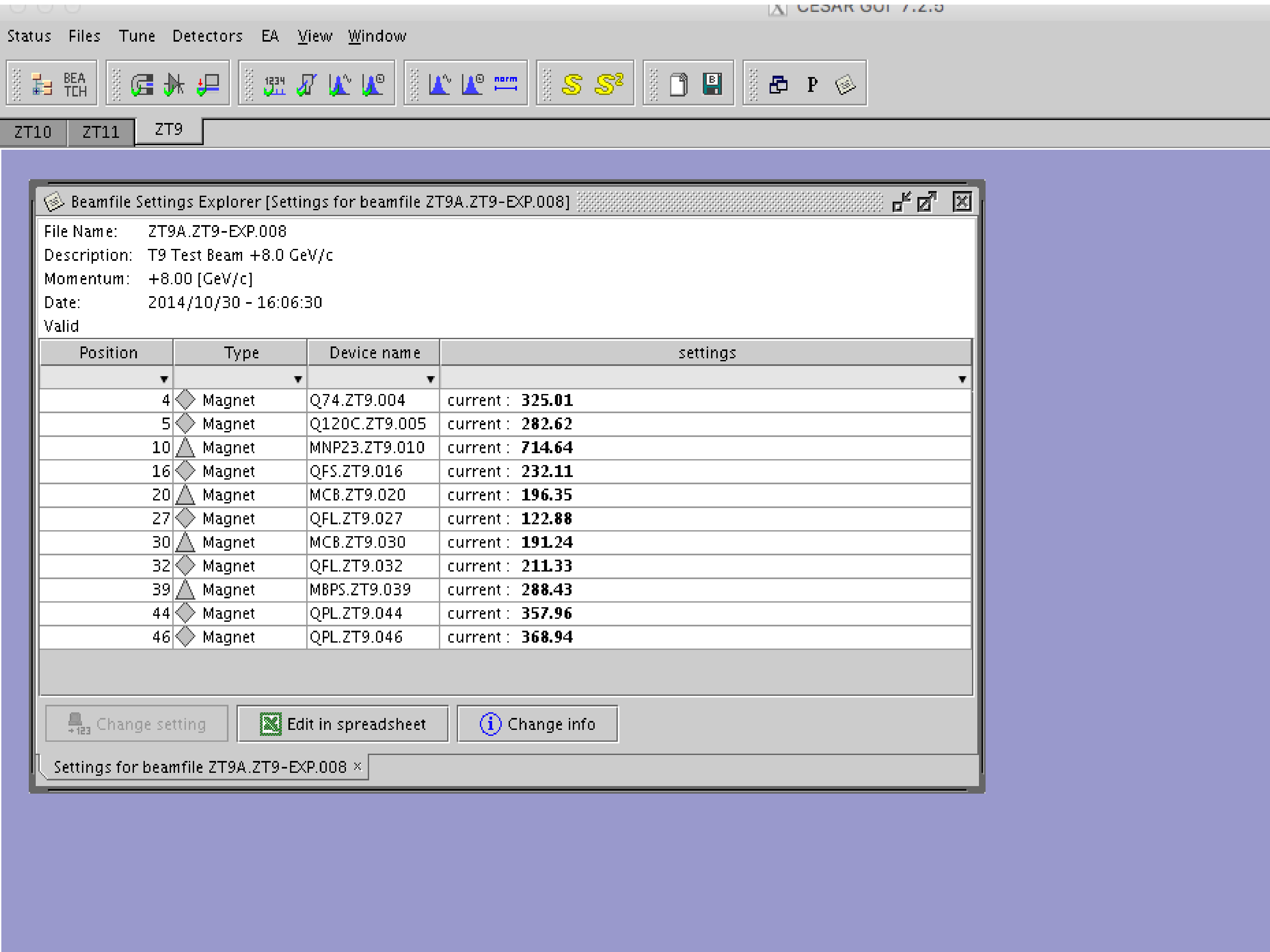
Momentum	QDE1	QFO2	BHZ1	QFO3	BHZ2	QFO4	BHZ3	QDE5	BVT1	QDE6	QFO7
1.00	40.66	38.07	89.28	29.01	24.54	15.36	23.91	26.42	35.83	44.74	46.12
1.50	60.99	55.22	133.92	43.52	36.82	23.04	35.86	39.62	53.76	67.12	69.18
2.00	81.32	72.00	178.56	58.03	49.09	30.72	47.81	52.83	71.69	89.49	92.24
2.50	101.65	88.77	223.21	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

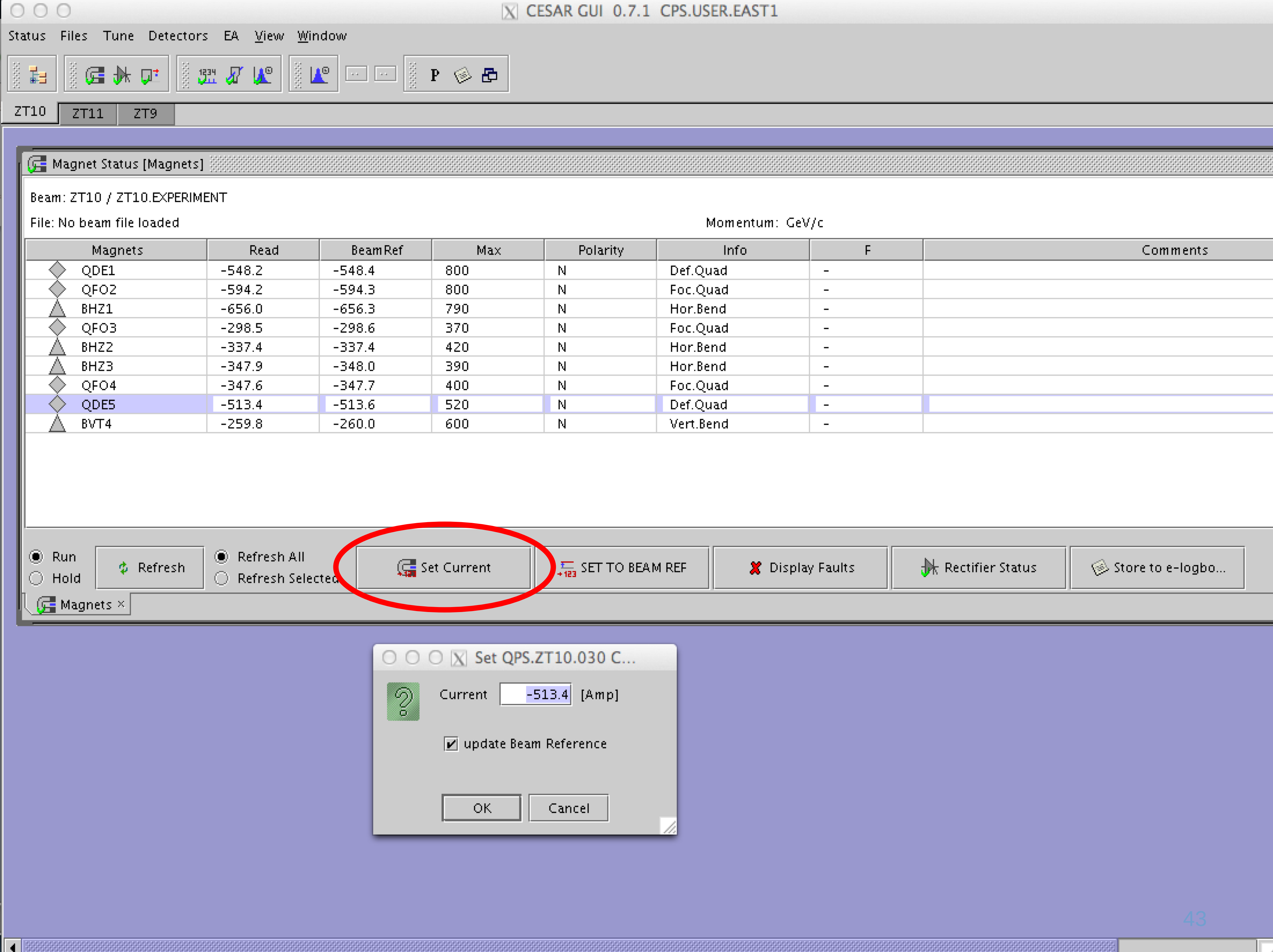
Momentum	Focus at XDWC		XDWC + 2m		XDWC + 4.5m		XDWC + 7m		XDWC + 9.5m		Parallel beam	
GeV/c	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7	QDE6	QFO7
1.00	45.57	47.99	44.00	44.18	42.38	40.93	41.24	38.88	40.30	37.12	36.09	32.11
1.50	68.36	71.98	65.99	66.27	63.57	61.40	61.86	58.32	60.45	55.68	54.14	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

