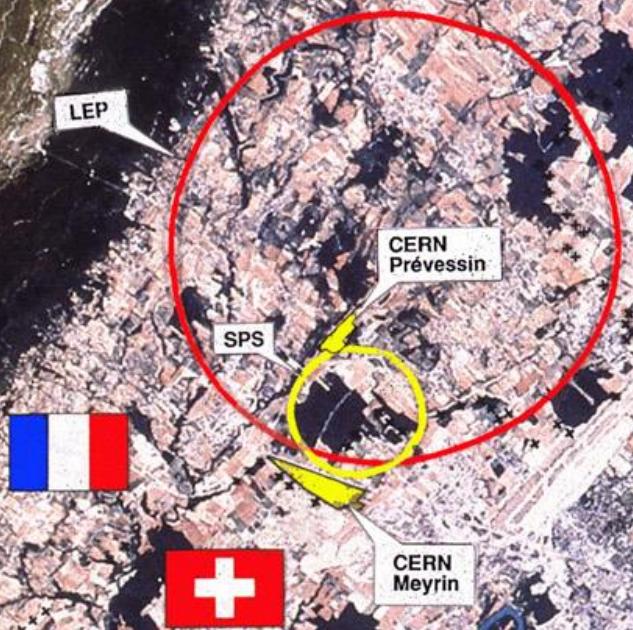


Introduction to accelerators

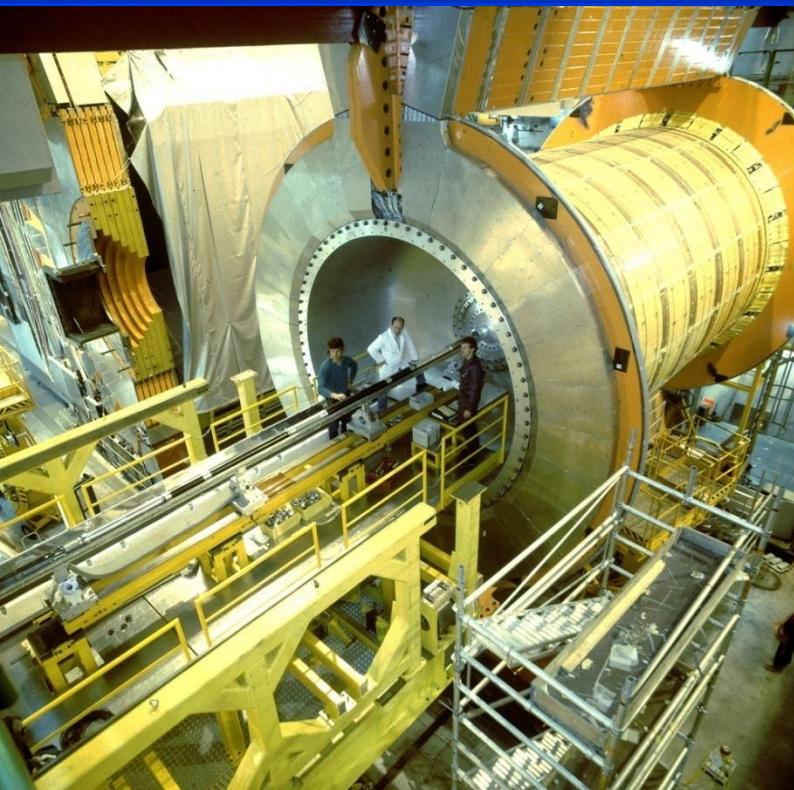
Django Manglunki

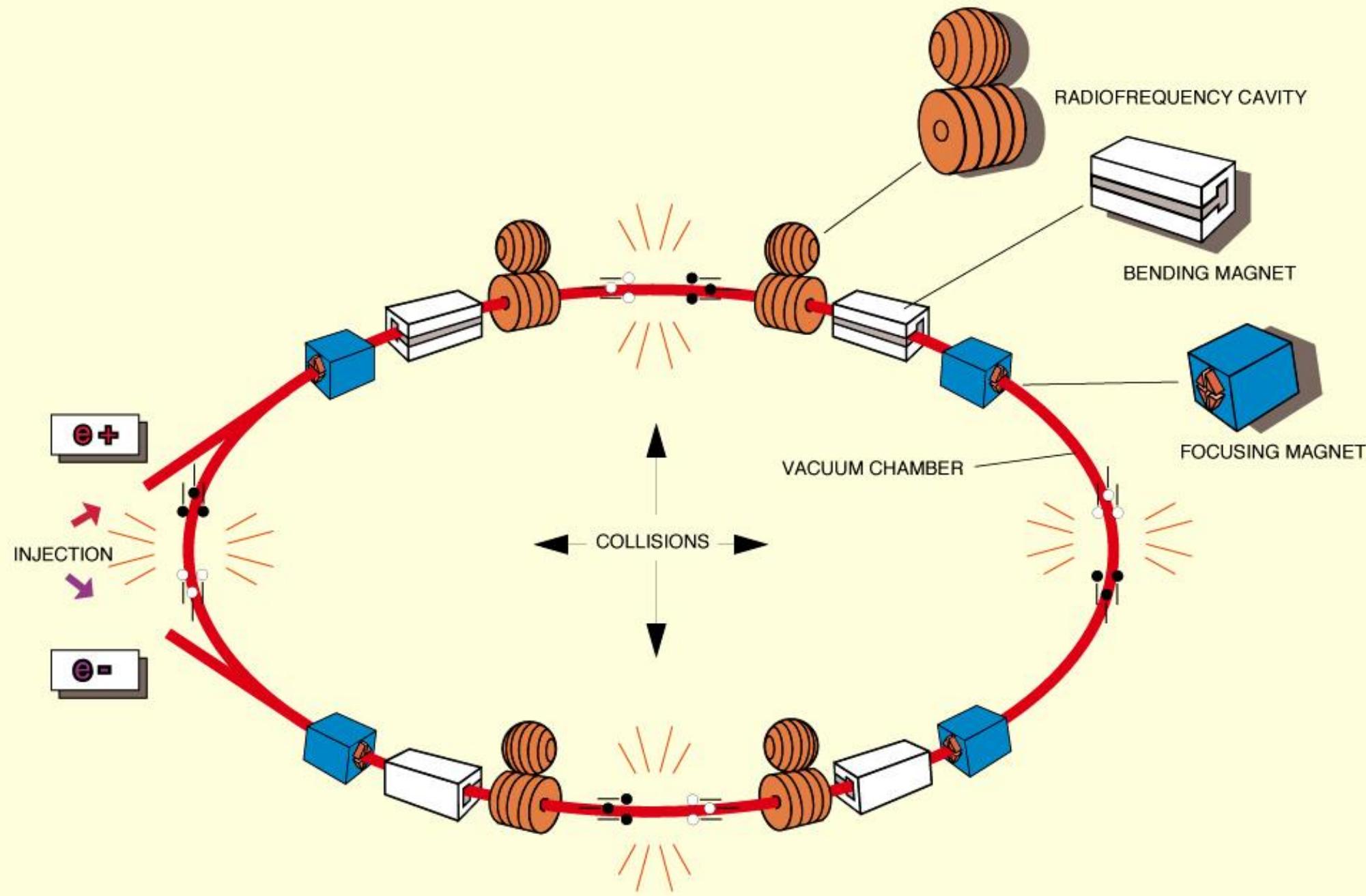
CERN/BE/OP



Tools for High Energy Physics

- Accelerators
- Detectors
- Computers



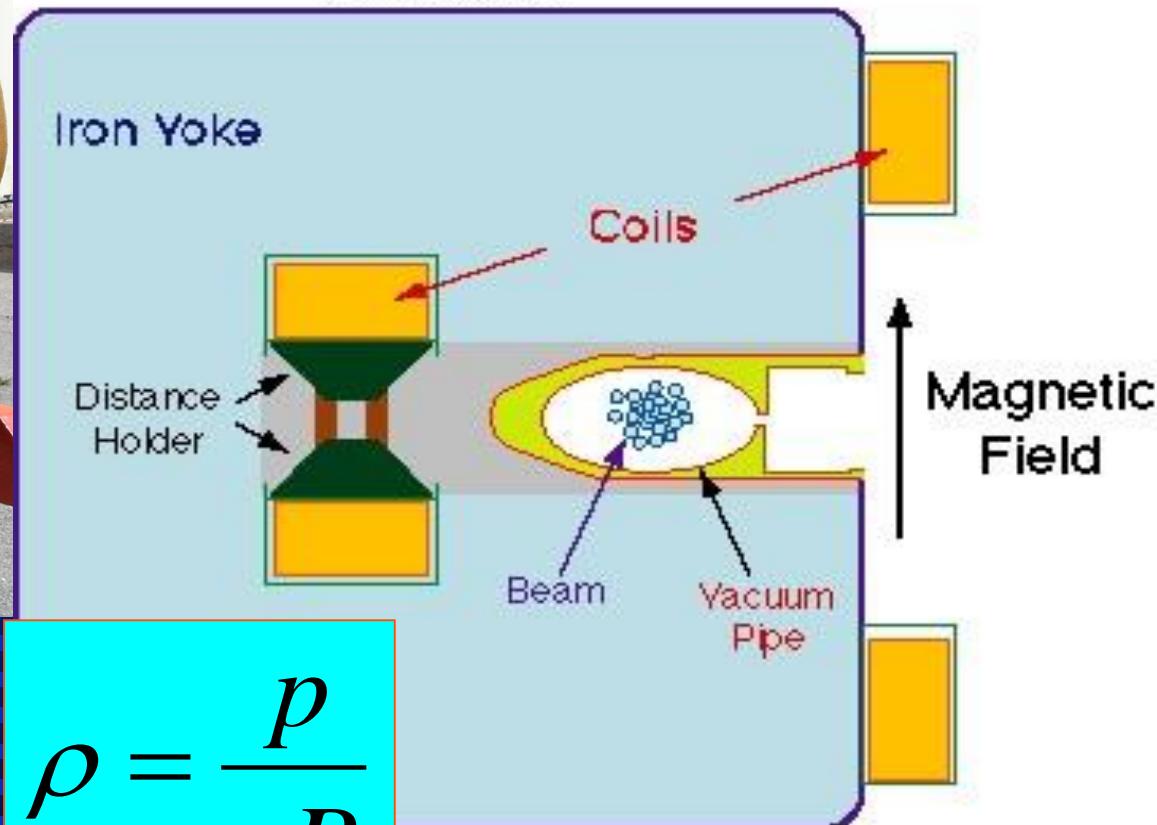


Bending magnets

- Bending by dipolar magnetic fields



$$\vec{F}_\perp = q(\vec{v} \times \vec{B})$$



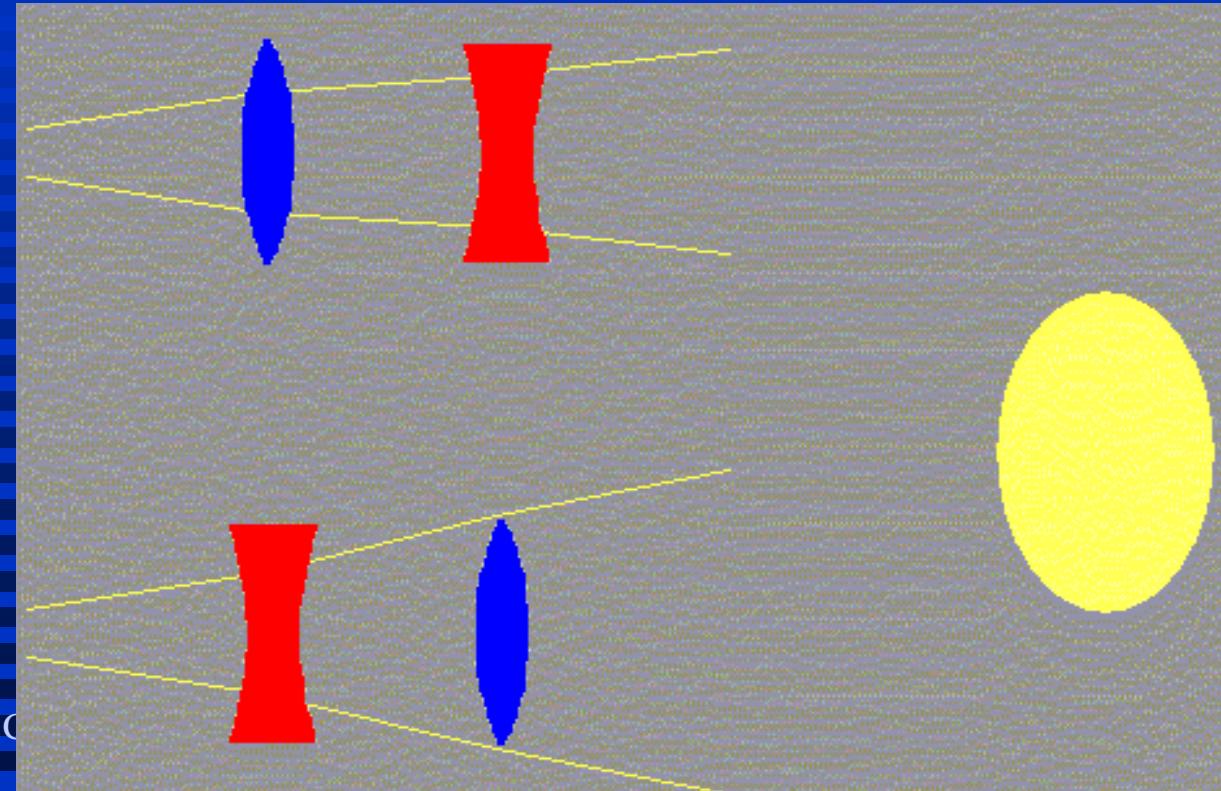
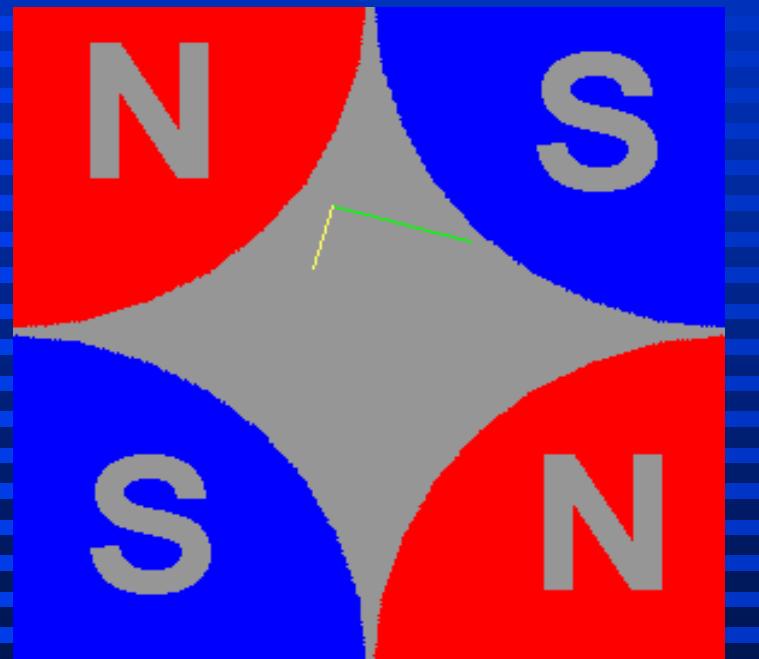
- The field must follow the energy (or, more exactly, the momentum)

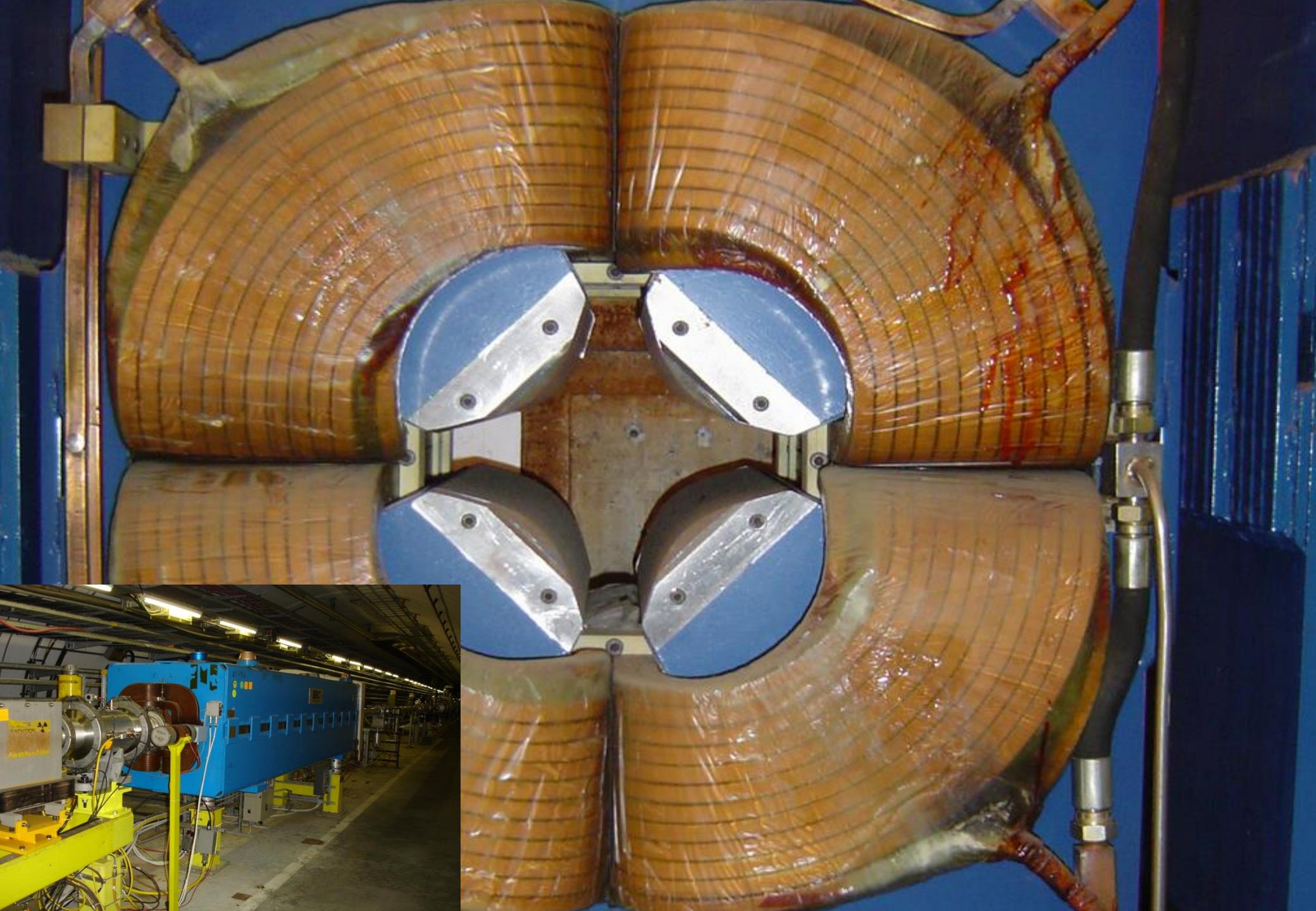
$$\rho = \frac{p}{qB}$$



Focusing magnets

- Focusing by quadrupolar magnetic fields
- One can only focus in one plane (H or V) at a time so we need to *alternate* gradients