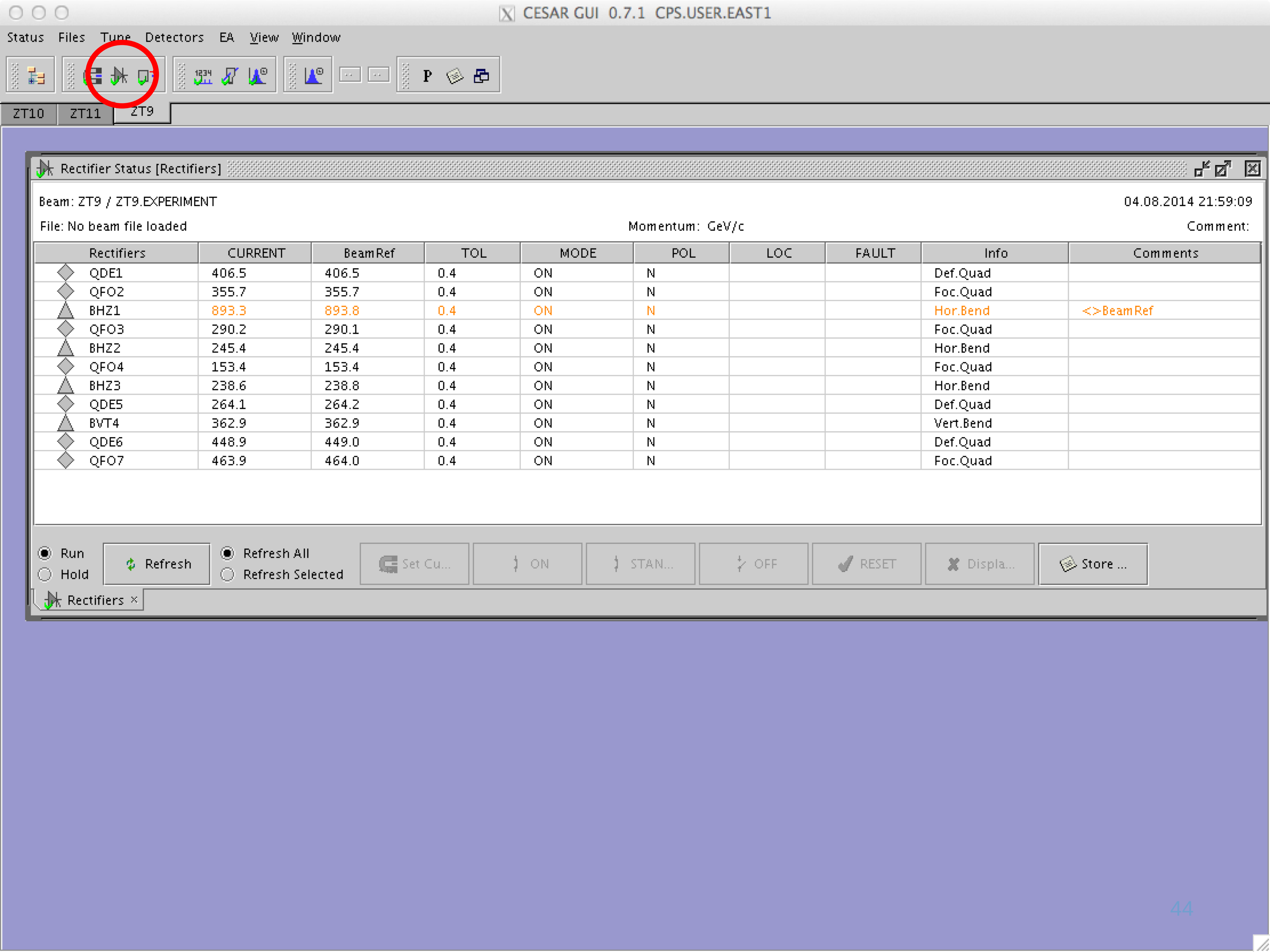


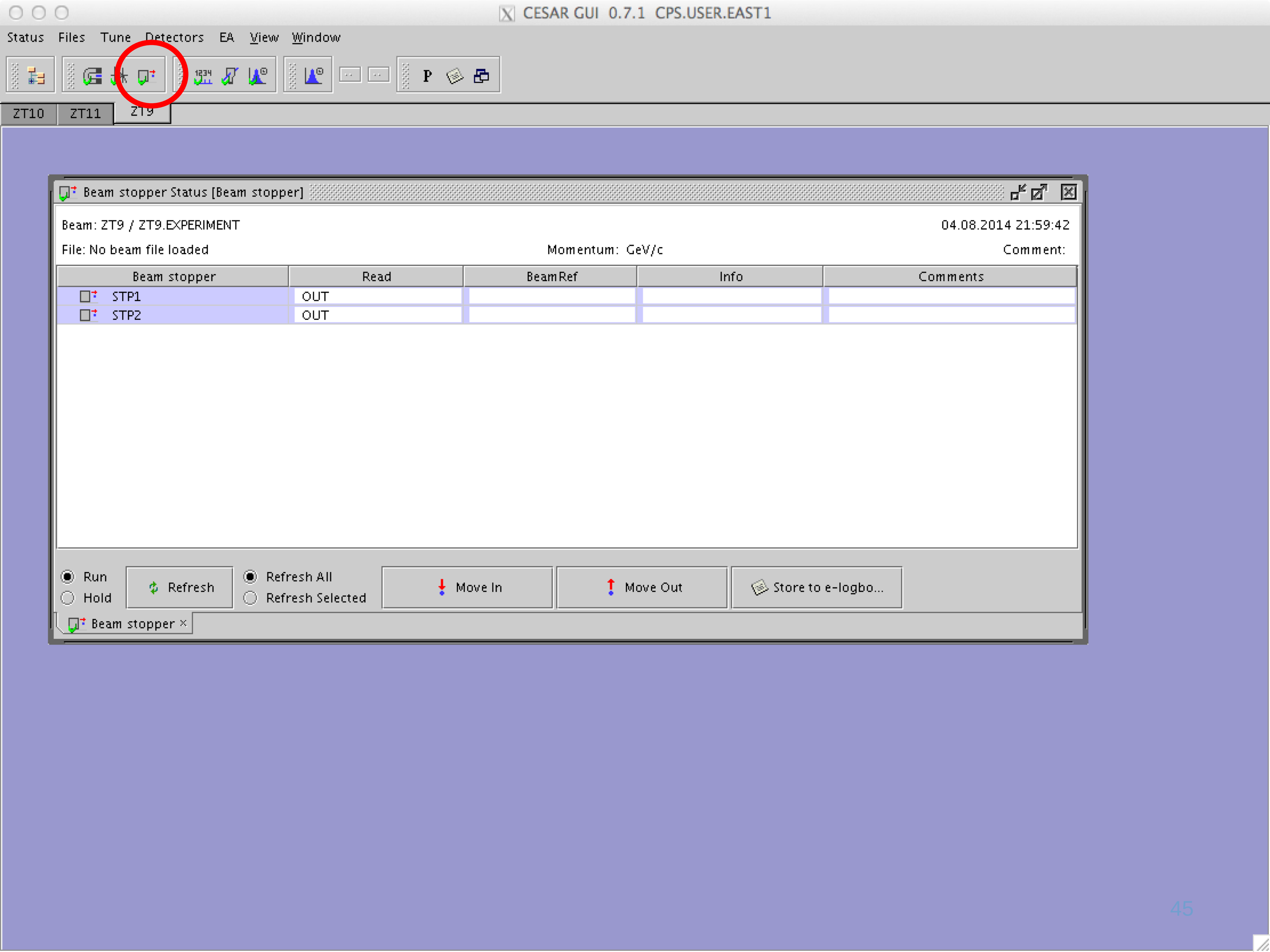
Beamfiles	Comment	Particle type	Momentum	Experiment	Zone	Beam generation	Initial Ener...	Intermedia...	Final Energy	Last Modifi...	Last Modifi...	Creation	Invalid since	Parent beamfile
ZT9A.ZT9-EXP.0	T9 Test Beam +3.0 GeV/c	PION_PLUS	+3.00	ZT9-EXP	ZT9A	Secondary	+3.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.003
ZT9A.ZT9-EXP.0	T9 Test Beam +1.0 GeV/c	PION_PLUS	+1.00	ZT9-EXP	ZT9A	Secondary	+1.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +2.0 GeV/c	PION_PLUS	+2.00	ZT9-EXP	ZT9A	Secondary	+2.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +3.0 GeV/c	PION_PLUS	+3.00	ZT9-EXP	ZT9A	Secondary	+3.00	+0.00	+0.00	2015/05/	eat9a EAST	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +4.0 GeV/c	PION_PLUS	+4.00	ZT9-EXP	ZT9A	Secondary	+4.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +5.0 GeV/c	PION_PLUS	+5.00	ZT9-EXP	ZT9A	Secondary	+5.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +6.0 GeV/c	PION_PLUS	+6.00	ZT9-EXP	ZT9A	Secondary	+6.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +7.0 GeV/c	PION_PLUS	+7.00	ZT9-EXP	ZT9A	Secondary	+7.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +8.0 GeV/c	PION_PLUS	+8.00	ZT9-EXP	ZT9A	Secondary	+8.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +9.0 GeV/c	PION_PLUS	+9.00	ZT9-EXP	ZT9A	Secondary	+9.00	+0.00	+0.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam +10 GeV/c	PION_PLUS	+10.00	ZT9-EXP	ZT9A	Secondary	+10.00	+0.00	+0.00	2016/08/	eat9a EAST	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -1.0 GeV/c	ELECTRON	-1.00	ZT9-EXP	ZT9A	Secondary	-1.00	+0.00	-1.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -2.0 GeV/c	ELECTRON	-2.00	ZT9-EXP	ZT9A	Secondary	-2.00	+0.00	-2.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -3.0 GeV/c	ELECTRON	-3.00	ZT9-EXP	ZT9A	Secondary	-3.00	+0.00	-3.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -4.0 GeV/c	ELECTRON	-4.00	ZT9-EXP	ZT9A	Secondary	-4.00	+0.00	-4.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -5.0 GeV/c	ELECTRON	-5.00	ZT9-EXP	ZT9A	Secondary	-5.00	+0.00	-5.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -6.0 GeV/c	ELECTRON	-6.00	ZT9-EXP	ZT9A	Secondary	-6.00	+0.00	-6.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -7.0 GeV/c	ELECTRON	-7.00	ZT9-EXP	ZT9A	Secondary	-7.00	+0.00	-7.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -8.0 GeV/c	ELECTRON	-8.00	ZT9-EXP	ZT9A	Secondary	-8.00	+0.00	-8.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -9.0 GeV/c	ELECTRON	-9.00	ZT9-EXP	ZT9A	Secondary	-9.00	+0.00	-9.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -10 GeV/c	ELECTRON	-10.00	ZT9-EXP	ZT9A	Secondary	-10.00	+0.00	-10.00	2014/10/	mataguez	2014/10/		
ZT9A.ZT9-EXP.0	T9 Test Beam -7.0 GeV/c - 20*40c	PION_PLUS	-7.00	ZT9-EXP	ZT9A	Secondary	-7.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.007
ZT9A.ZT9-EXP.0	T9 Test Beam -6.0 GeV/c - 20*40c	PION_PLUS	-6.00	ZT9-EXP	ZT9A	Secondary	-6.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.006
ZT9A.ZT9-EXP.0	T9 Test Beam -5.0 GeV/c - 20*40c	PION_PLUS	-5.00	ZT9-EXP	ZT9A	Secondary	-5.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.005
ZT9A.ZT9-EXP.0	T9 Test Beam -4.0 GeV/c - 20*40c	PION_PLUS	-4.00	ZT9-EXP	ZT9A	Secondary	-4.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.004
ZT9A.ZT9-EXP.0	T9 Test Beam -3.0 GeV/c - 20*40c	PION_PLUS	-3.00	ZT9-EXP	ZT9A	Secondary	-3.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.003
ZT9A.ZT9-EXP.0	T9 Test Beam -2.0 GeV/c - 20*40c	PION_PLUS	-2.00	ZT9-EXP	ZT9A	Secondary	-2.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.002
ZT9A.ZT9-EXP.0	T9 Test Beam -1.0 GeV/c - 20*40c	PION_PLUS	-1.00	ZT9-EXP	ZT9A	Secondary	-1.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.001
ZT9A.ZT9-EXP.0	T9 Test Beam -8.0 GeV/c - 20*40c	PION_PLUS	-8.00	ZT9-EXP	ZT9A	Secondary	-8.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.008
ZT9A.ZT9-EXP.0	T9 Test Beam -9.0 GeV/c - 20*40c	PION_PLUS	-9.00	ZT9-EXP	ZT9A	Secondary	-9.00	+0.00	+0.00	2015/05/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.009
ZT9A.ZT9-EXP.0	T9 Test Beam -10 GeV/c - 20*40cr	PION_PLUS	-10.00	ZT9-EXP	ZT9A	Secondary	-10.00	+0.00	+0.00	2015/09/	eat9a EAST	2015/05/		ZT9A.ZT9-EXP.010
ZT9A.ZT9-EXP.0	T9 Test Beam -12 GeV/c - 20*40cr	PION_PLUS	-12.00	ZT9-EXP	ZT9A	Secondary	-12.00	+0.00	+0.00	2016/09/	eaop INJ-C	2015/05/		ZT9A.ZT9-EXP.032
ZT9A.ZT9-EXP.0	T9 Test Beam -11 GeV/c - 20*40cr	PION_PLUS	-11.00	ZT9-EXP	ZT9A	Secondary	-11.00	+0.00	+0.00	2015/06/	eat9a EAST	2015/05/		
ZT9A.ZT9-EXP.0	T9 Test Beam -0.5 GeV/c	ELECTRON	-0.50	ZT9-EXP	ZT9A	Secondary	-0.50	+0.00	-0.50	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.011
ZT9A.ZT9-EXP.0	Beamline for Schools 2015	ELECTRON	-1.00	ZT9-EXP	ZT9A	Secondary	-1.00	+0.00	-1.00	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.100
ZT9A.ZT9-EXP.0	Beamline for Schools 2015	ELECTRON	-2.00	ZT9-EXP	ZT9A	Secondary	-2.00	+0.00	-2.00	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.100
ZT9A.ZT9-EXP.0	Beamline for Schools 2015	ELECTRON	+1.00	ZT9-EXP	ZT9A	Secondary	+1.00	+0.00	+1.00	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.034
ZT9A.ZT9-EXP.0	Beamline for Schools 2015	ELECTRON	+3.00	ZT9-EXP	ZT9A	Secondary	+3.00	+0.00	+3.00	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.036
ZT9A.ZT9-EXP.0	Beamline for Schools 2015	ELECTRON	+6.00	ZT9-EXP	ZT9A	Secondary	+6.00	+0.00	+6.00	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.037
ZT9A.ZT9-EXP.0	Beamline for Schools 2015	ELECTRON	+3.30	ZT9-EXP	ZT9A	Secondary	+3.30	+0.00	+3.30	2015/09/	eat9a EAST	2015/09/		ZT9A.ZT9-EXP.036