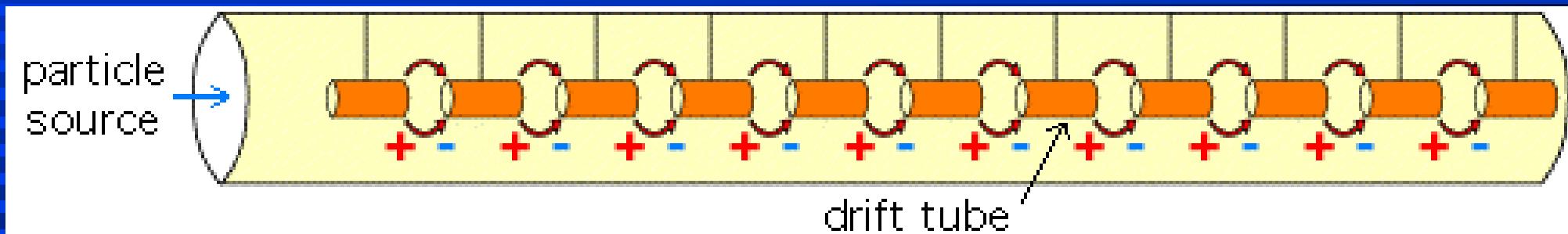




RF cavities



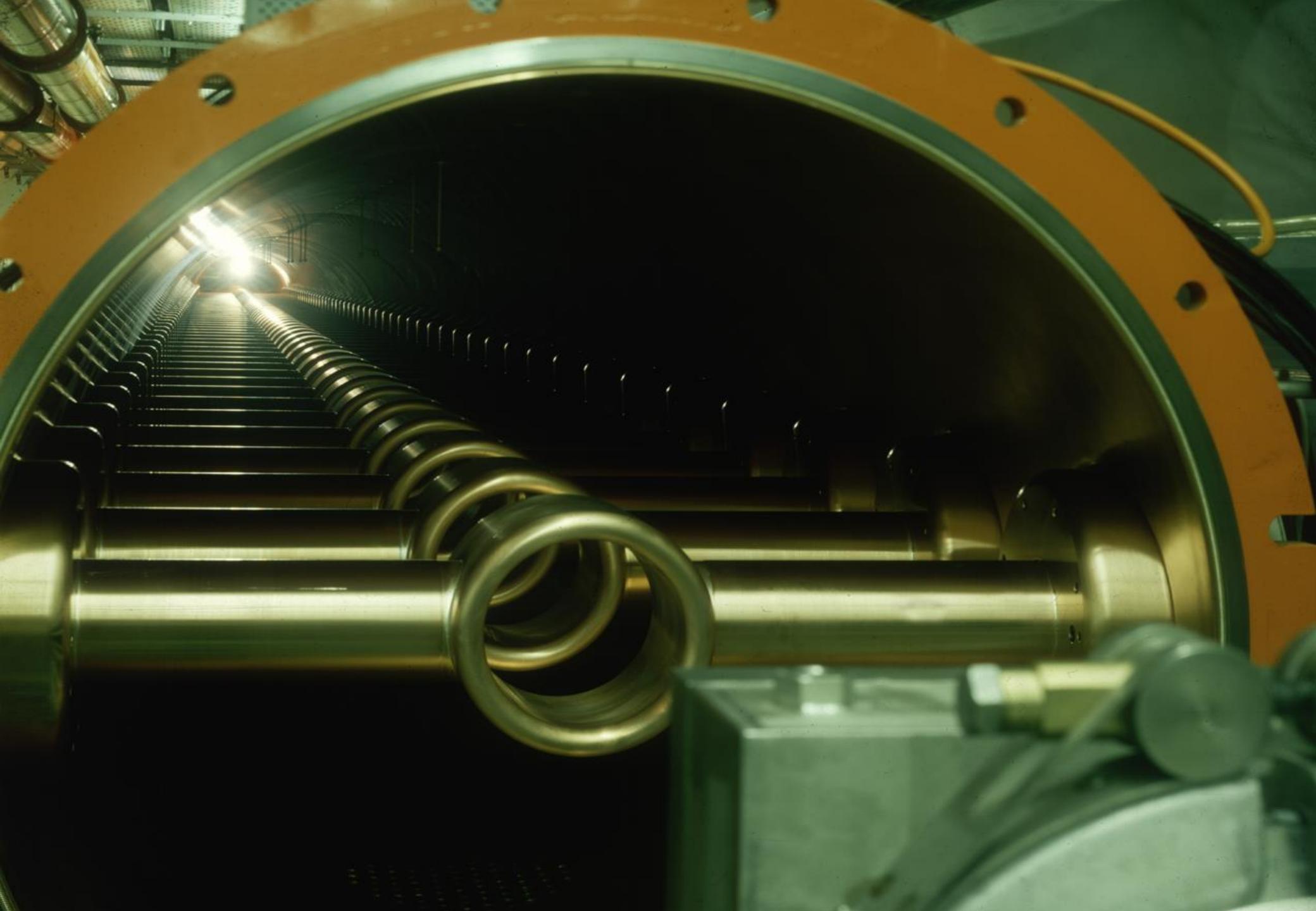
- Acceleration by electric fields



$$\vec{F}_{\parallel} = q\vec{E}$$

$$\Delta K = q\Delta V$$

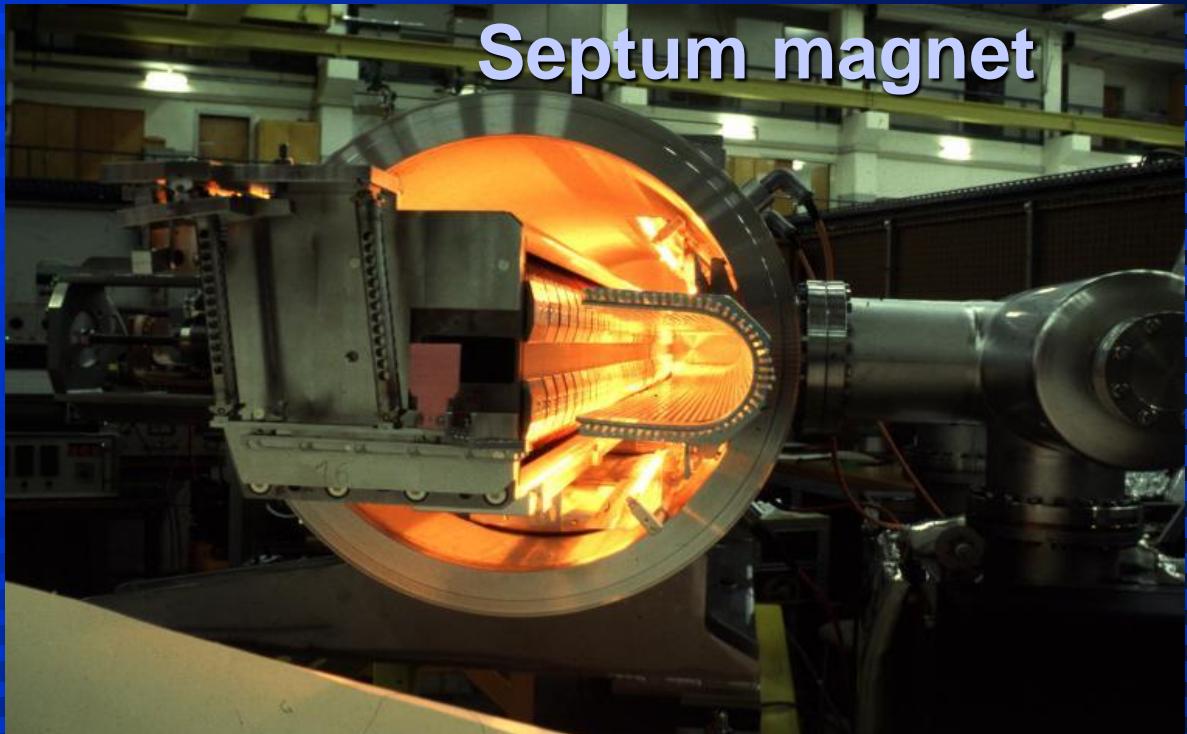
- 1 eV = 1 electron accelerated by 1 Volt



Injection/ejection systems

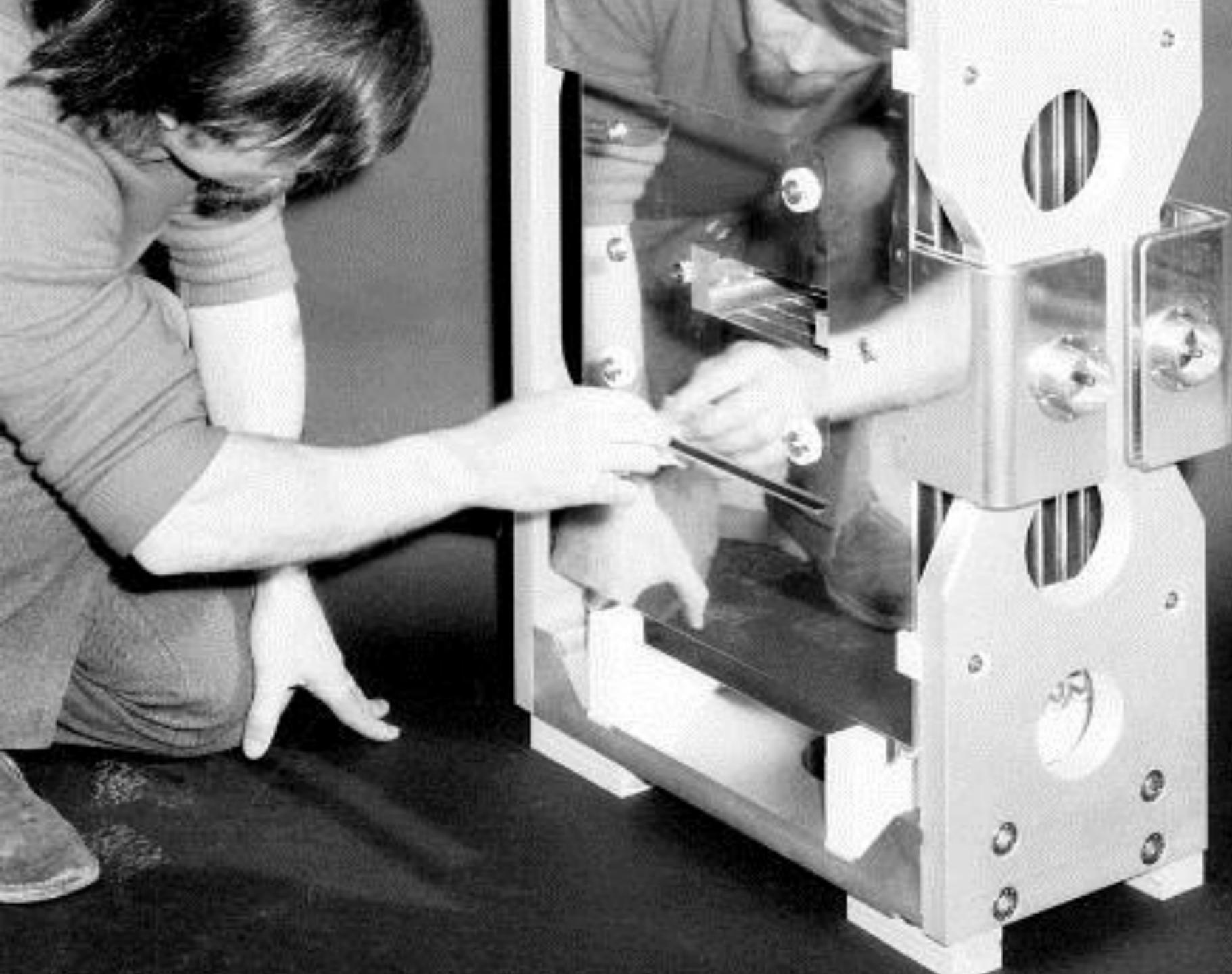


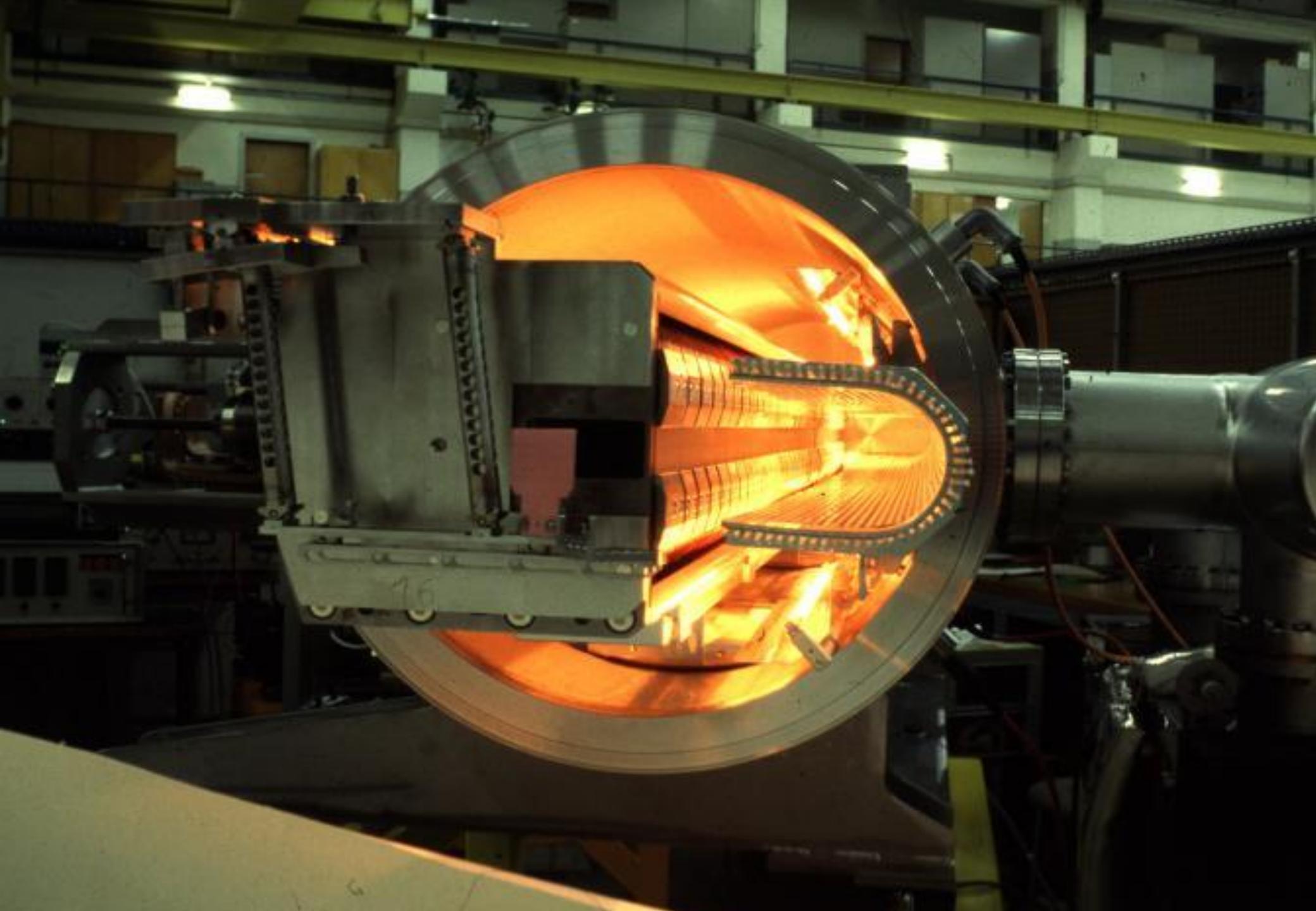
Kicker magnet



Septum magnet

Note: there are other systems

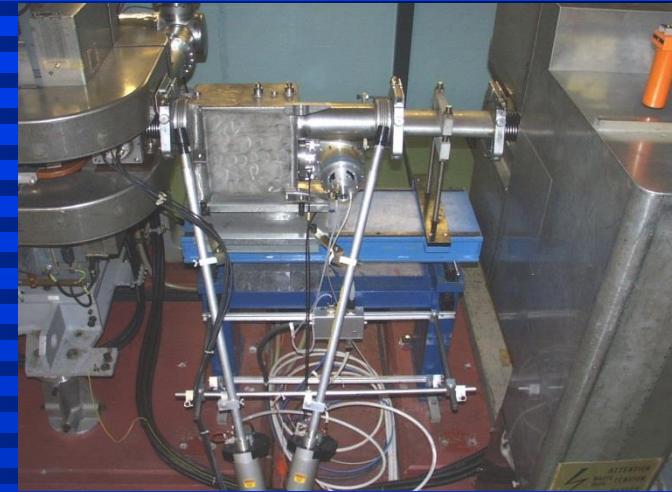
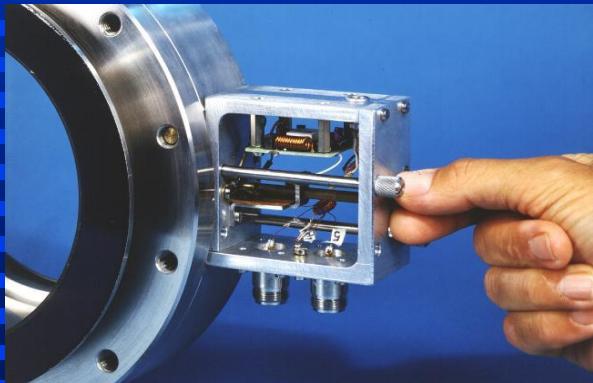




Other components

- Vacuum pumps
- Instrumentation
- Corrector magnets
- Safety elements

● ...

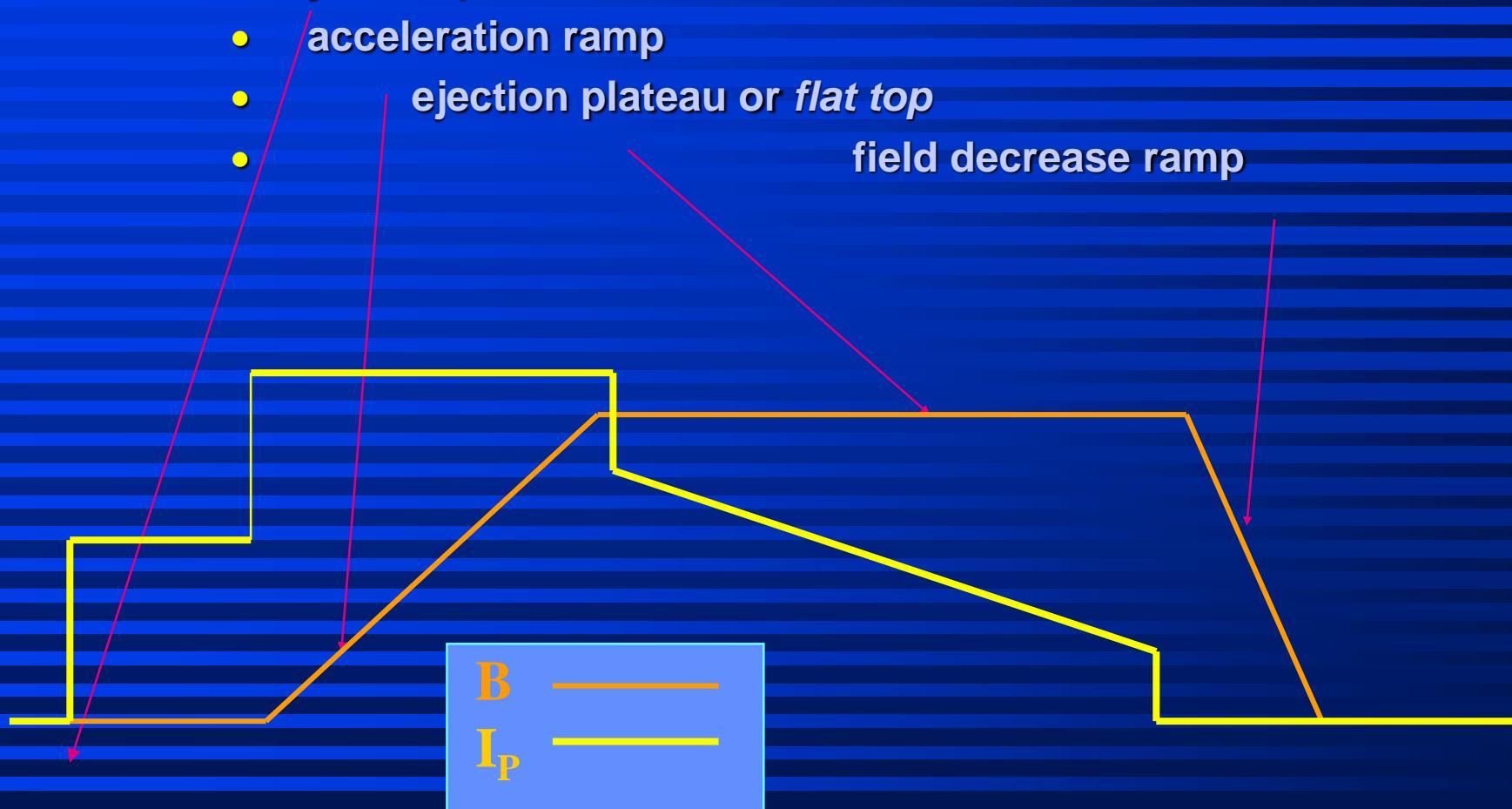




Cycles & Supercycles

- Cycle:

- Injection plateau or *flat bottom*
- acceleration ramp
- ejection plateau or *flat top*
- field decrease ramp

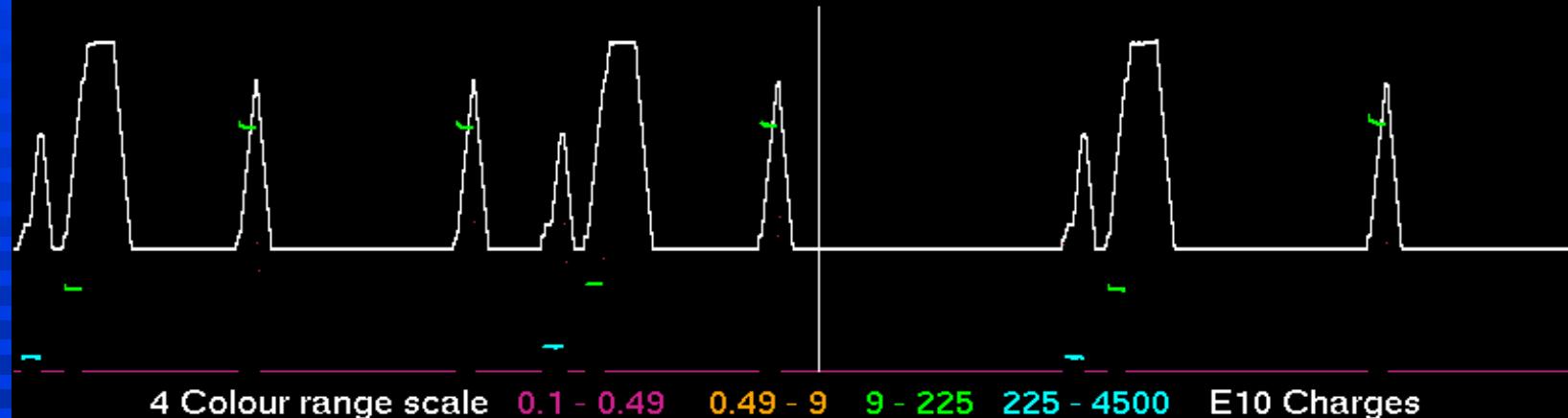


PS Supercycle

CPS Supercycle

supercycle length: 43.2 seconds (36 BP)

May 04 18:23:55



ZERO

CPS User : TOF 175.95 E10 PROTON For: TT2_D3

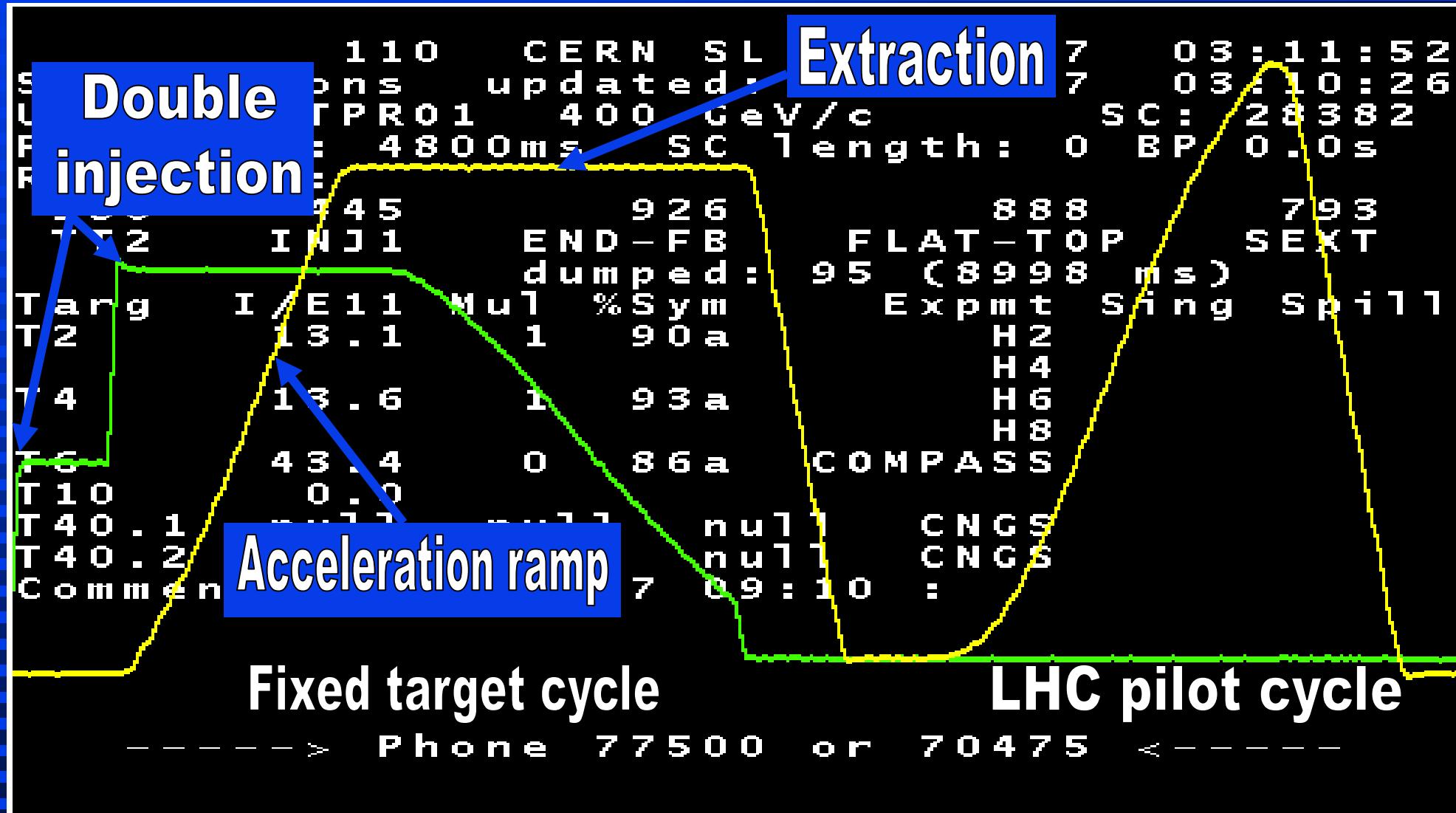
Beam for Isolde : 0 E10 BPNM = 19/36 MTG-level = 15

Comments: 04 May 2004 11:40:01

Energy, Intensity, Destination...

No Message

SPS supercycle



Cycles & Supercycles

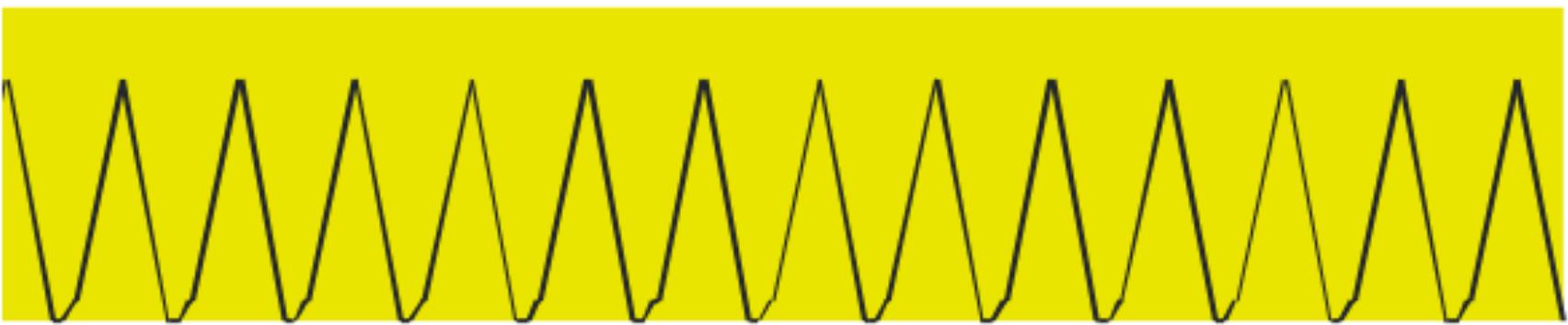
► SPS



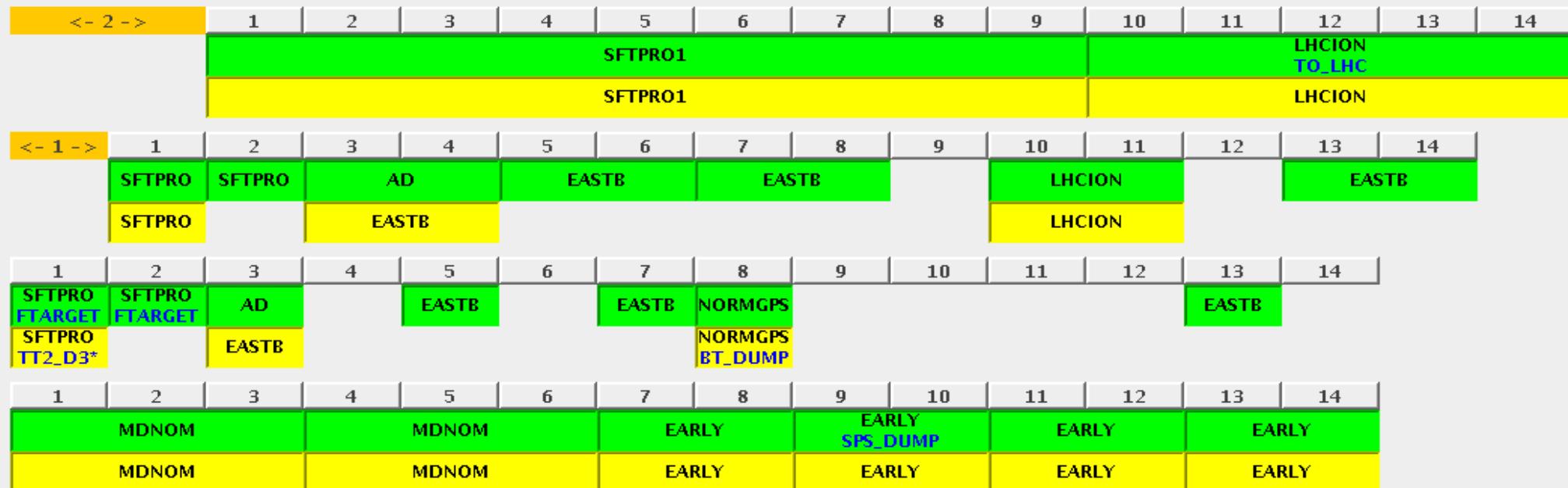
► CPS

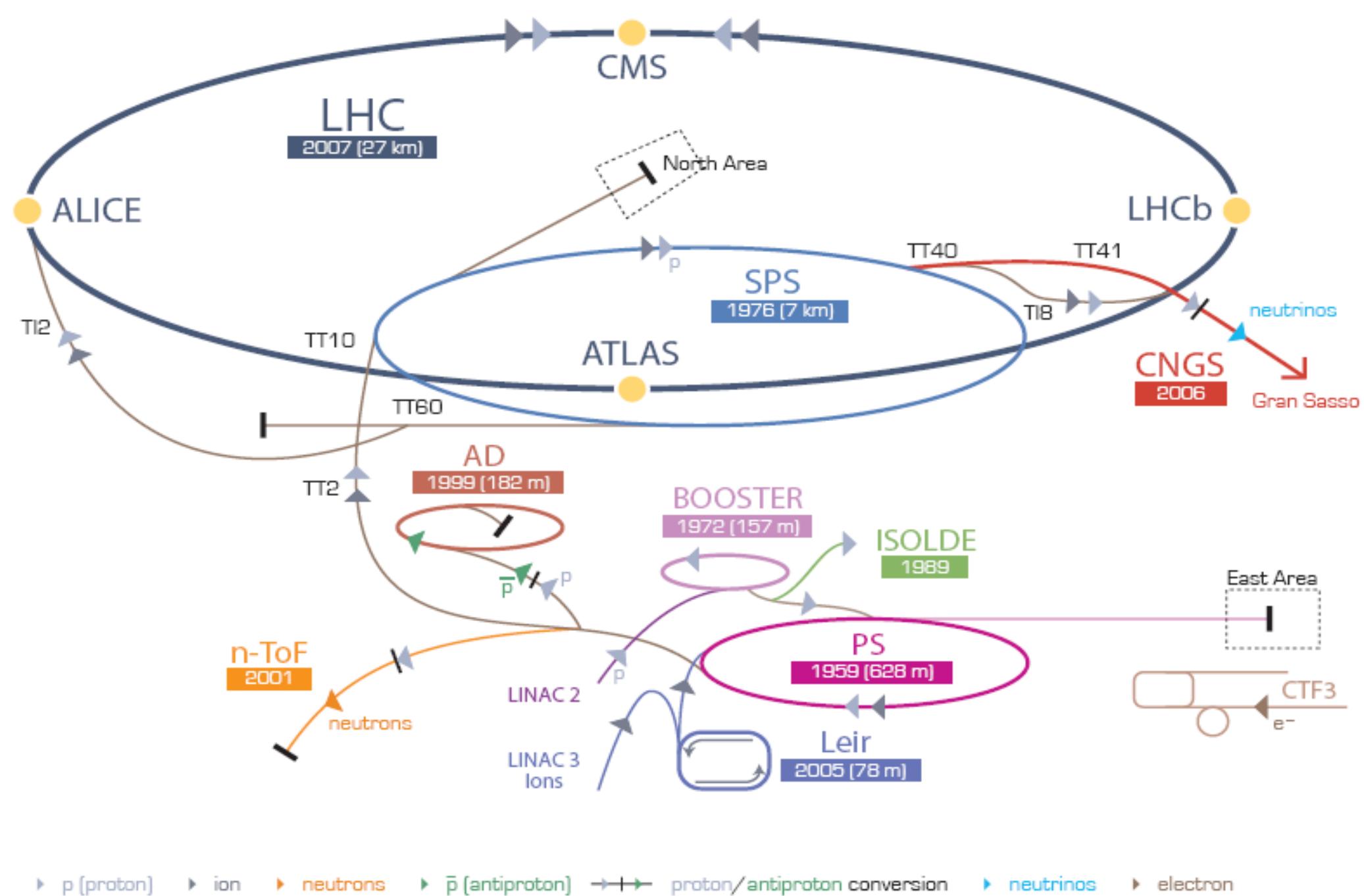


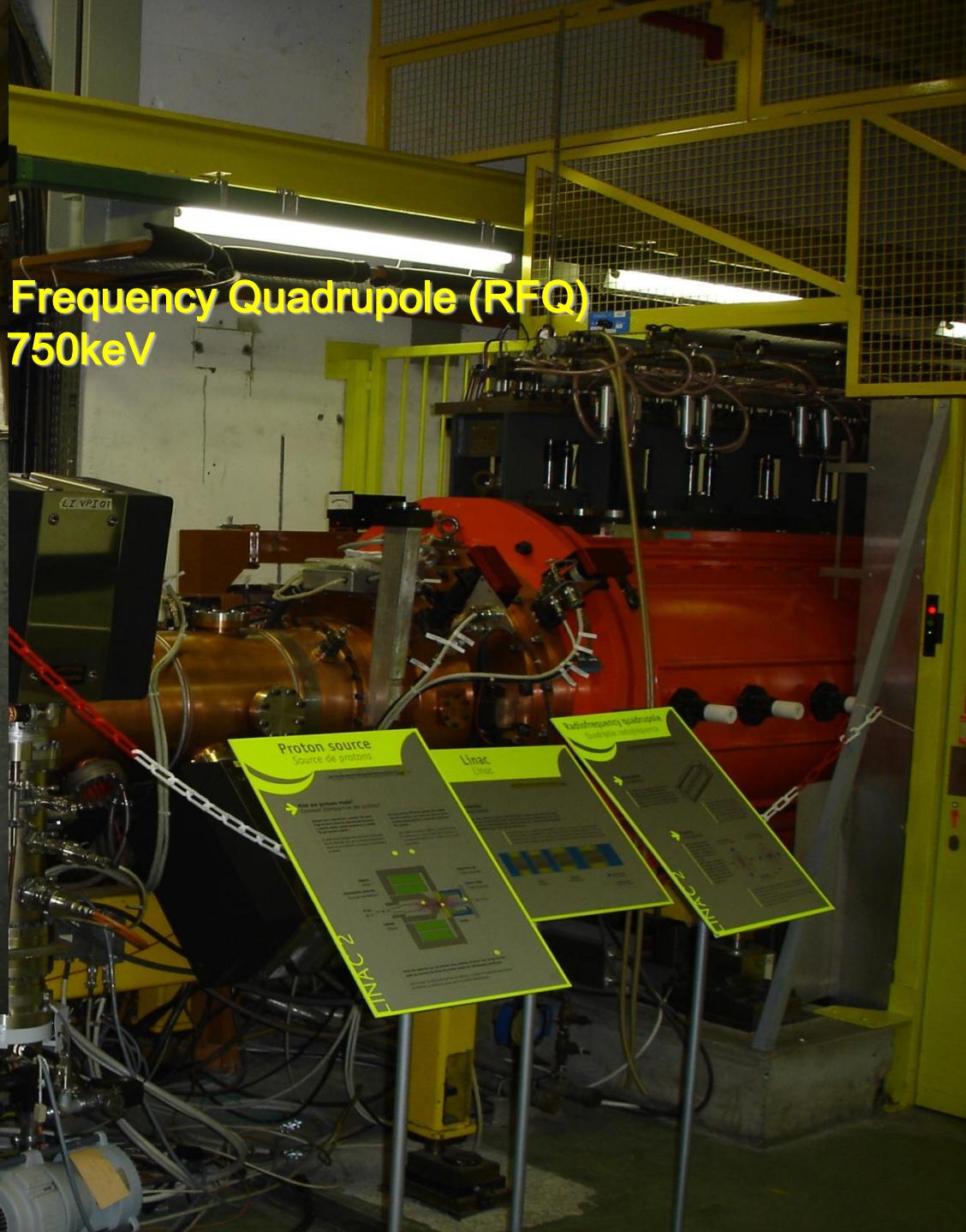
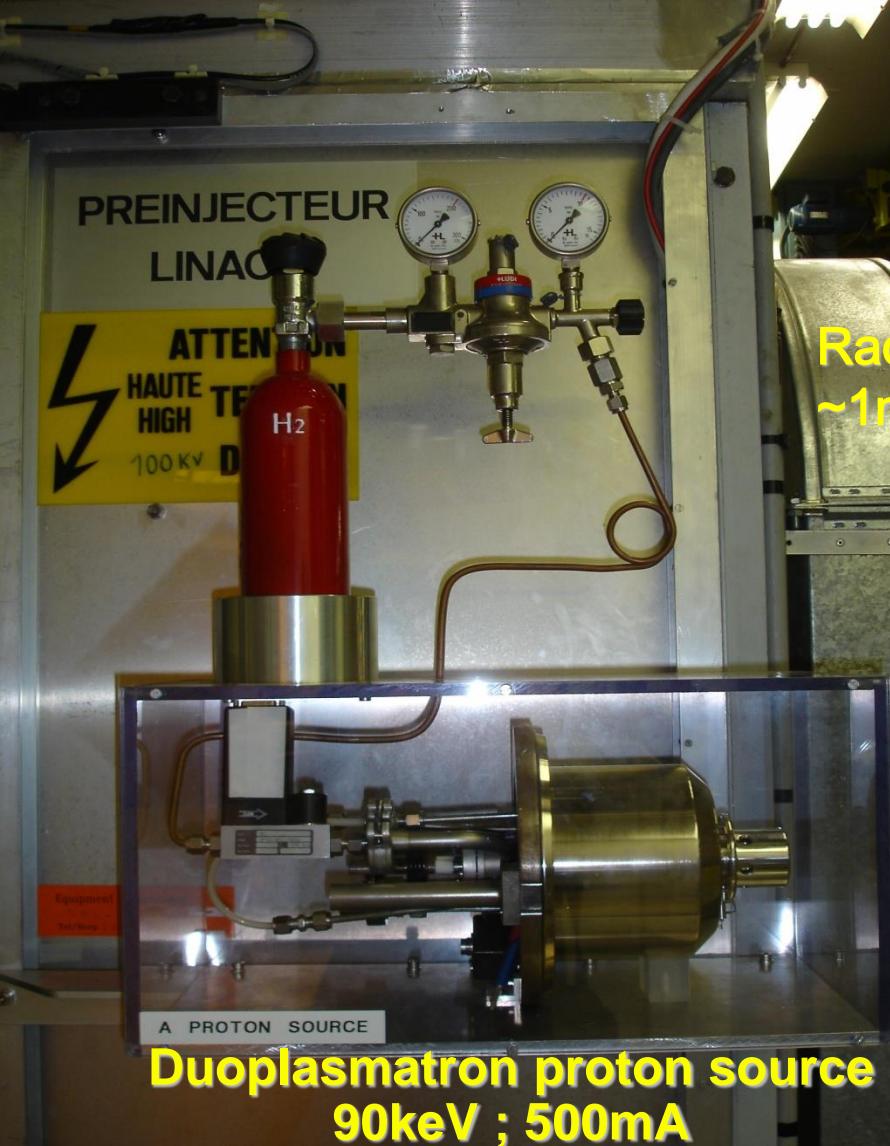
► PSB