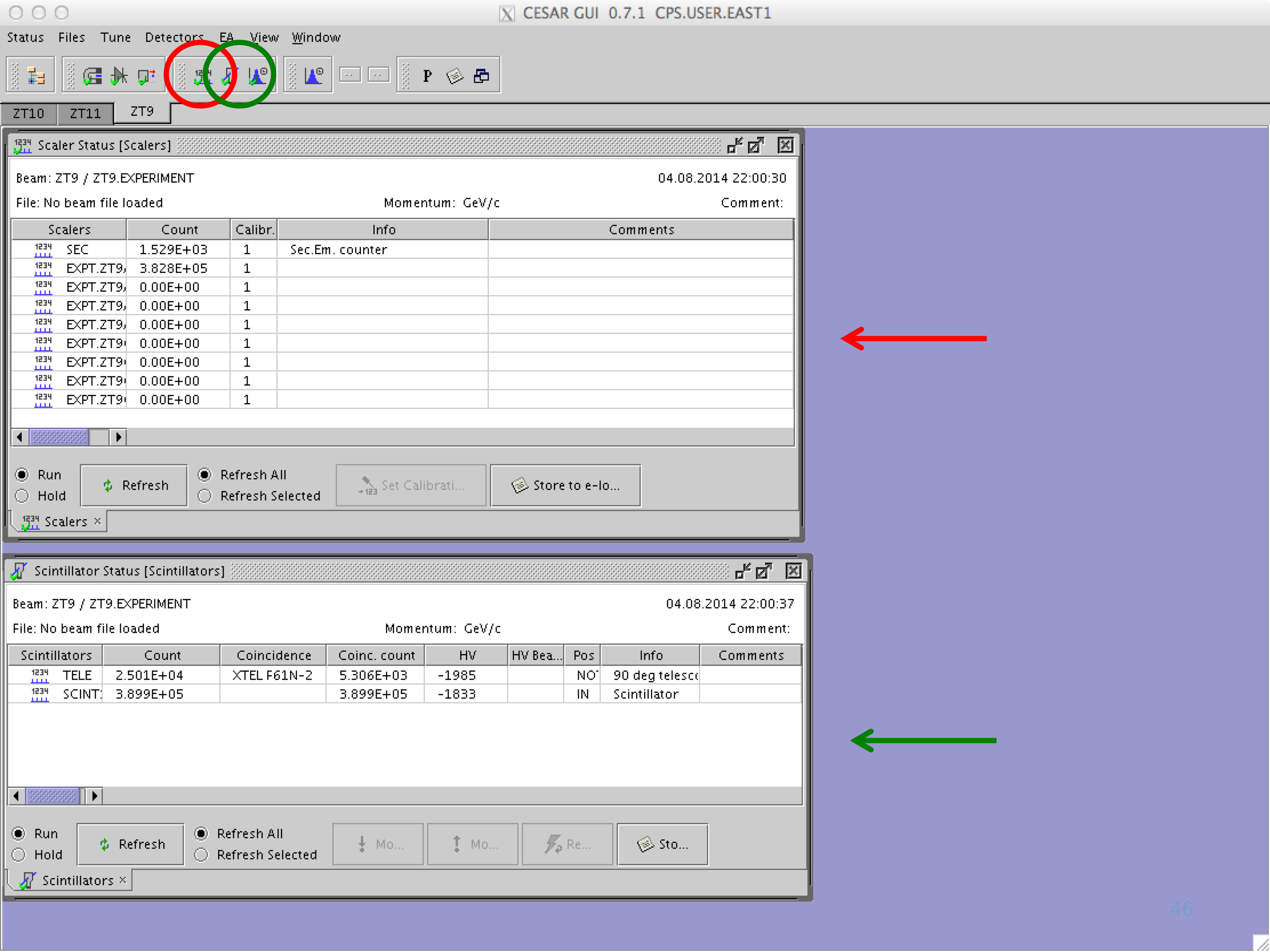


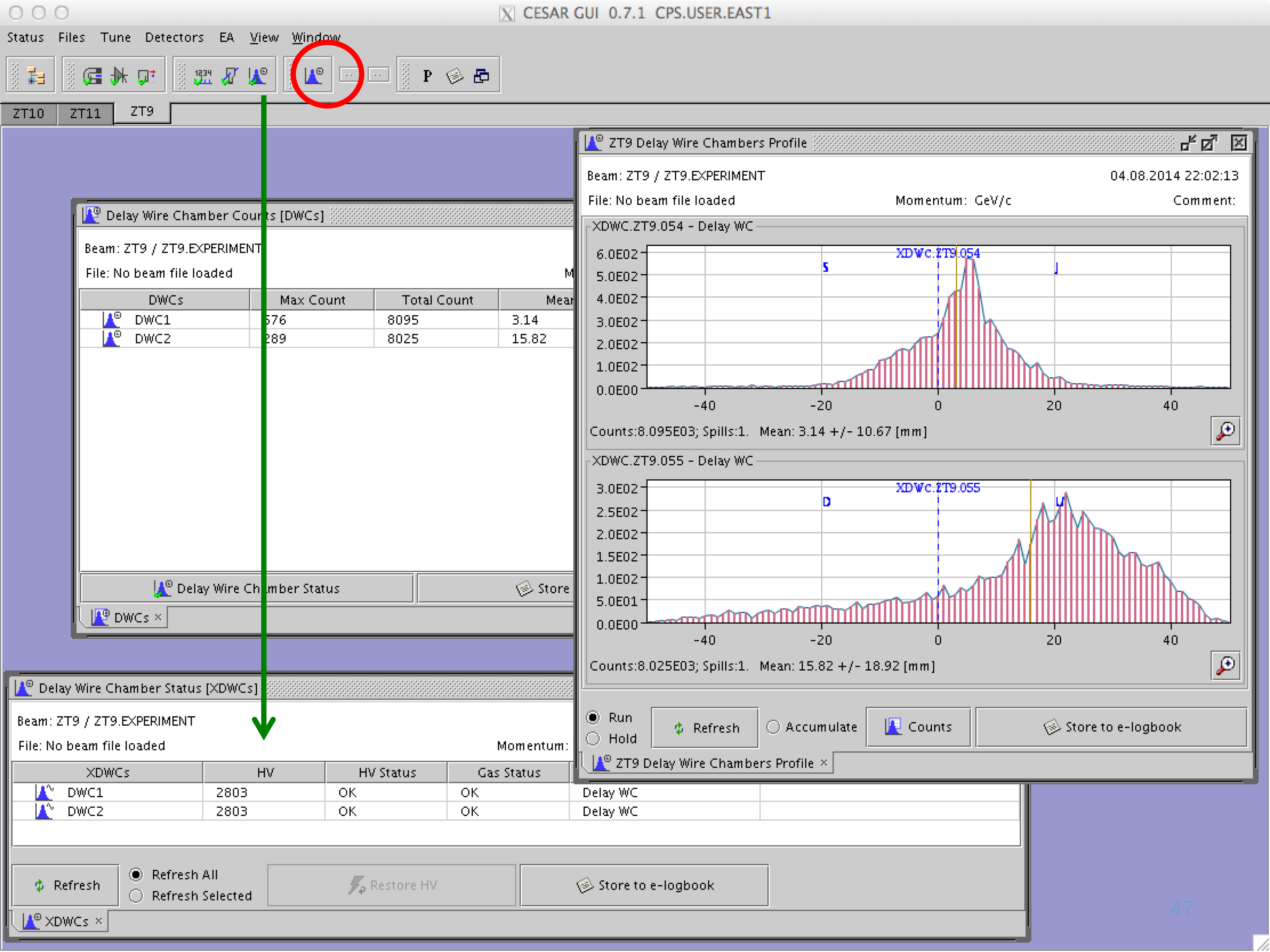
Position	Type	Device name	settings
4	Magnet	Q74.ZT9.004	current : **325.01**
5	Magnet	Q120C.ZT9.005	current : **282.62**
10	Magnet	MNP23.ZT9.010	current : **714.64**
16	Magnet	QFS.ZT9.016	current : **232.11**
20	Magnet	MCB.ZT9.020	current : **196.35**
27	Magnet	QFL.ZT9.027	current : **122.88**
30	Magnet	MCB.ZT9.030	current : **191.24**
32	Magnet	QFL.ZT9.032	current : **211.33**
39	Magnet	MBPS.ZT9.039	current : **288.43**