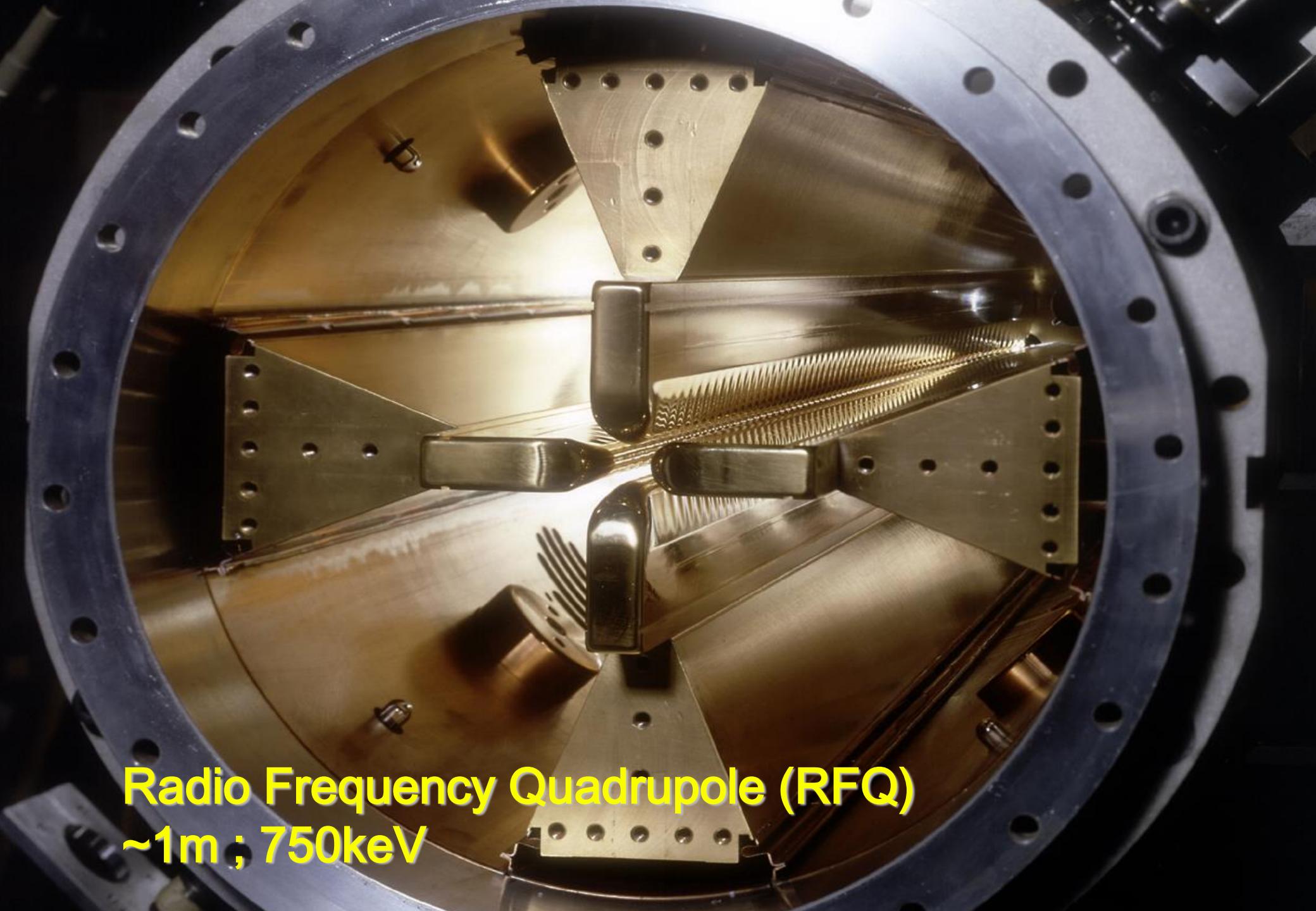


Cycles & Supercycles







A close-up photograph showing the internal components of a Radio Frequency Quadrupole (RFQ) accelerator. The structure is made of polished metal, likely stainless steel or copper, with a circular cross-section. Inside, there are several parallel, wavy metal plates that form the quadrupole field. These plates are supported by a central vertical post and are held in place by various mechanical supports and brackets. The lighting highlights the metallic surfaces and the intricate details of the internal assembly.

Radio Frequency Quadrupole (RFQ)
~1m ; 750keV

Linac 2
30m ; 50MeV ; 180mA

Proton source
LI VP102

ENTREE INTER
ENTRANCE FOR

21



RADIATION

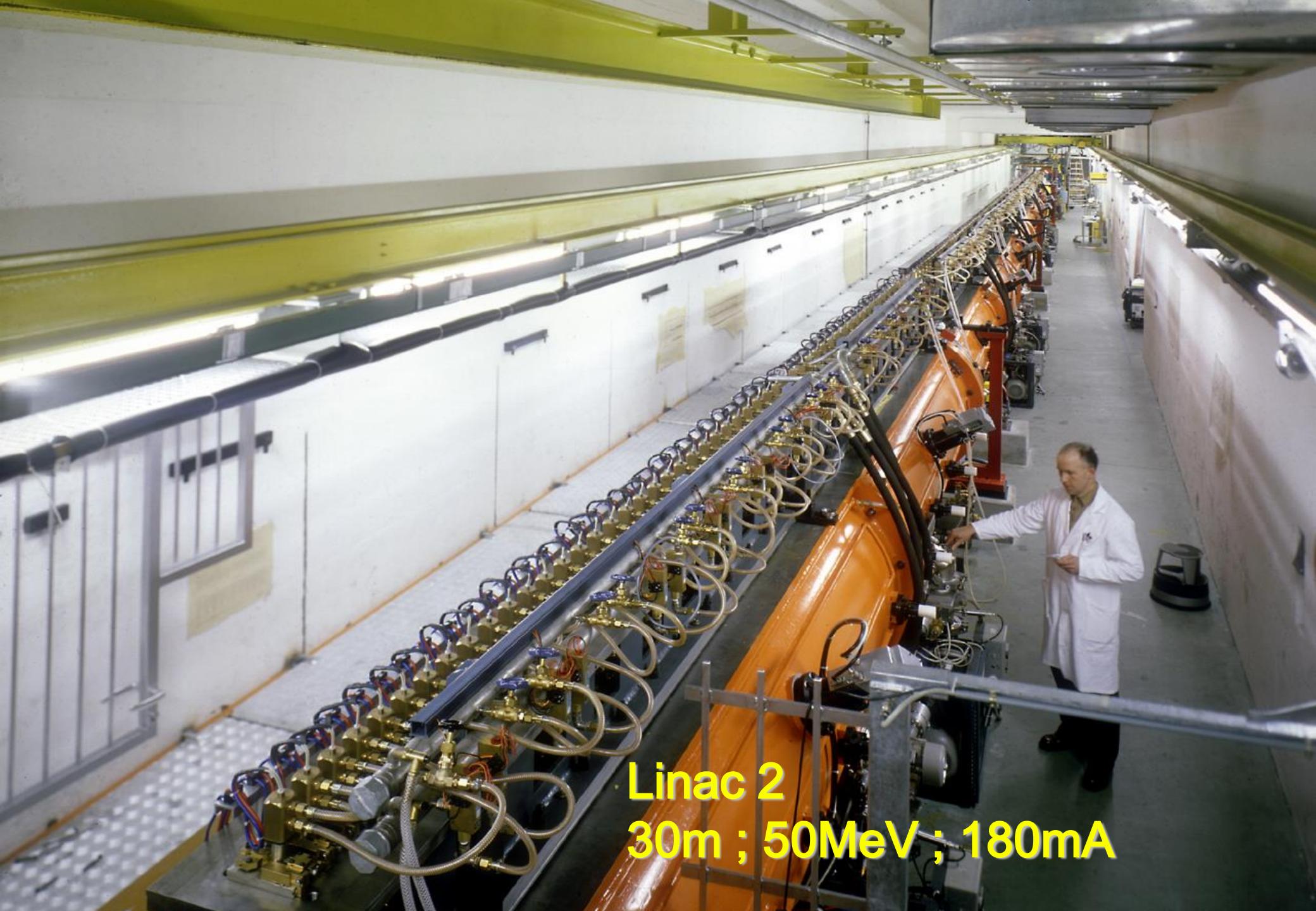
ZONE
CONTROLEE

CON

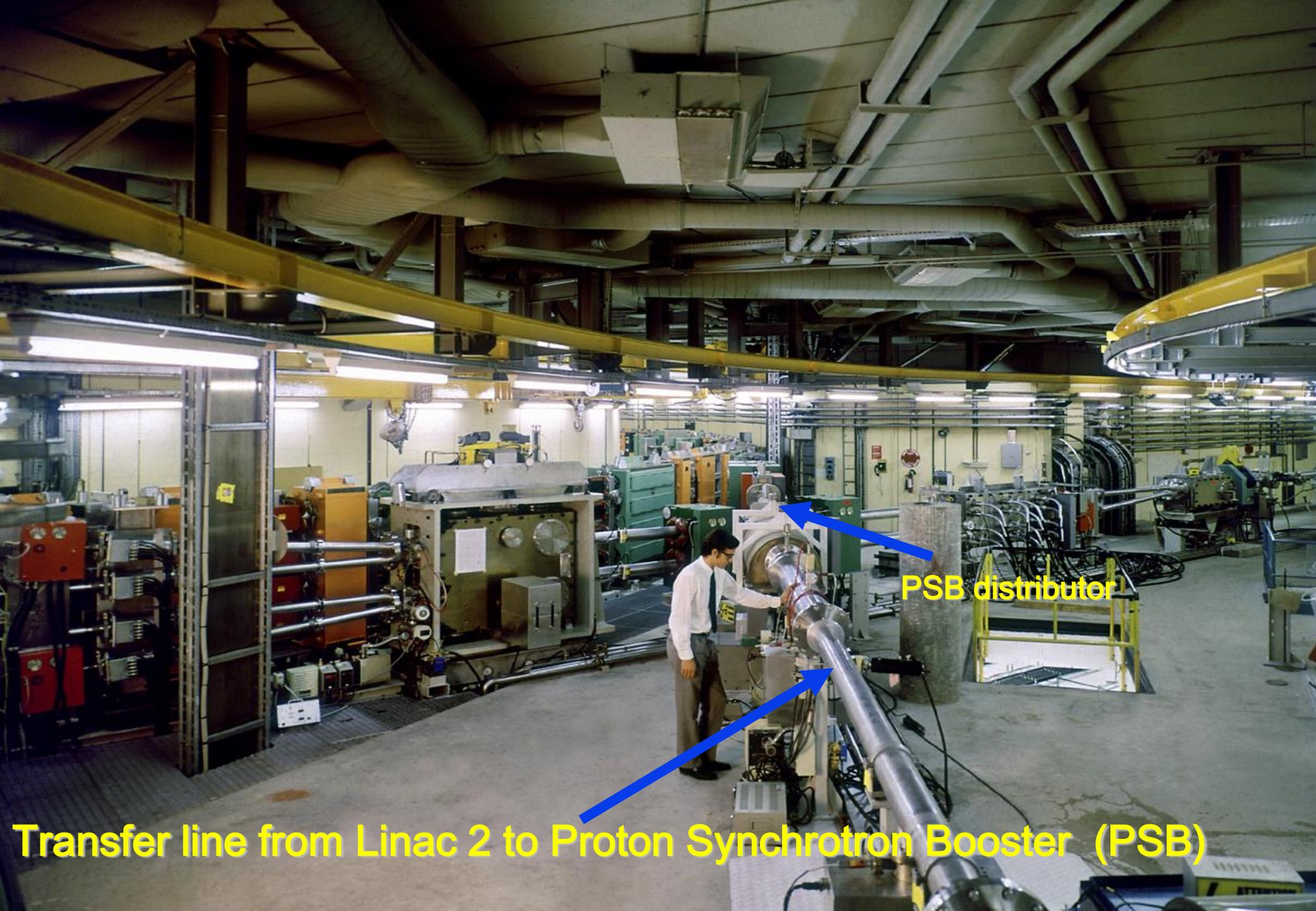
FILM BADGE

OBLIG
REQU

Temps de séjour limité
Limited occupancy time



Linac 2
30m ; 50MeV ; 180mA



PSB distributor

Transfer line from Linac 2 to Proton Synchrotron Booster (PSB)



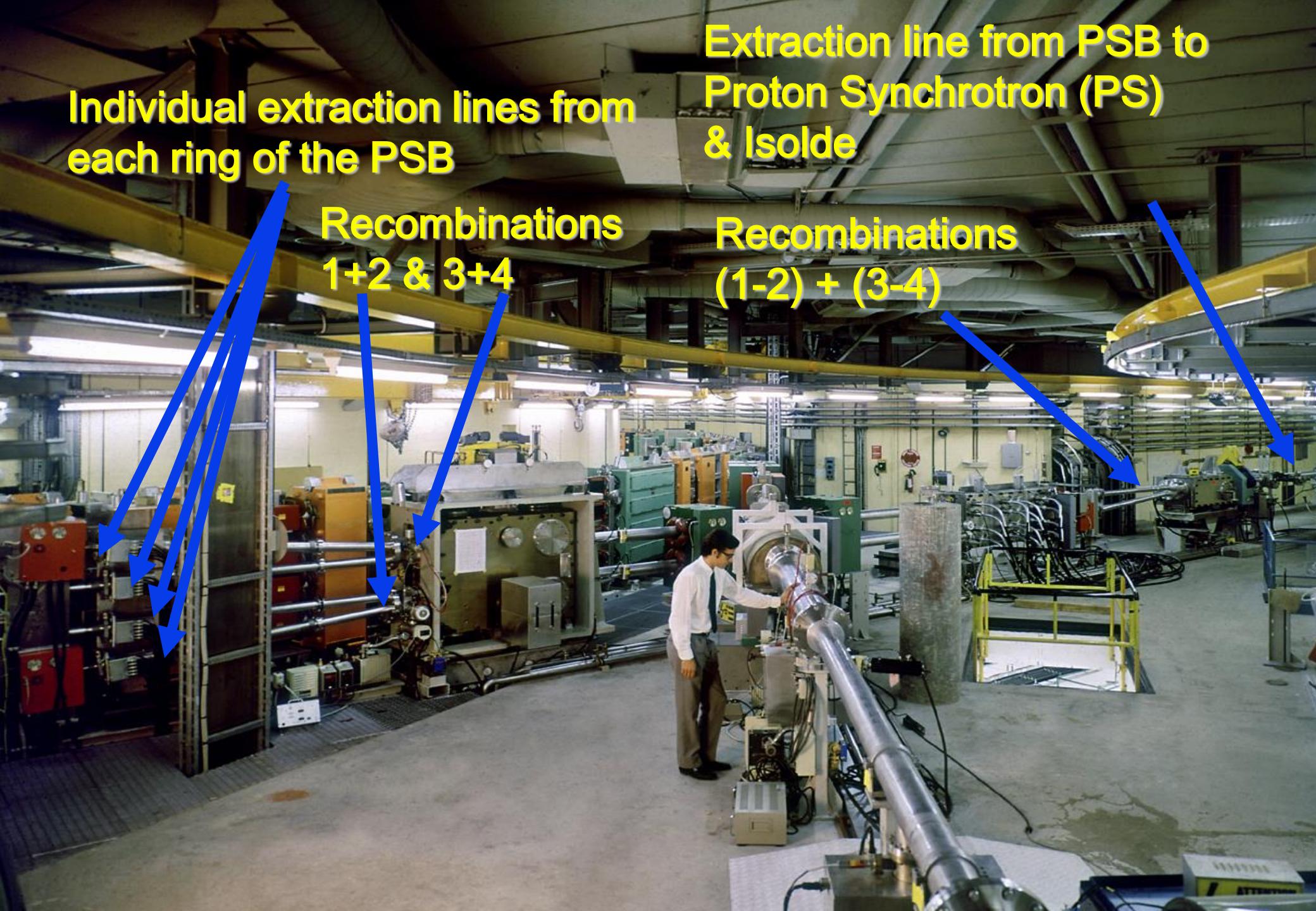
Proton Synchrotron Booster
4 rings ; 157m each
1.4GeV ; 10^{13} p⁺/ring

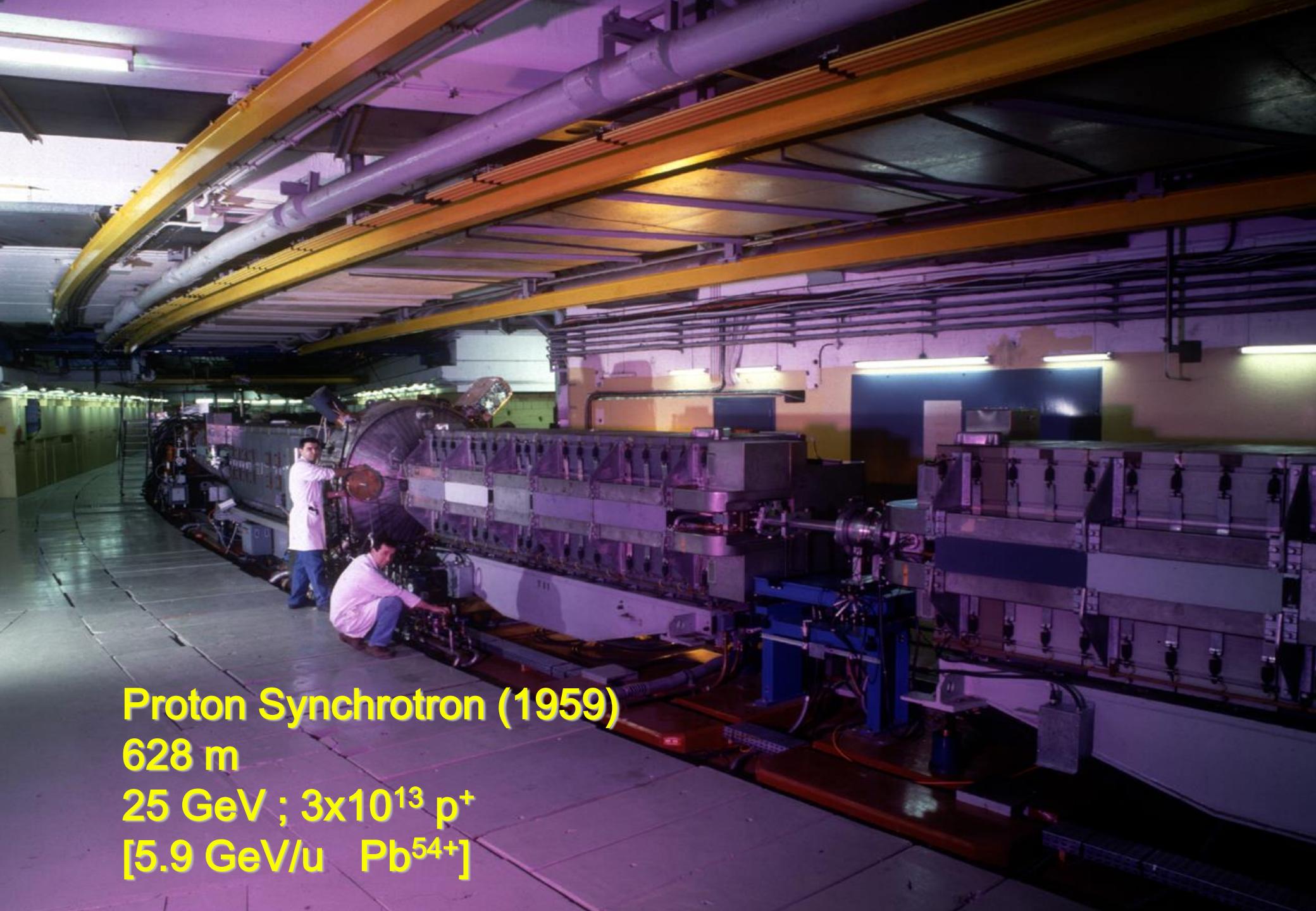
Individual extraction lines from each ring of the PSB

Extraction line from PSB to Proton Synchrotron (PS) & Isolde

Recombinations
1+2 & 3+4

Recombinations
(1-2) + (3-4)





Proton Synchrotron (1959)

628 m

25 GeV ; 3×10^{13} p⁺
[5.9 GeV/u Pb⁵⁴⁺]



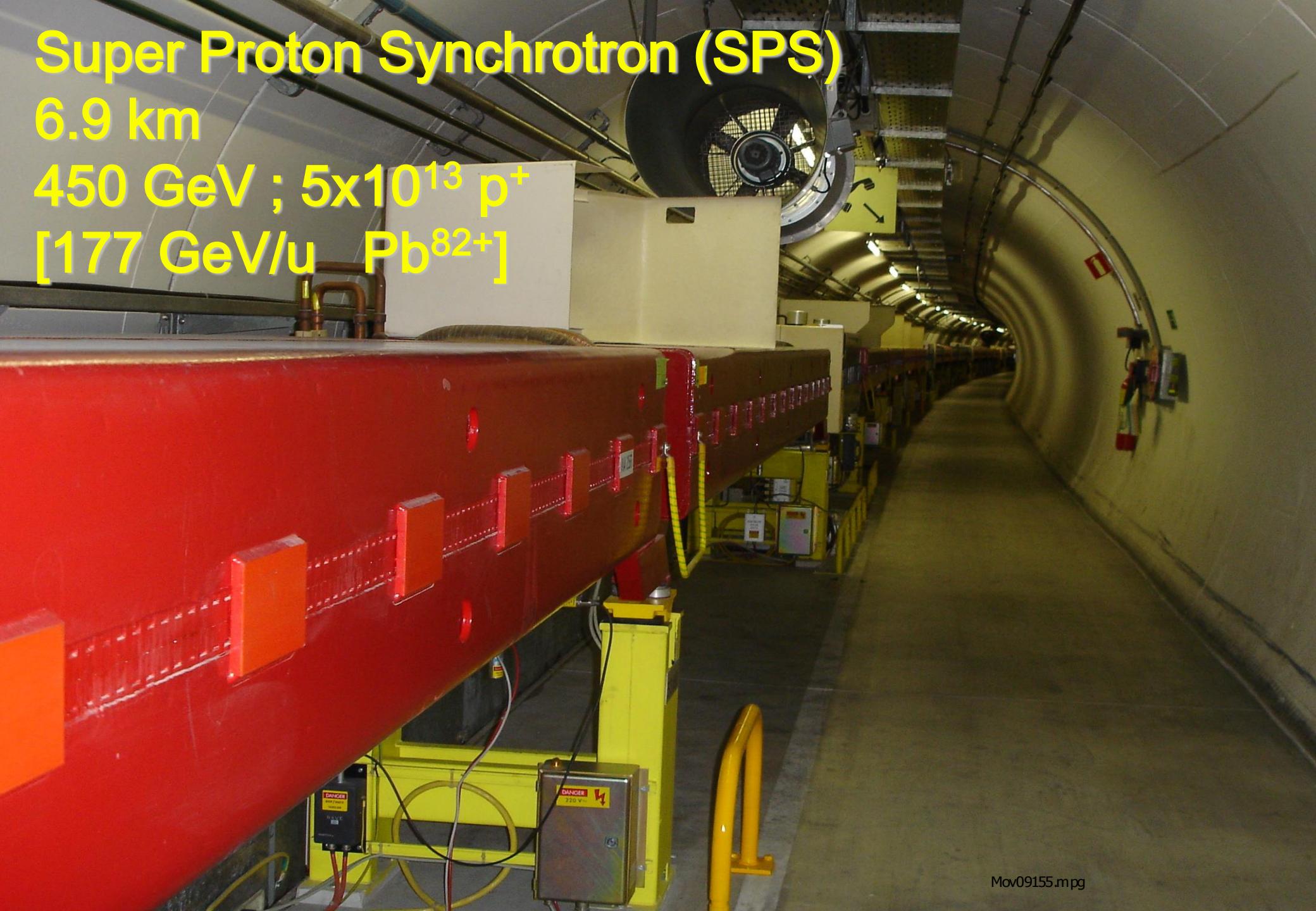
TT2 transfer line from PS to SPS, AD,
nTOF, and D3 dump

Super Proton Synchrotron (SPS)

6.9 km

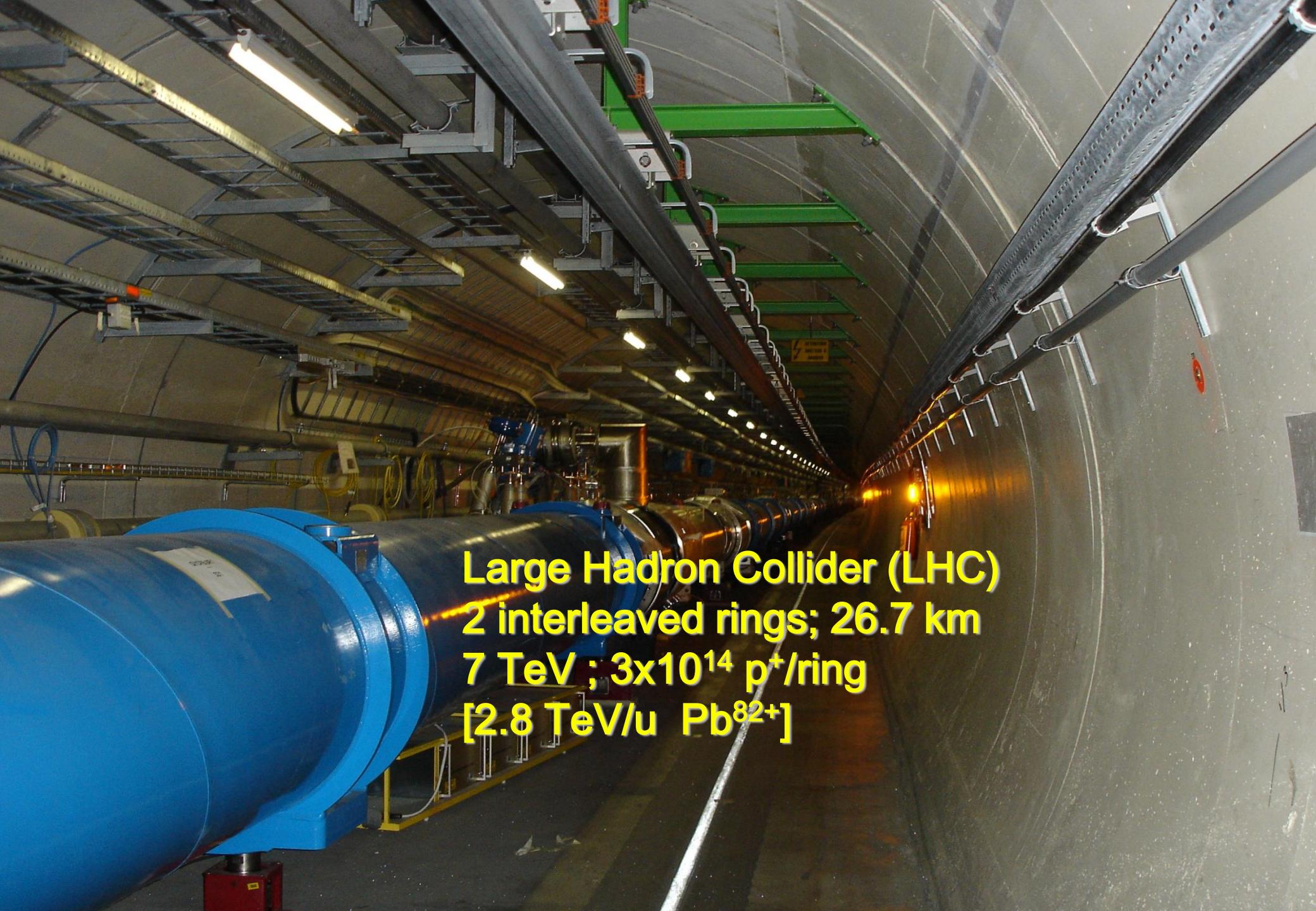
450 GeV ; 5×10^{13} p⁺

[177 GeV/u Pb⁸²⁺]





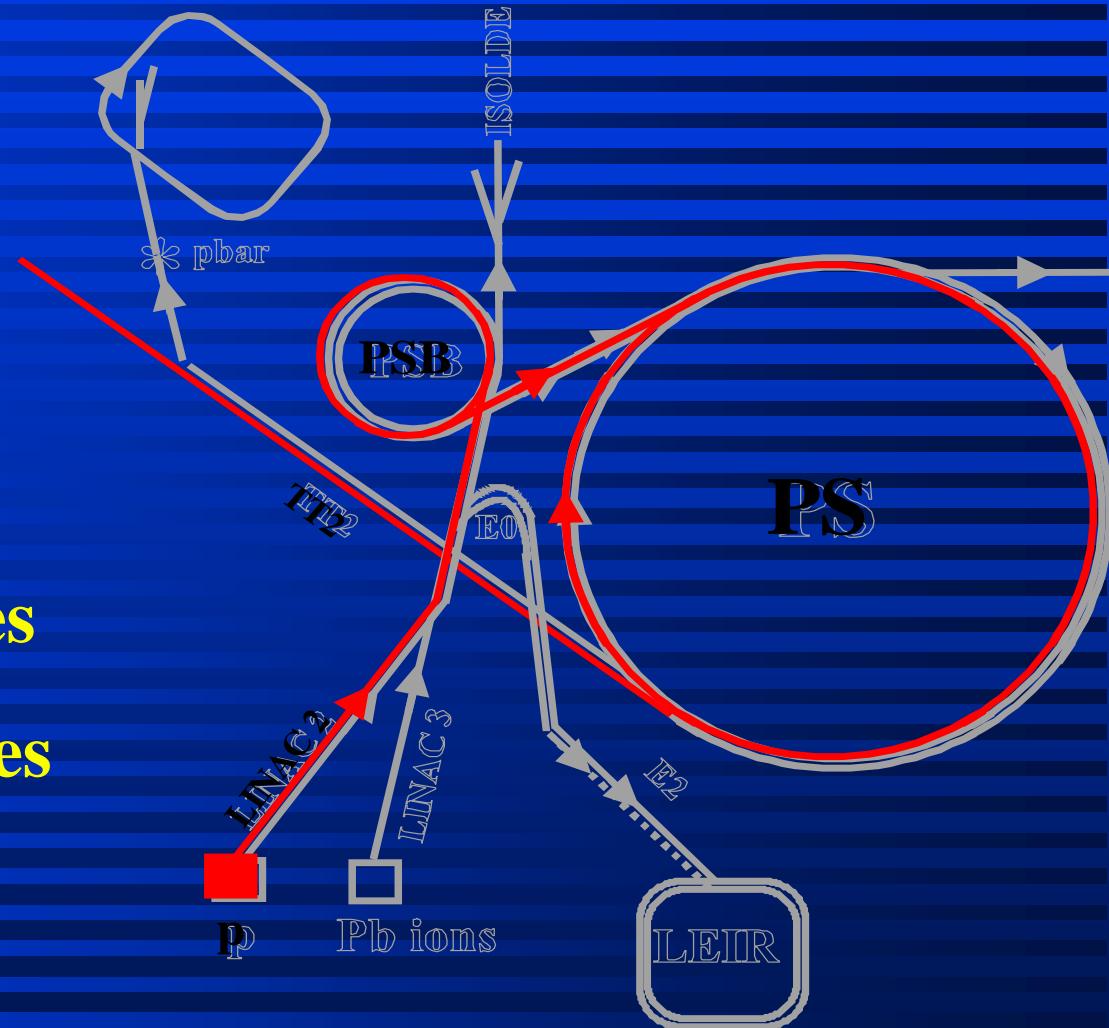
TI8 counter-clockwise transfer line from SPS to LHC

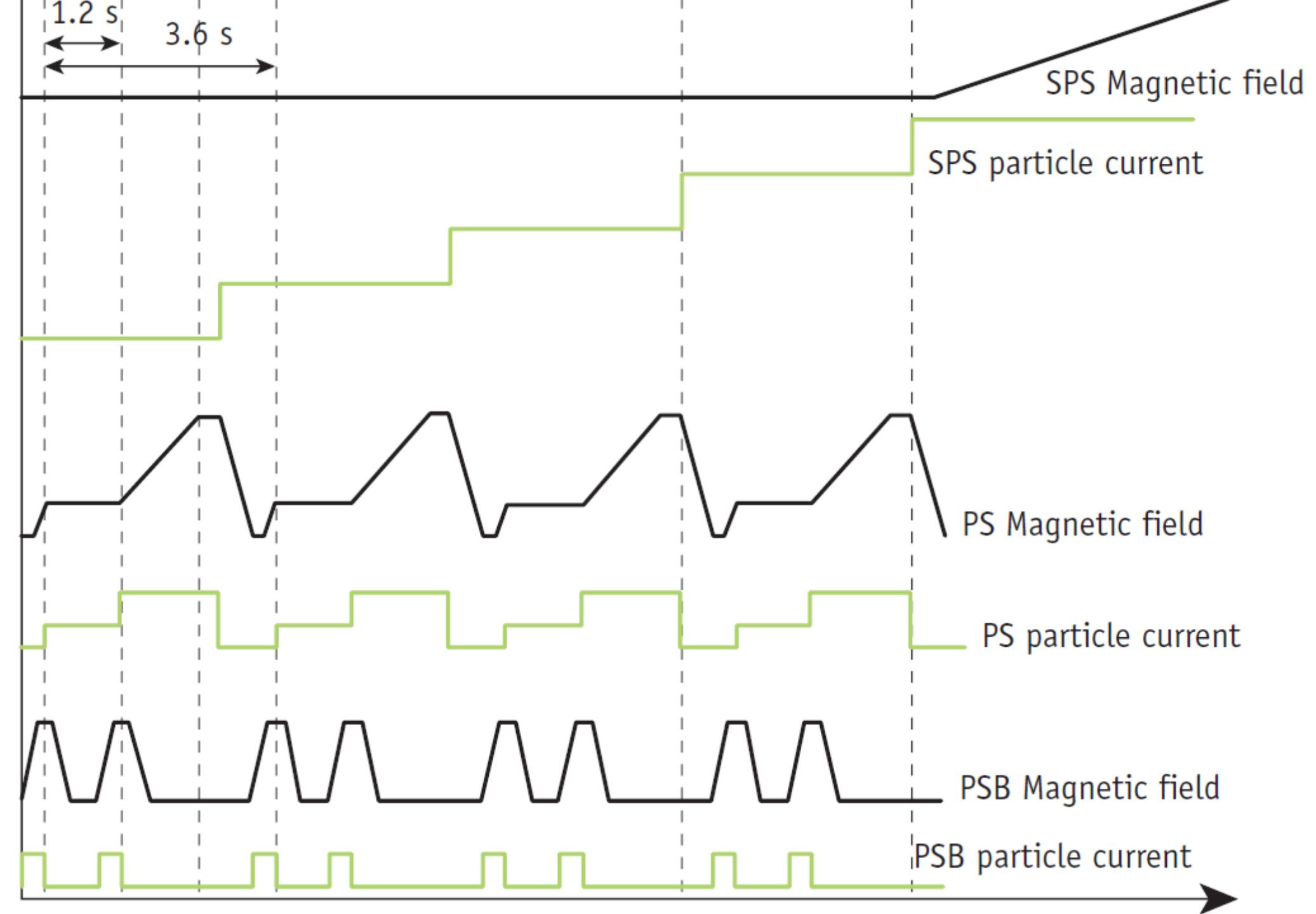


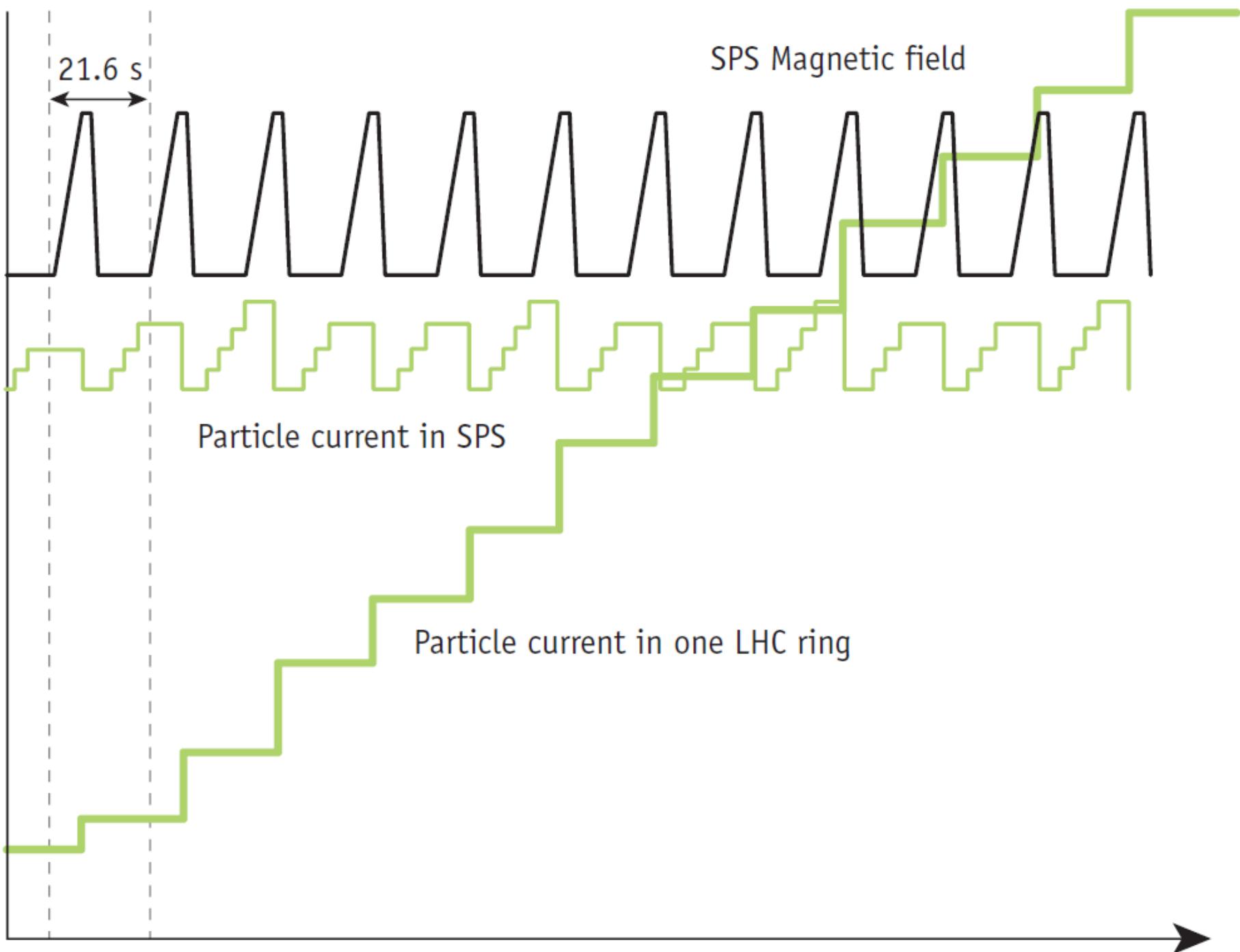
Large Hadron Collider (LHC)
2 interleaved rings; 26.7 km
7 TeV ; 3×10^{14} p⁺/ring
[2.8 TeV/u Pb⁸²⁺]