44	Magnet	QPL.ZT9.044	current : **357.96**
46	Magnet	QPL.ZT9.046	current : **368.94**

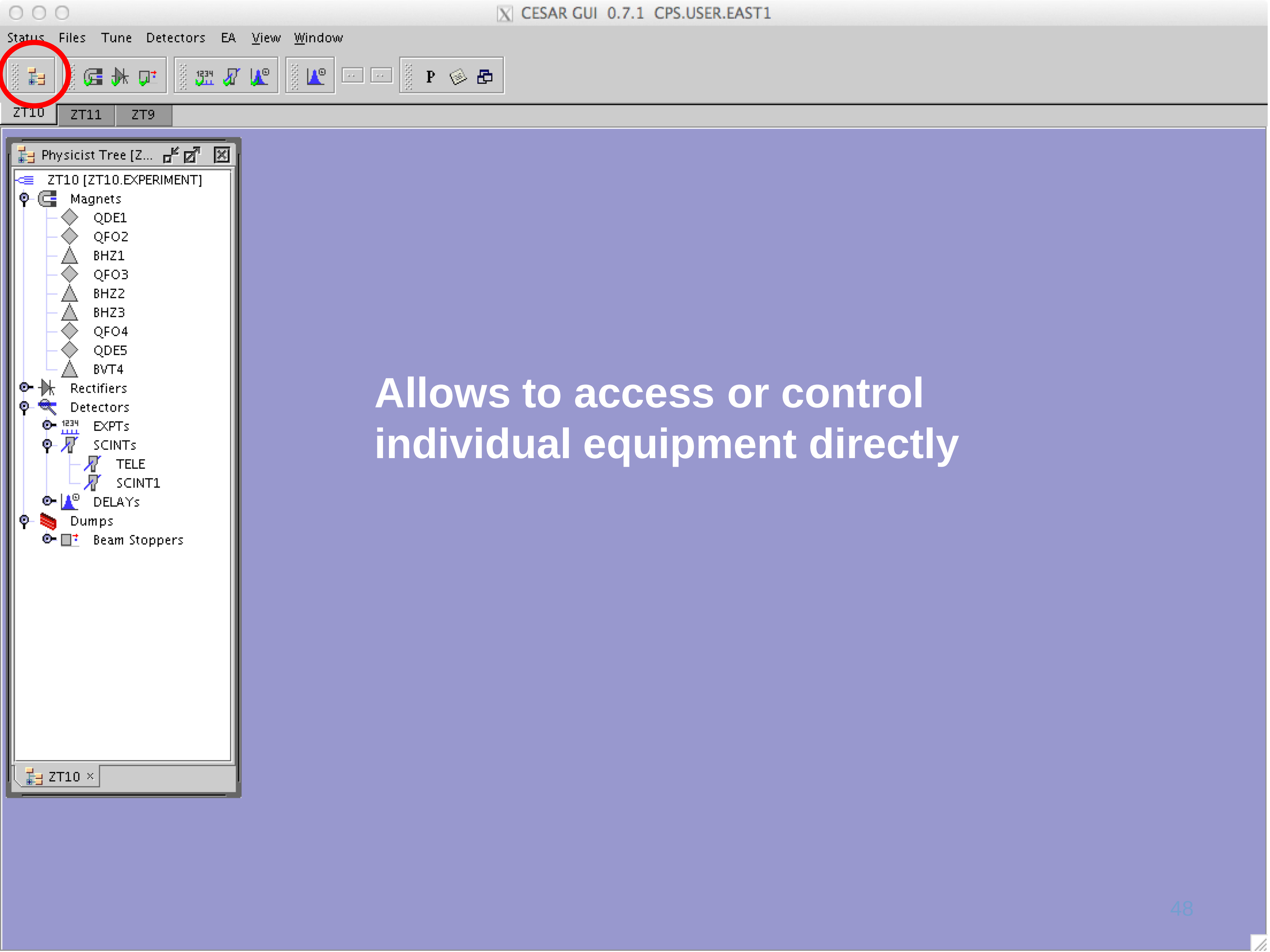

CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
ZT10 ZT11 ZT9
Magnet Status [Magnets]
Beam: ZT10 / ZT10.EXPERIMENT
File: No beam file loaded
Momentum: GeV/c
Magnets Read BeamRef Max Polarity Info F Comments
QDE1 -548.2 -548.4 800 N Def.Quad -
QFO2 -594.2 -594.3 800 N Foc.Quad -
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