Proton beam production for LHC

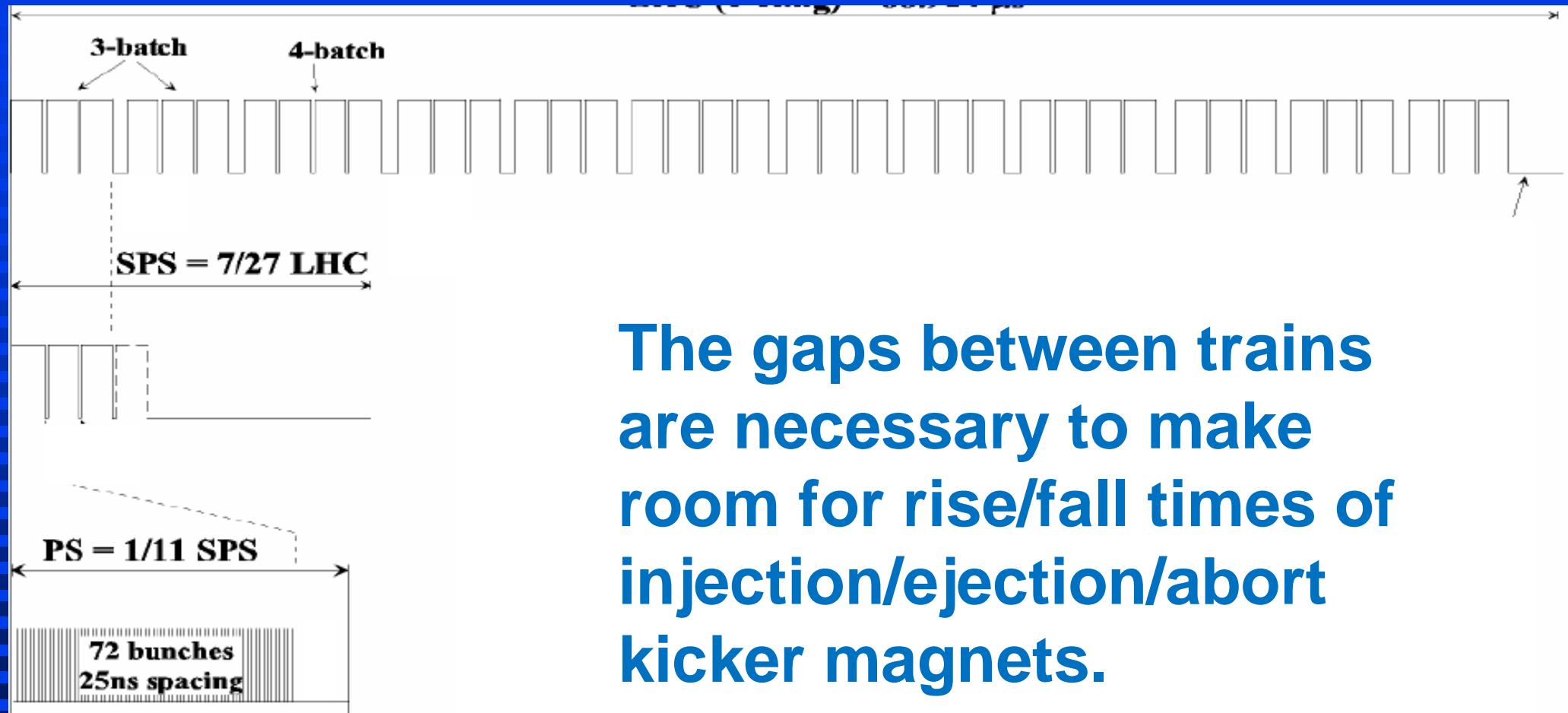
- Linac2 (50MeV)
- PSB (1.4GeV) 4+2 bunches
- PS (25GeV) 72 bunches
- SPS (450 GeV) 4 x 72 bunches
- LHC (7 TeV) 2 x 2808 bunches



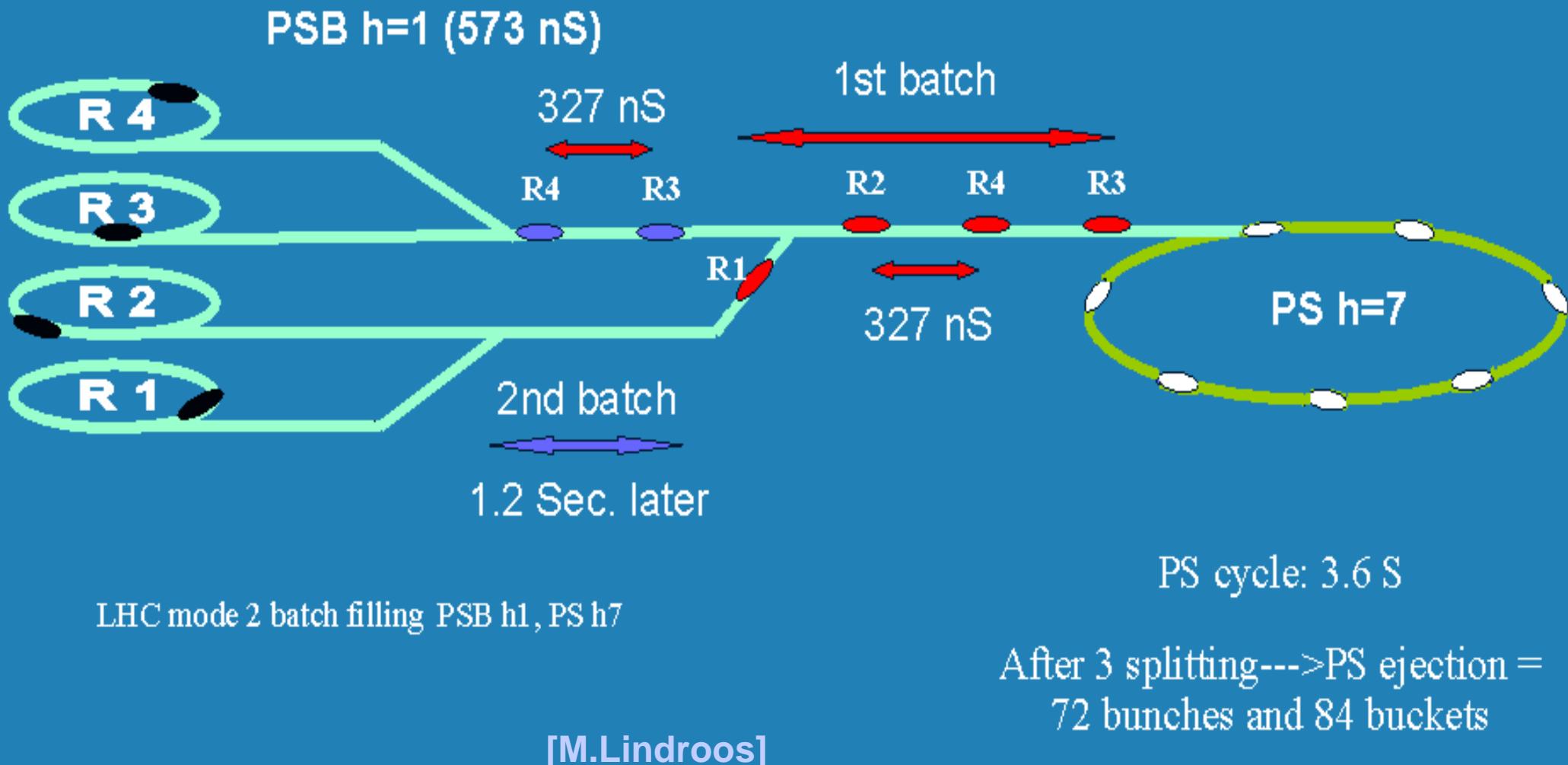


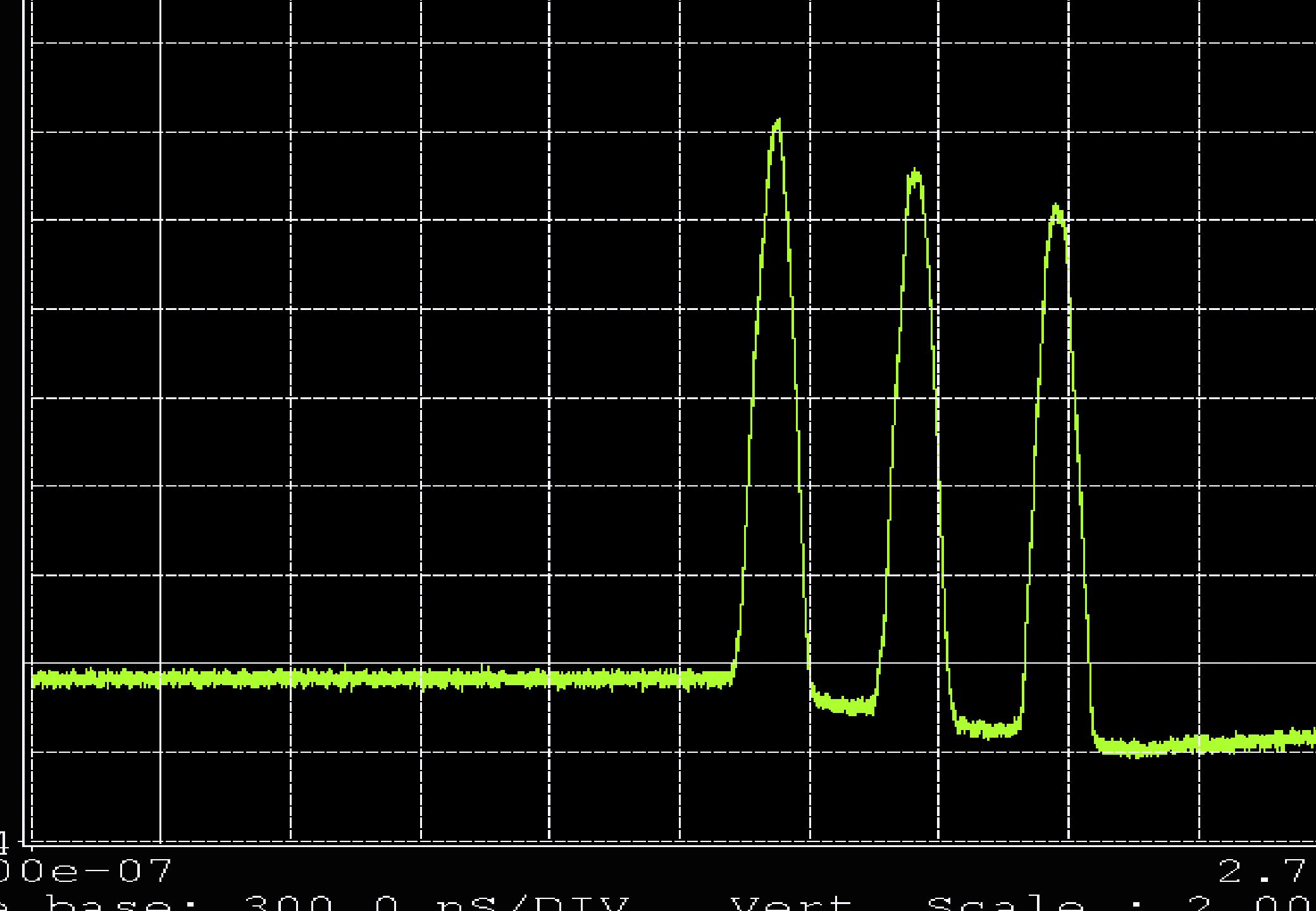


12 injections from SPS to LHC



Double batch injection from PSB to PS





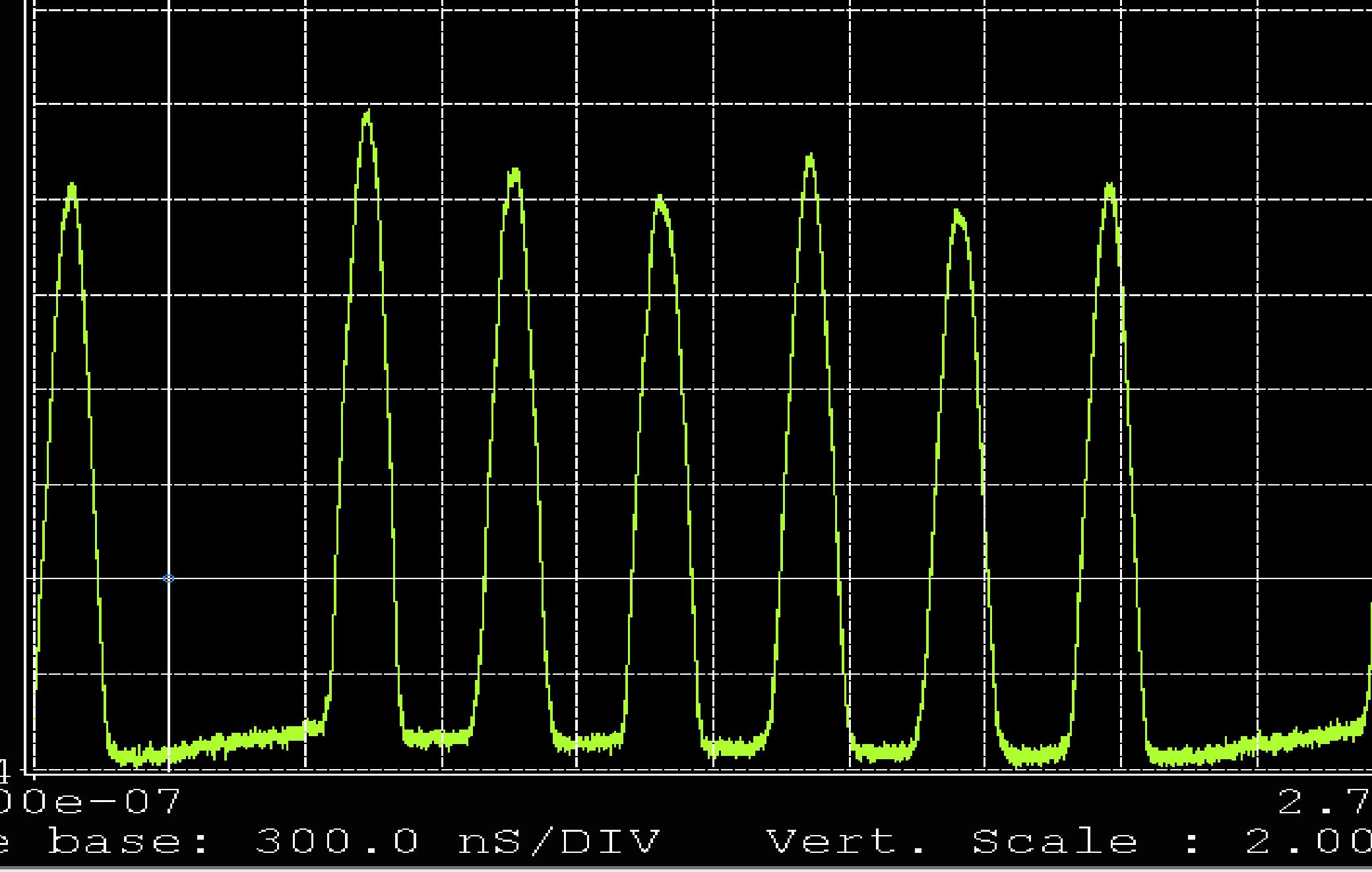
300e-07

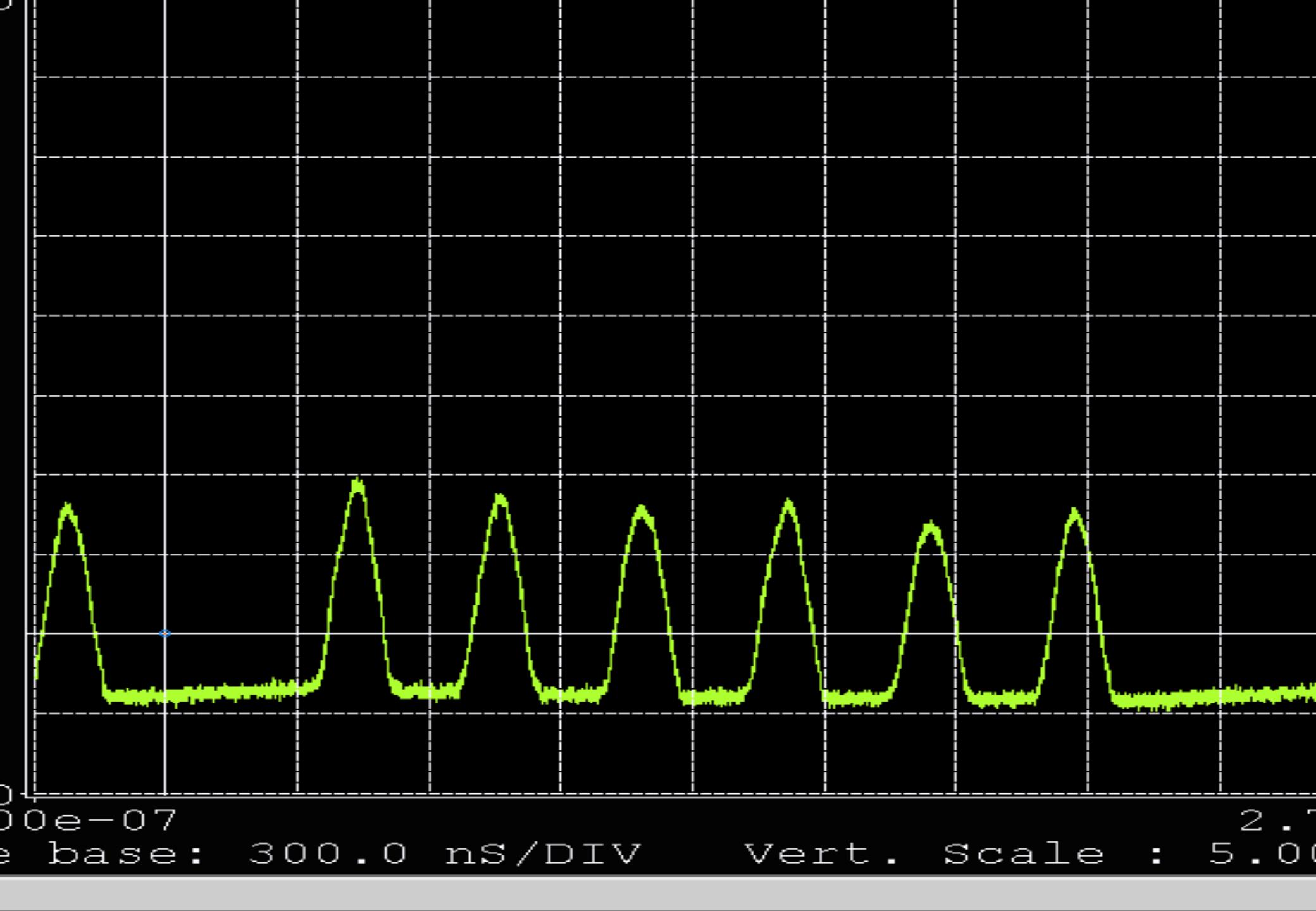
base: 300.0 ns/DIV

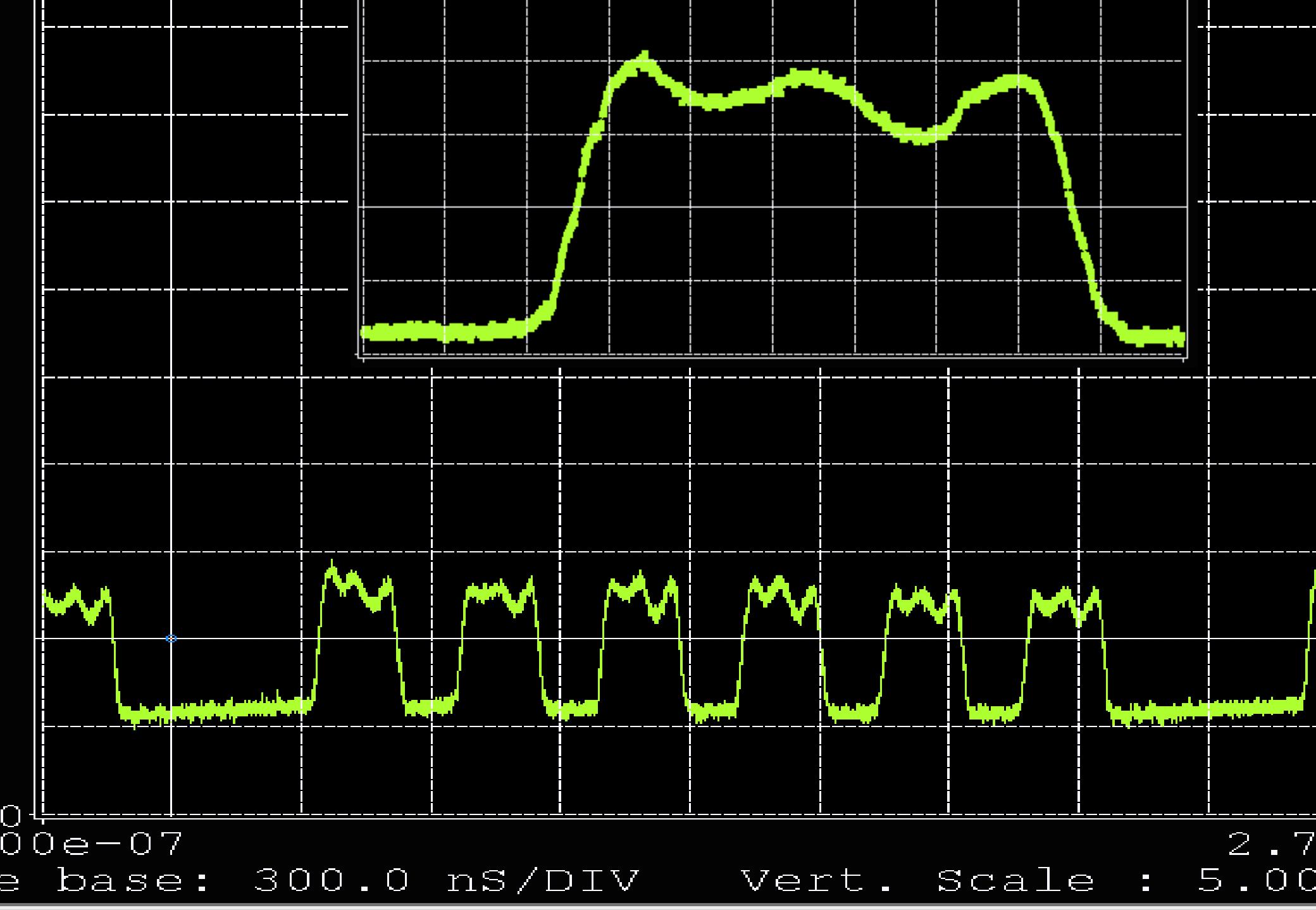
Vert Scale

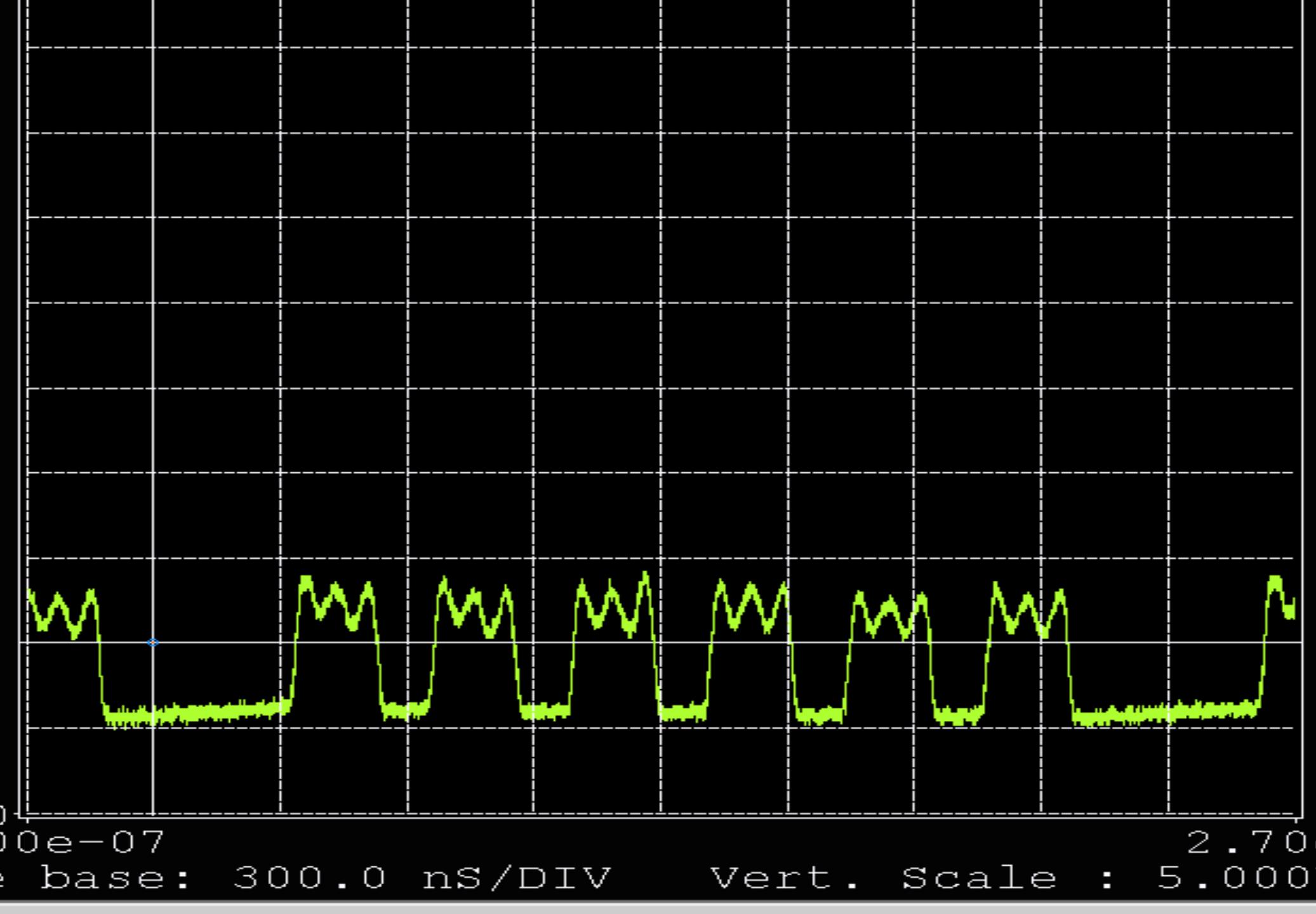
: 2.00

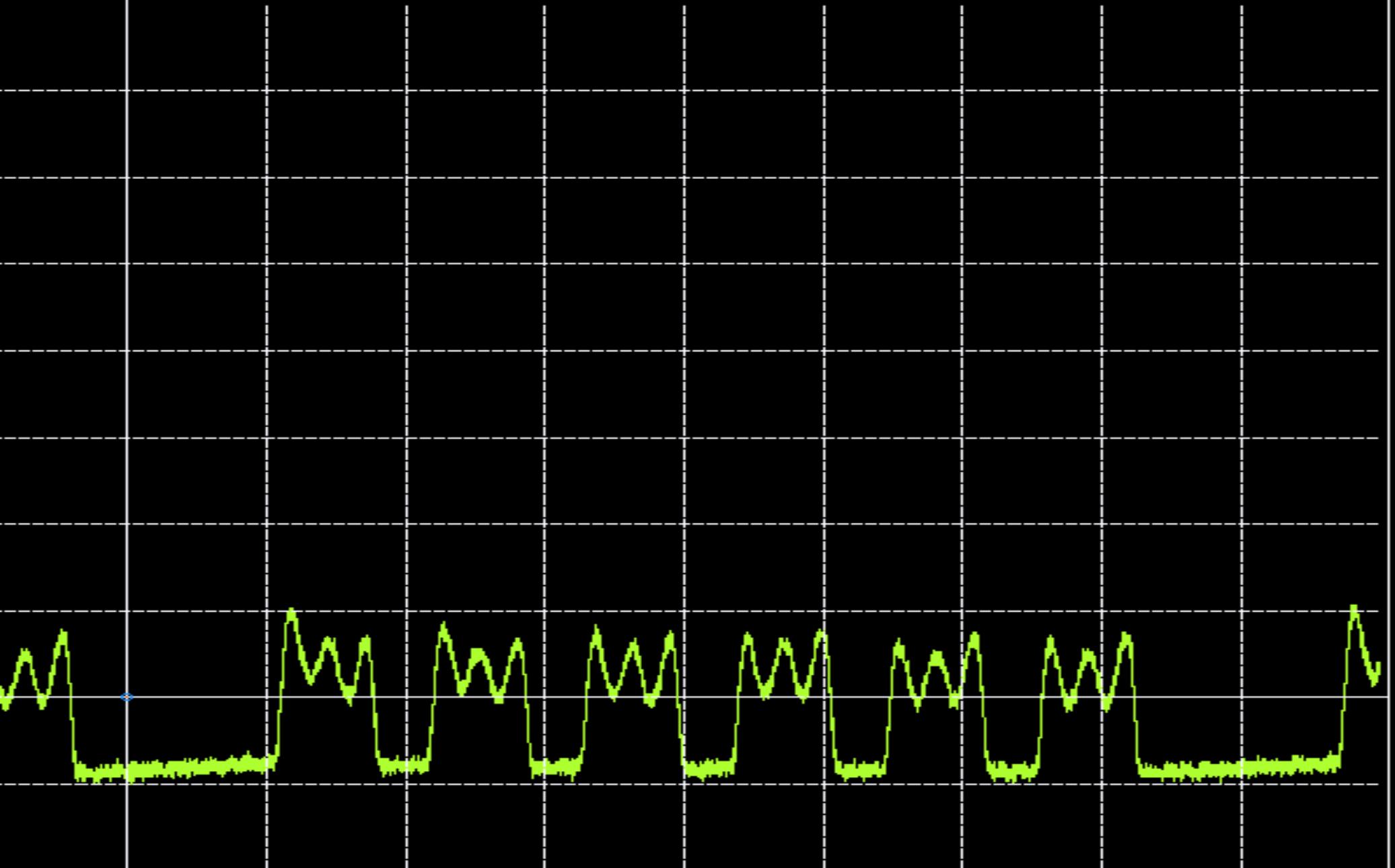
2.7









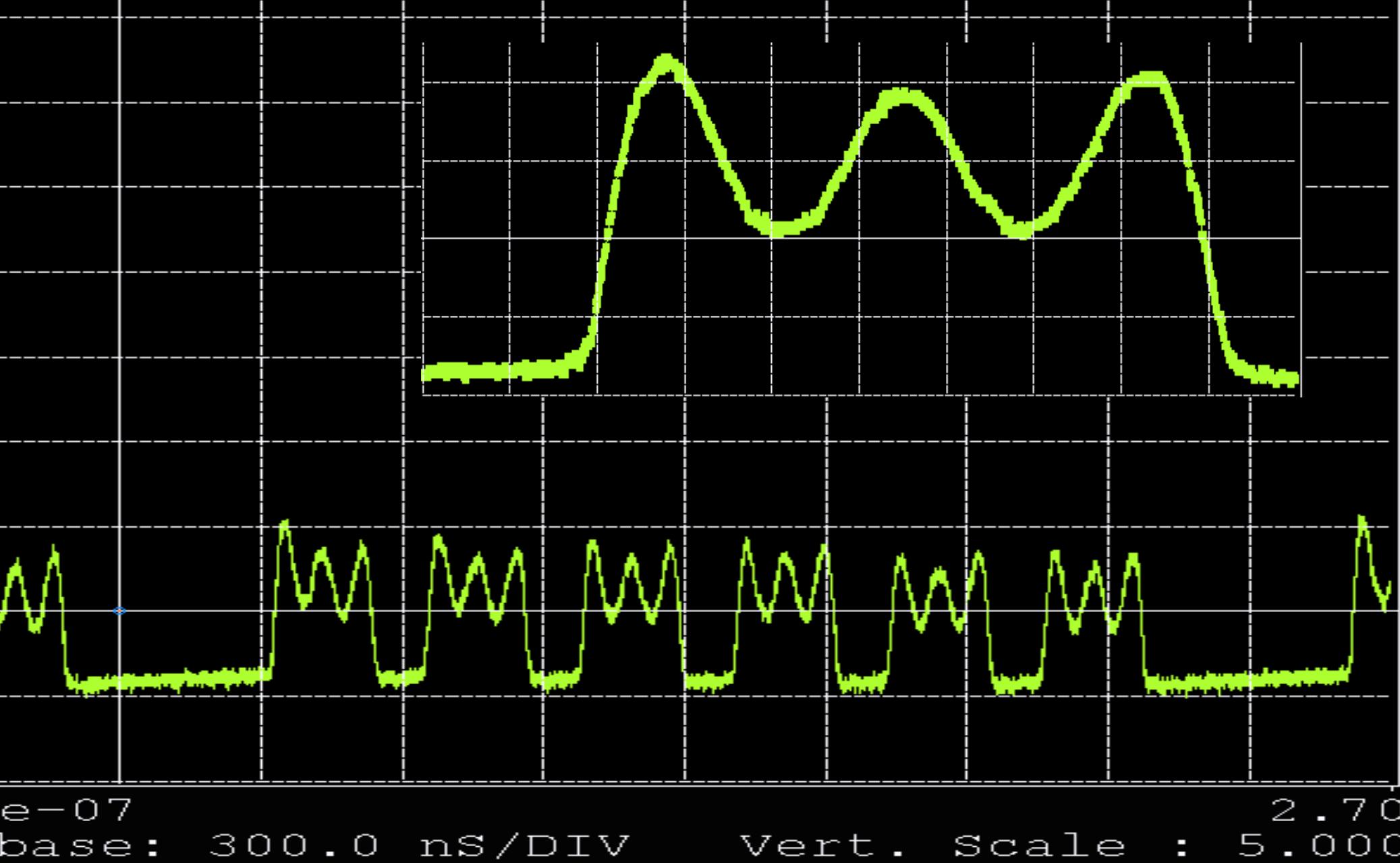


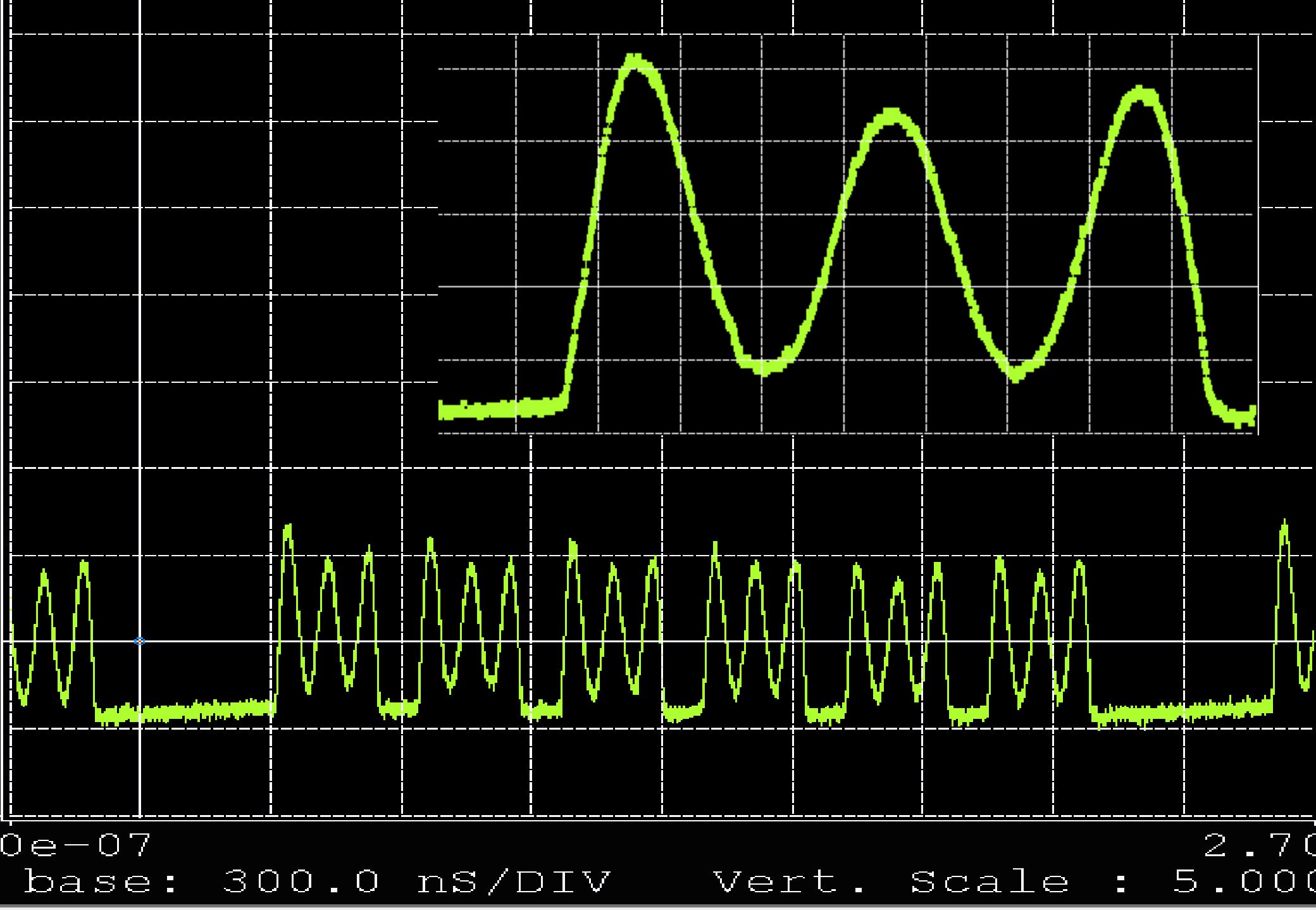