CESAR GUI 0.7.1 CPS.USER.EAST1
Status Files Tune Detectors EA View Window
ZT10 ZT11 ZT9
Rectifier Status [Rectifiers]
Beam: ZT9 / ZT9.EXPERIMENT
04.08.2014 21:59:09
File: No beam file loaded
Momentum: GeV/c
Comment:
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
Run
Hold
Refresh
Refresh All
Refresh Selected
Set Cu...
ON
STAN...
OFF
RESET
Displa...
Store ...
Rectifiers ×


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
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
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
Counts:8.095E03; Spills:1. Mean: 3.14 +/- 10.67 [mm]
XDWC.ZT9.055 - Delay WC
Counts:8.025E03; Spills:1. Mean: 15.82 +/- 18.92 [mm]
Run
Hold
Refresh
Accumulate
Counts
Store to e-logbook
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
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



Allows to access or control individual equipment directly

Experiments at Accelerators

Fixed Target (FT)

- Many particle types
- Precision physics
- Easier installation, easier access
- Less space restrictions
- Larger flexibility
  - Large momentum range
  - Flexible particle types

But only fraction of beam energy available for physics:

$$E_{CM} \approx \sqrt{2\, m_0\, E_{beam}}$$

Collider

- All beam energy available for producing new particles/physics
- Just one particle type (e.g. protons)
- "Discovery machines"
- $\sqrt{s} \approx 2\, E_{beam}$

Physics at FT and collider are both useful and needed

1 GeV = 1 Billion electron Volt

= 1.6 10^{10} J

Our Users and their Requirements

- Experiments (CLOUD, P349)
  - require stable and reliable beams
  - only location for PS based experiments
- Test beams for detector R&D
  - require wide range of beam momenta, ideally overlapping with North Area
  - require different particle types (e, h, μ)
  - require easy access
- Users of irradiation facilities IRRAD and CHARM
  - require high flux and variable radiation fields
- Outreach (Beamline for Schools)
  - requires plug and play infrastructure

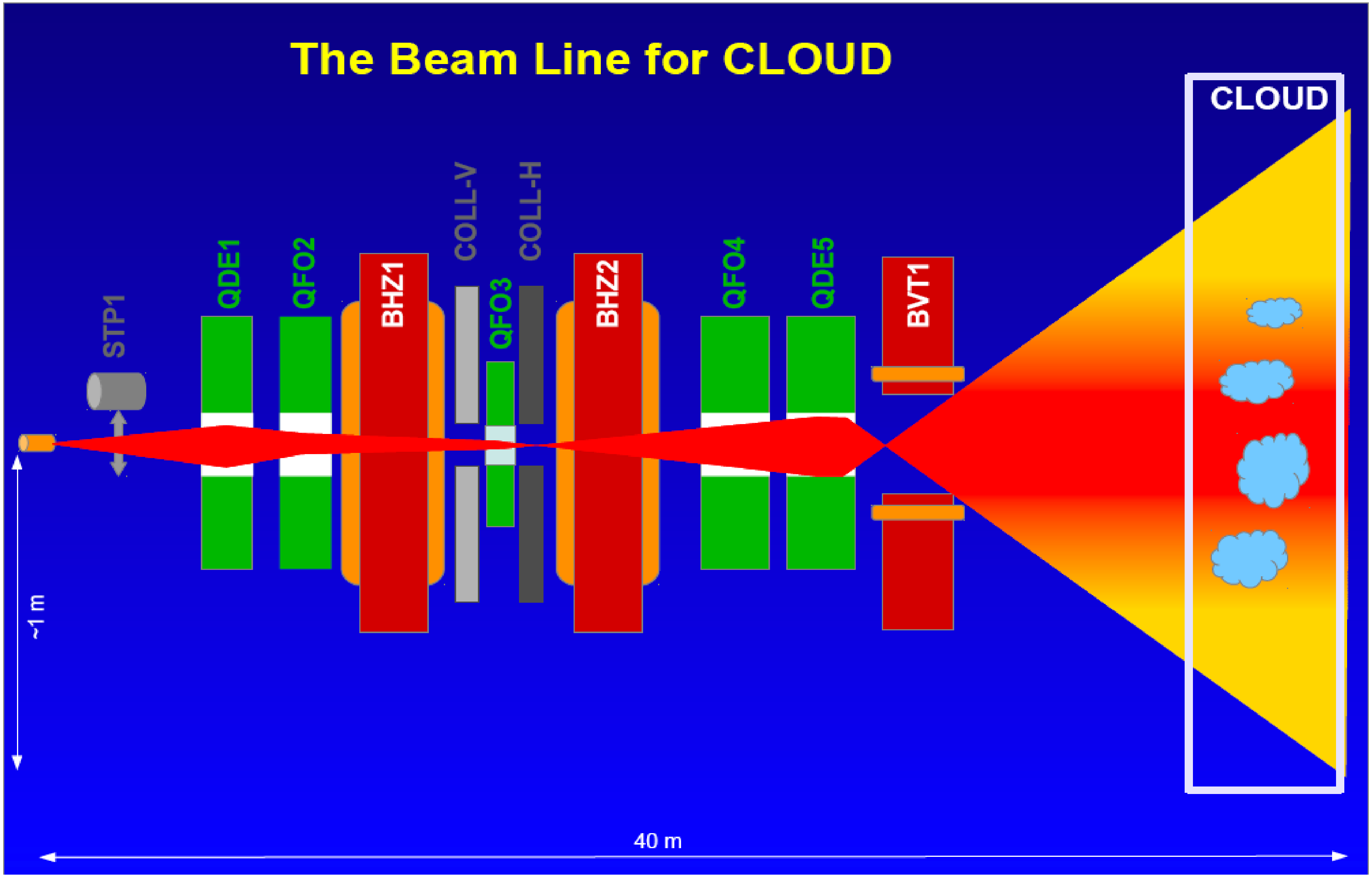
Test Beams for Detector R&D

- Particle detector development with wide energy ranges (LHC, FCC, Fixed Target Experiments, ILC, GSI,…)
- Spaceborne experiments (PAMELA, AMS, GLAST, PEBS,…)
- Neutrino, dark matter, and BSM search experiments (SHiP, BabyMIND, OPERA, MINOS, …)
- AIDA telescope (better flexibility through different test beams, e.g. DESY, North Area, …)

Typical test campaigns:

- Tracking detector characterisation
- Calorimeter calibrations
- Prototype development
- Proof-of-concept
- Design validation
- Performance assessment
- Preparation for North Area tests

The East Area Beams: T11



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	
EAST_ NORTH	24 GeV/c	0.4 s	2-3 10^{11}	2.4 s	For test beams T9+T10 + CLOUD
EAST_ IRRAD	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.

Targets and particle production

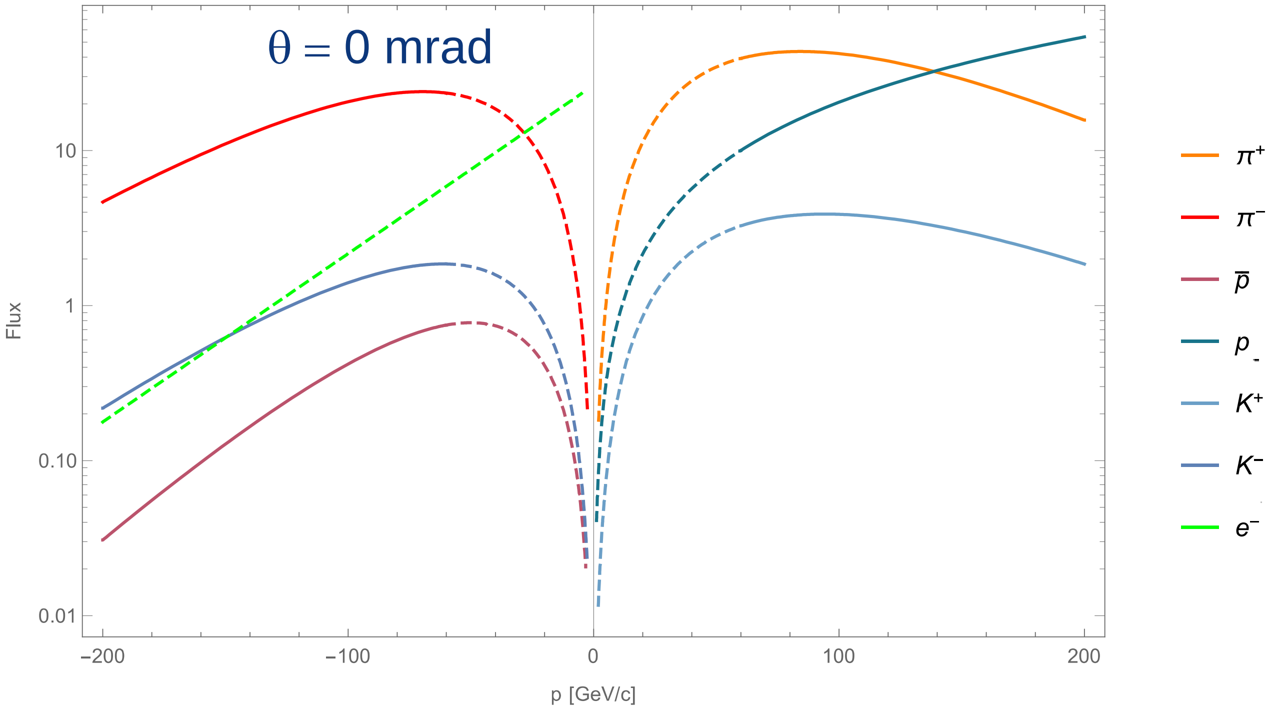
Atherton parameterisation (CERN 80-07):

$$\frac{d^2N}{dp\,d\Omega} = A\left[\frac{B}{p_0}\,e^{-Bp/p_0}\right]\left[\frac{2Cp^2}{2\pi}\,e^{-C(p\theta)^2}\right]$$

$$\frac{d^2N}{dp\,d\Omega} = A\left[\frac{(B+1)}{p_0}\left(\frac{p}{p_0}\right)^B\right]\left[\frac{2Cp^2}{2\pi}\,e^{-C(p\theta)^2}\right]$$

with primary momentum p_0 and production angle θ

Flux per solid angle [steradian], per interacting proton, and per dp [GeV/c]



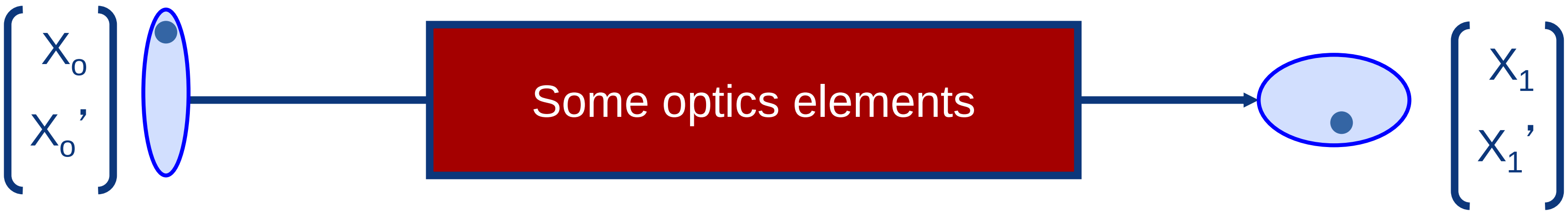
	A	B	C
p	0.8	-0.6	3.5

	A	B	C
π^+	1.2	9.5	5.0
π^-	0.8	11.5	5.0
K^+	0.16	8.5	3.0
K^-	0.10	13.0	3.5
$\bar{p}$	0.06	16.0	3.0

Note: Extrapolation for momenta below 60 GeV/c

Matrix elements

More useful for calculating



Transfer matrix R

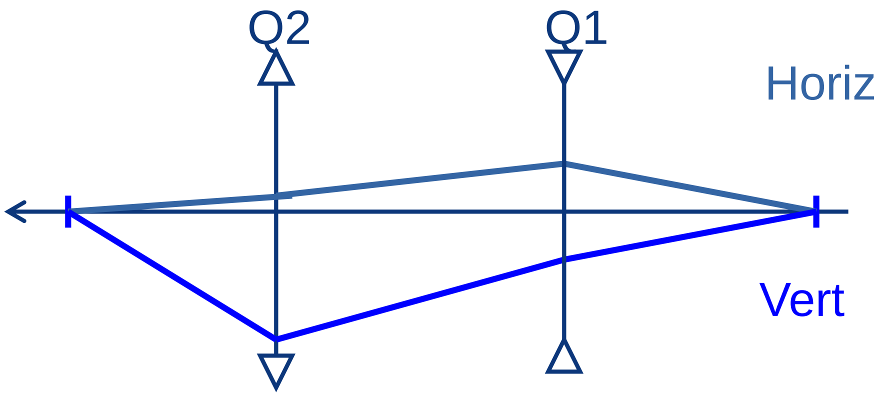
$$\begin{pmatrix} X_1 \\ X_1' \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{pmatrix} \begin{pmatrix} X_o \\ X_o' \end{pmatrix} = \begin{pmatrix} R_{11} X_o + R_{12} X_o' \\ R_{21} X_o + R_{22} X_o' \end{pmatrix}$$

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

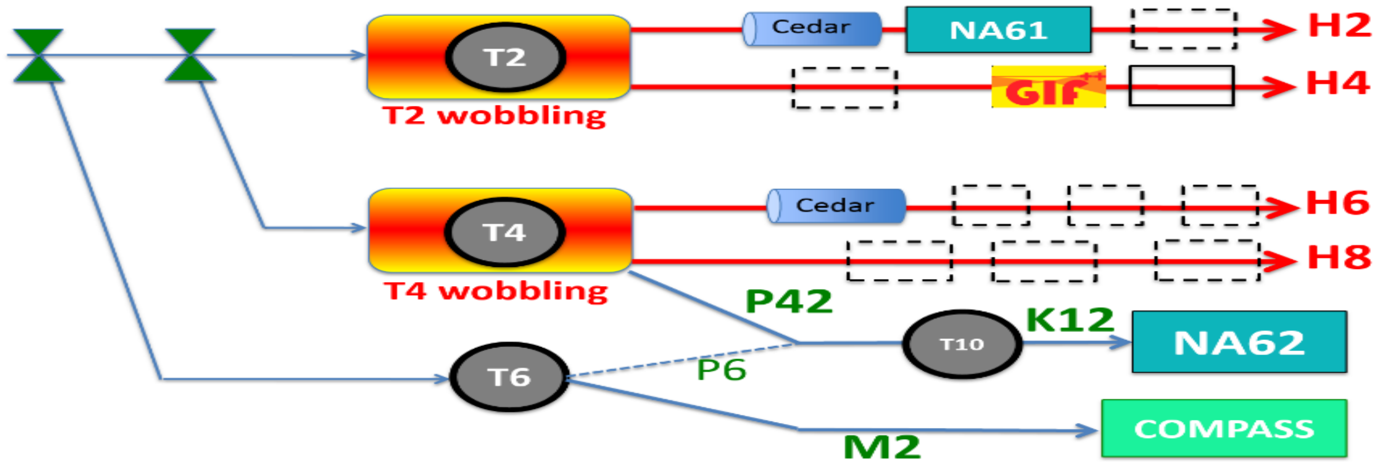
POSITION	TYPE		STRENGTH	*	HORIZONTAL				*	VERTICAL				*	DISPERSION			
METERS			T*M,T/M*M	*	R11	R12	R21	R22	*	R33	R34	R43	R44	*	R16	R26	R36	R46
			T/M**2*M	*	MM/MM	MM/MR	MR/MM	MR/MR	*	MM/MM	MM/MR	MR/MM	MR/MR	*	MM/PC	MR/PC	MM/PC	MR/PC
0.000	3	TARGET		*	1.000	0.000	0.000	1.000	*	1.000	0.000	0.000	1.000	*	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

Transport table

1T9 test beam optics TRANSPORT RUN28/02/08

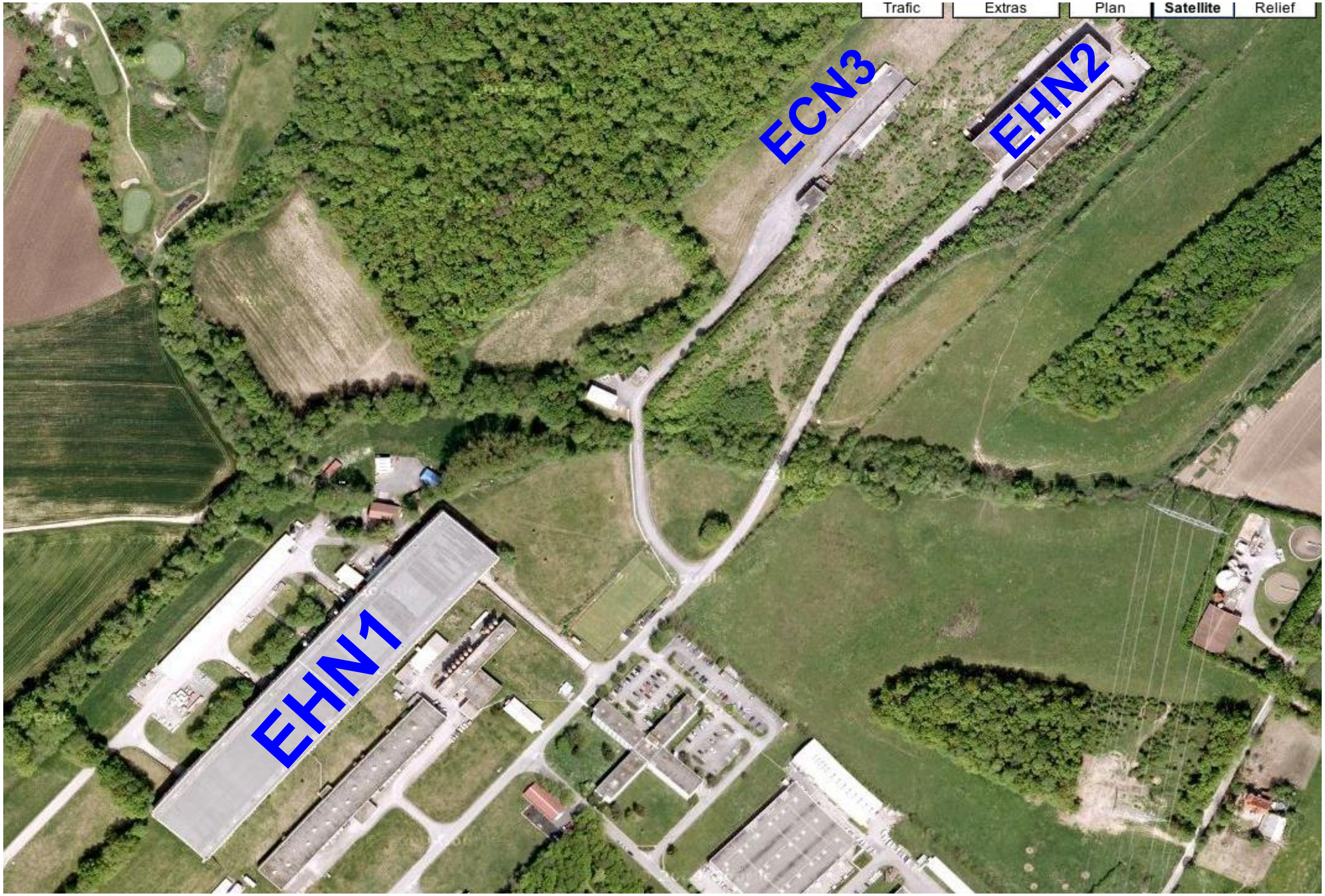
0POSITION	TYPE		STRENGTH	H O R I Z O N T A L				V E R T I C A L				D I S P E R S I O N			
METERS			T*M,T/M*M T/M**2*M	R11 MM/MM	R12 MM/MR	R21 MR/MM	R22 MR/MR	R33 MM/MM	R34 MM/MR	R43 MR/MM	R44 MR/MR	R16 MM/PC	R26 MR/PC	R36 MM/PC	R46 MR/PC
0.000	3	PG3H		1.000	0.000	0.000	1.000	1.000	0.000	0.000	1.000	0.000	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

North Area – beam lines



Beam line	Target station	Momentum range	Particle types	User zones	Typical users
H2	from T2	≤ 400 GeV/c	p, h, e, μ, ions	PPE152, 172	NA61, CMS
H4		≤ 400 GeV/c	p, h, e, μ, ions	PPE134, 154, 164	NA63, NA64, GIF
H6	from T4	≤ 205 GeV/c	h, e, μ	PPE126, 146, 156	
H8		≤ 400 GeV/c	p, h, e, μ, ions	PPE138, 158, 168	LHCb, ATLAS, UA9
P42/K12	T4/T10	70 GeV/c	P, K, μ	ECN3	NA62
M2	T6	100GeV/c – 270 GeV/c	p, h, e, μ	EHN2	COMPASS

North Area



North Area – EHN1 experimental hall