e-07

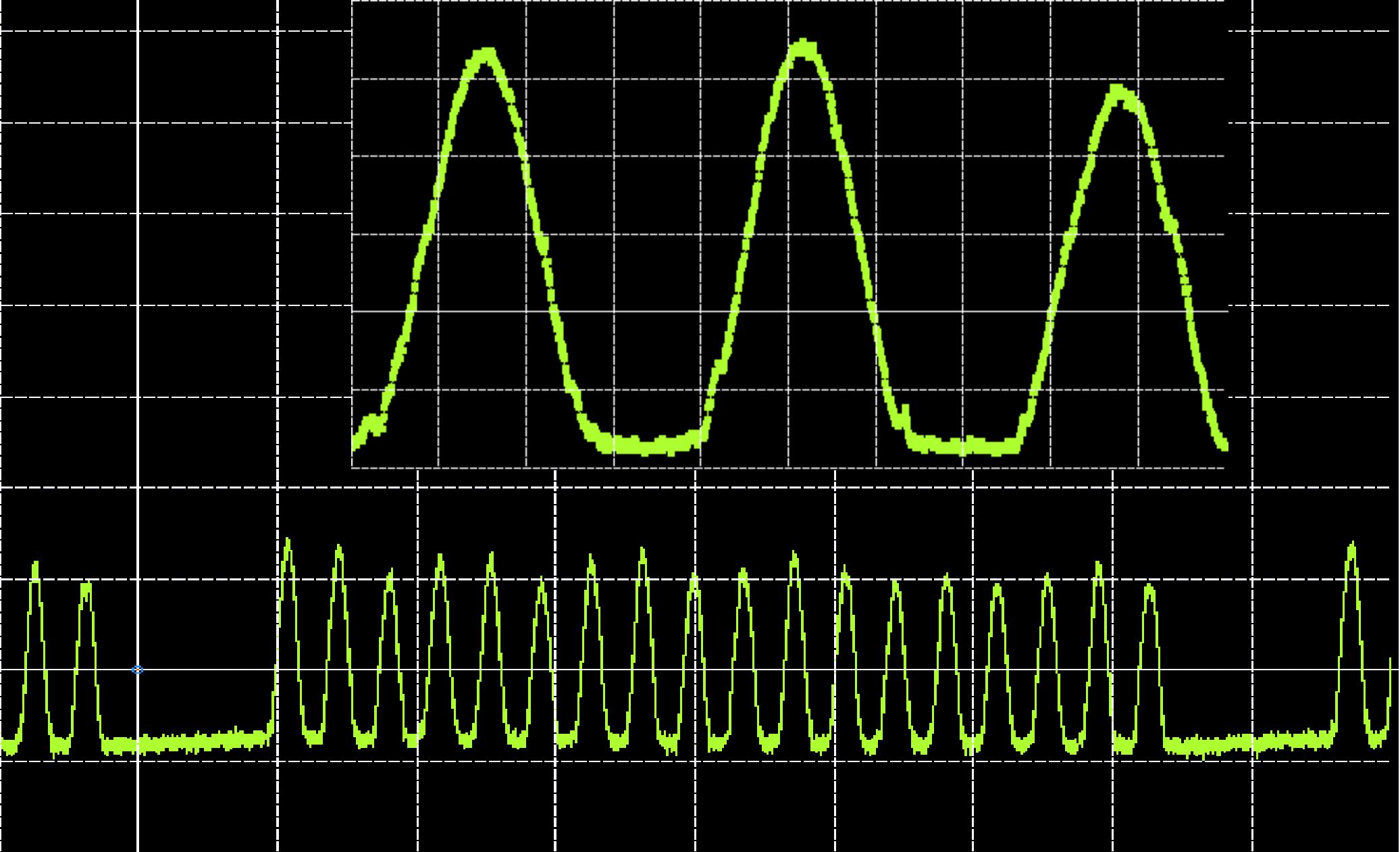
base: 300.0 ns/DIV

2.70

Vert. Scale : 5.000







0e-07

base: 300.0 ns/DIV

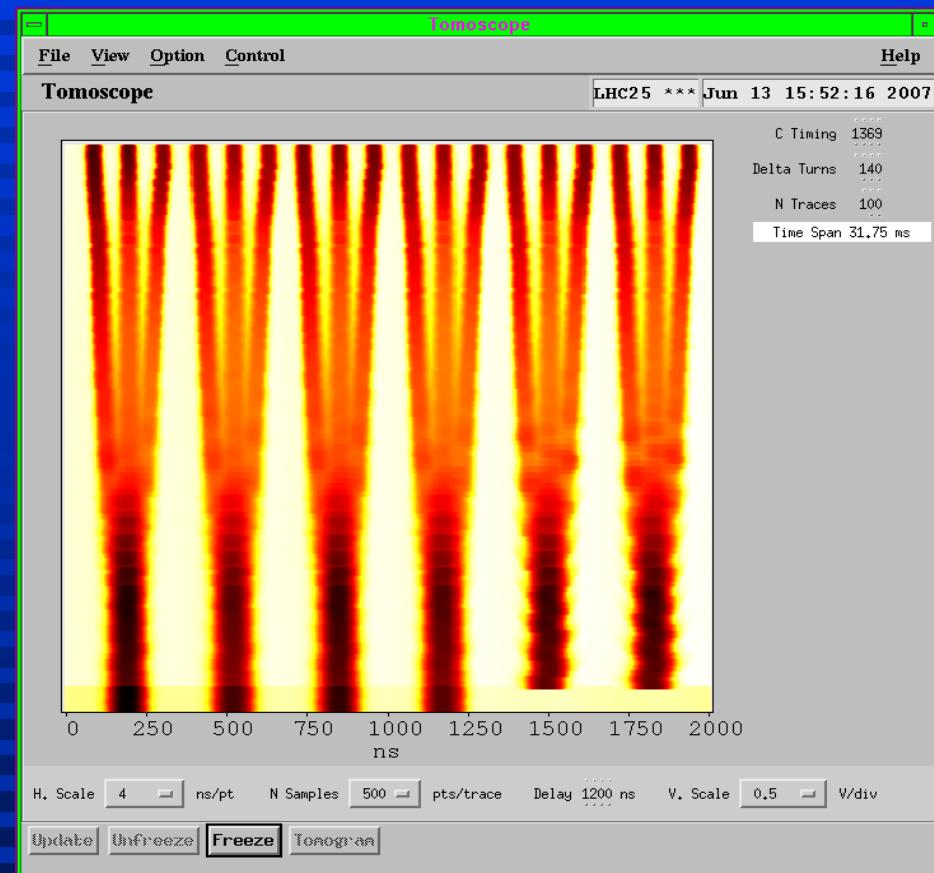
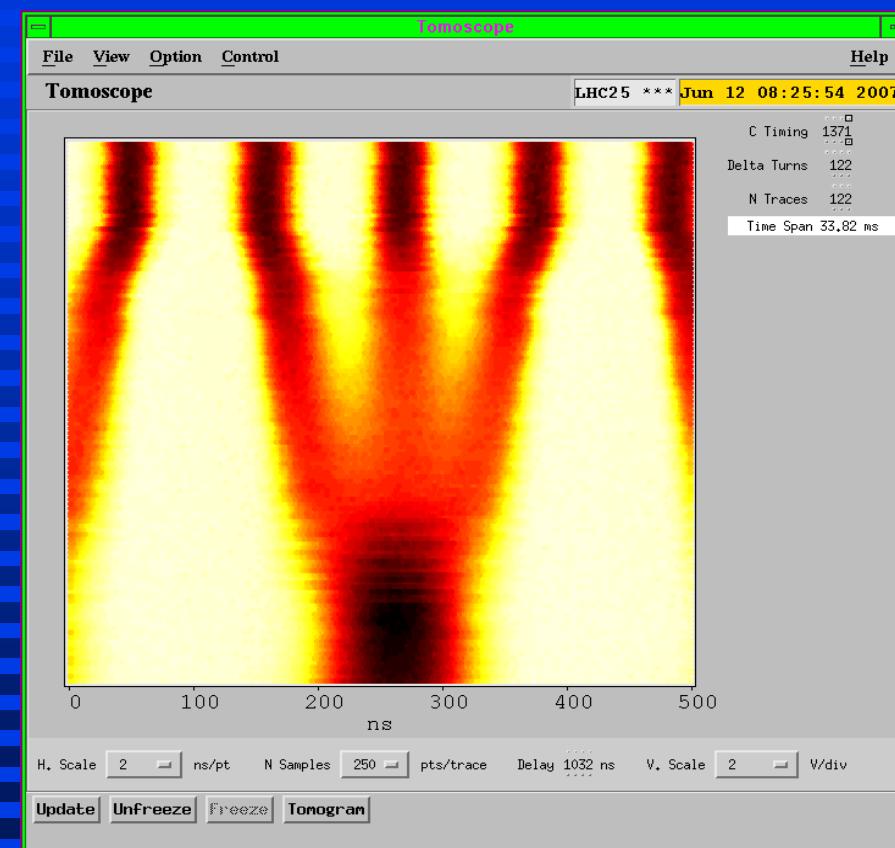
2.70

Vert. Scale : 5.000

Triple bunch splitting in PS

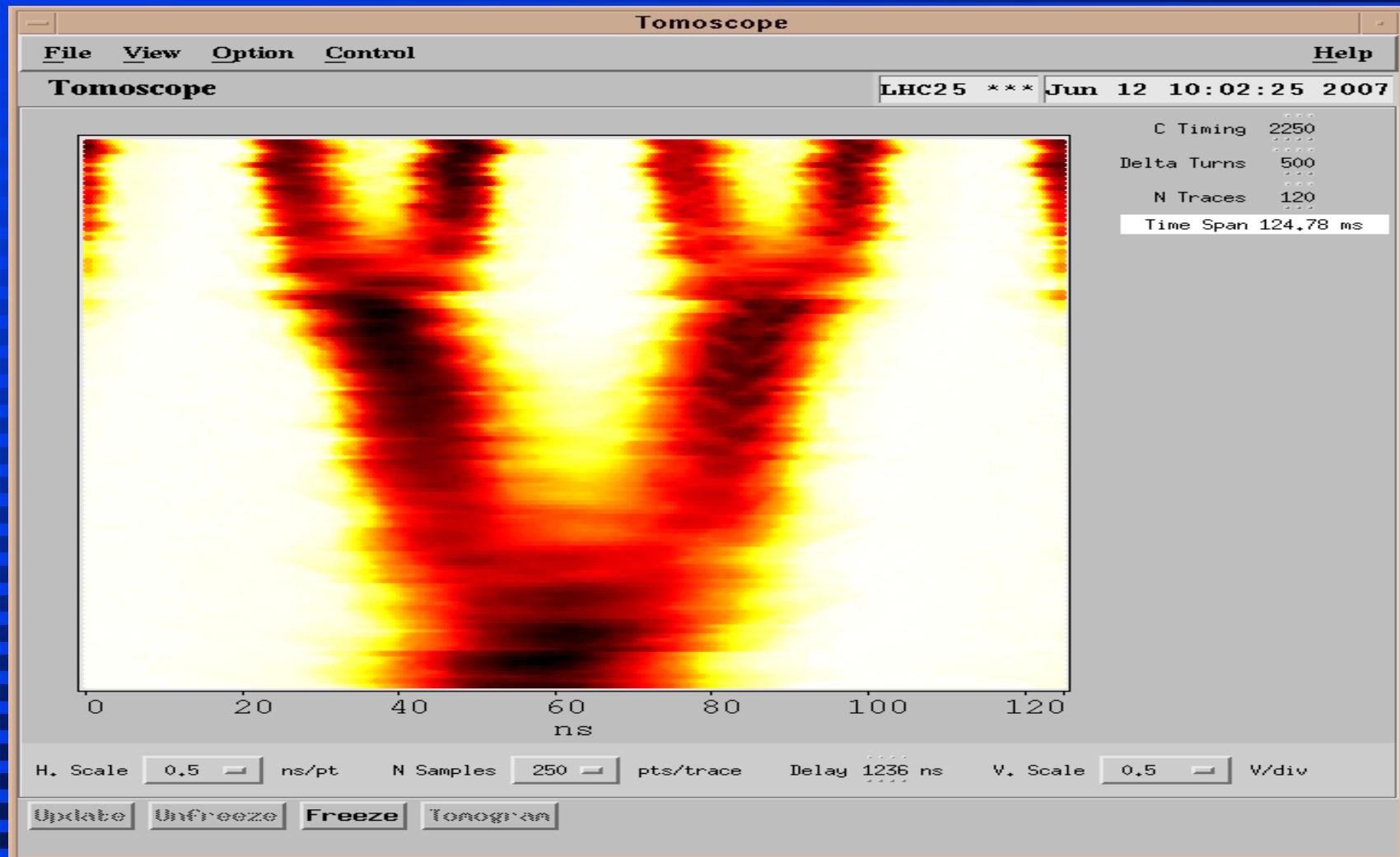
“Waterfall” representation: V=time, H=position, colour=density

time

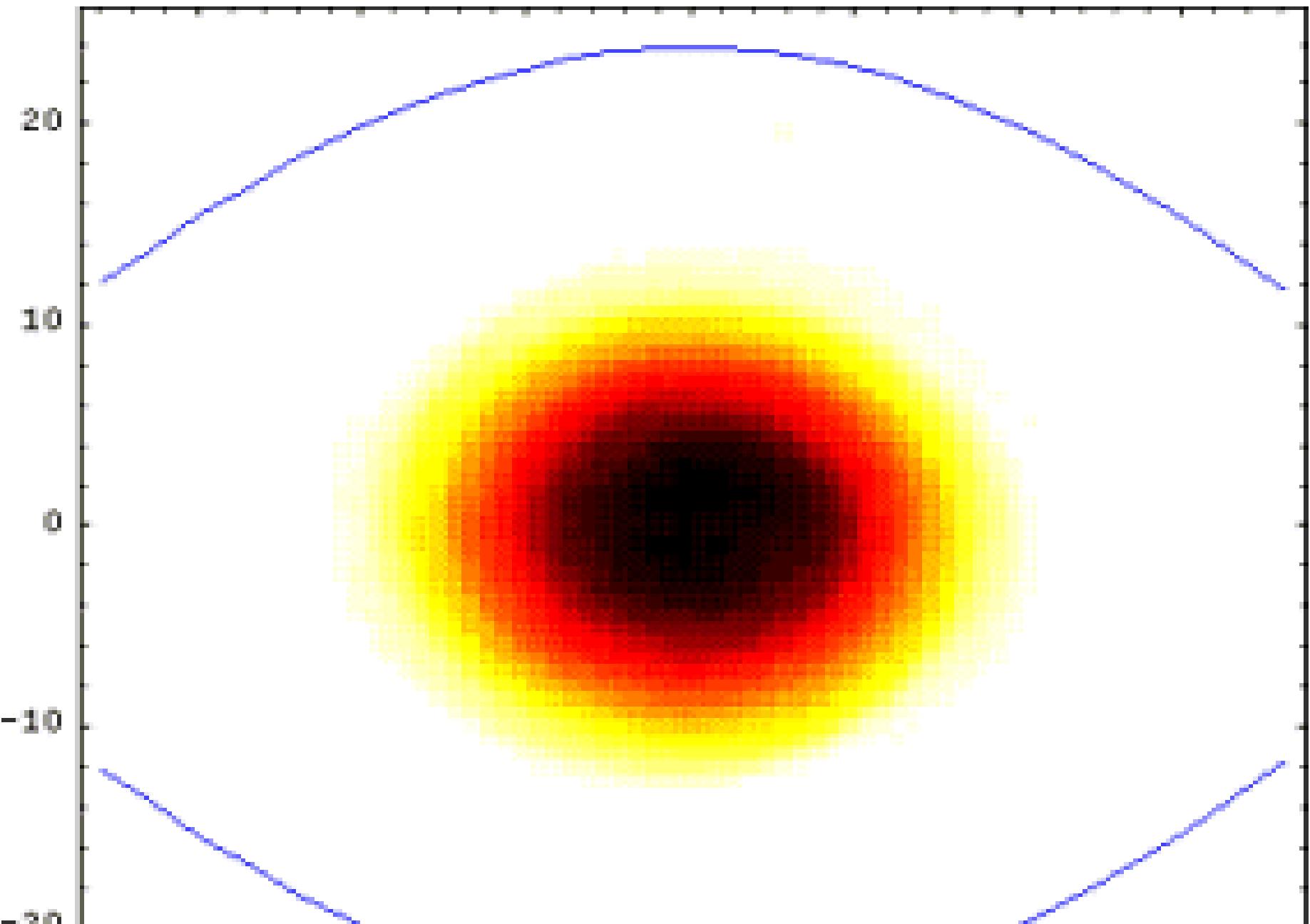


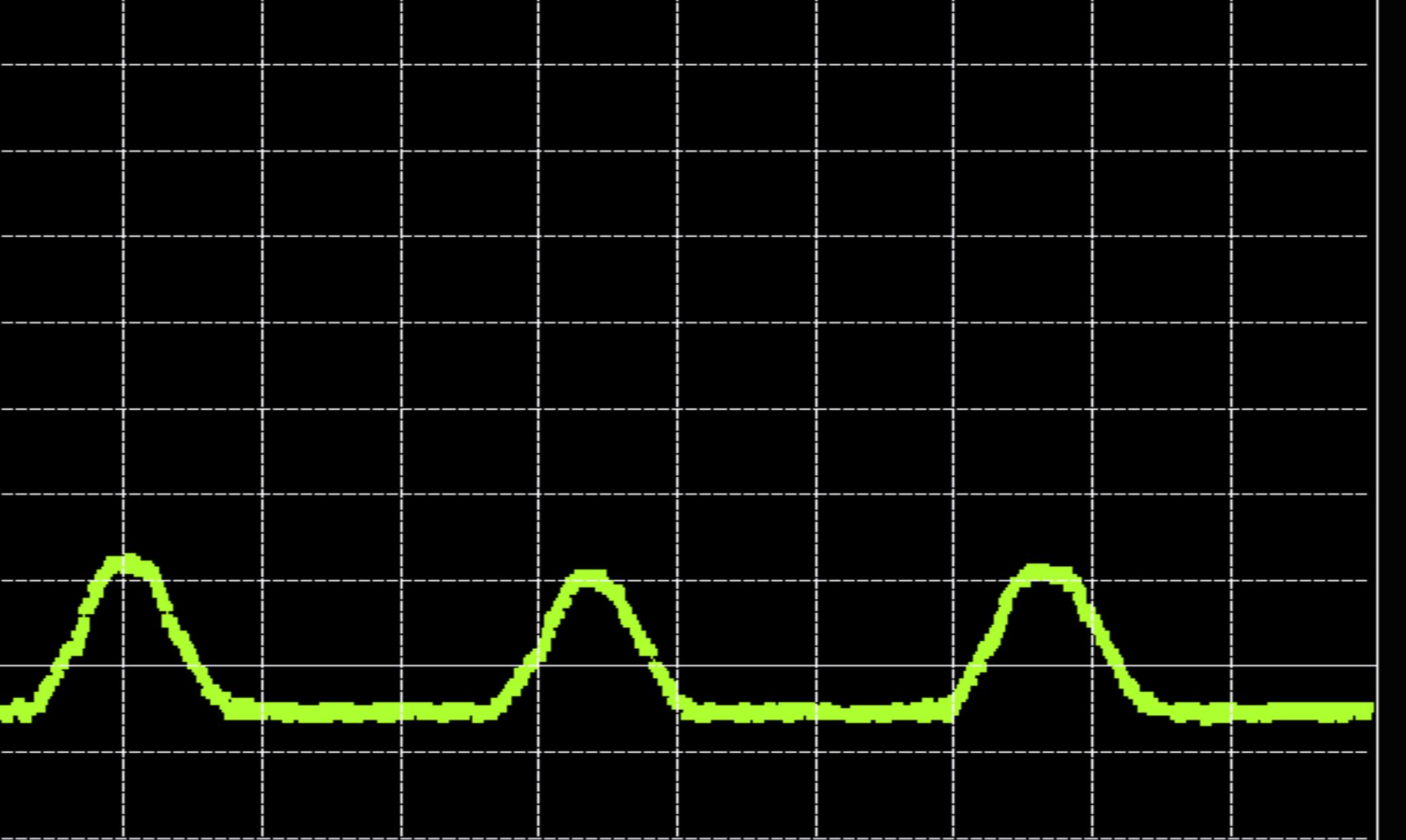
→ position

Two more bunch splittings in PS

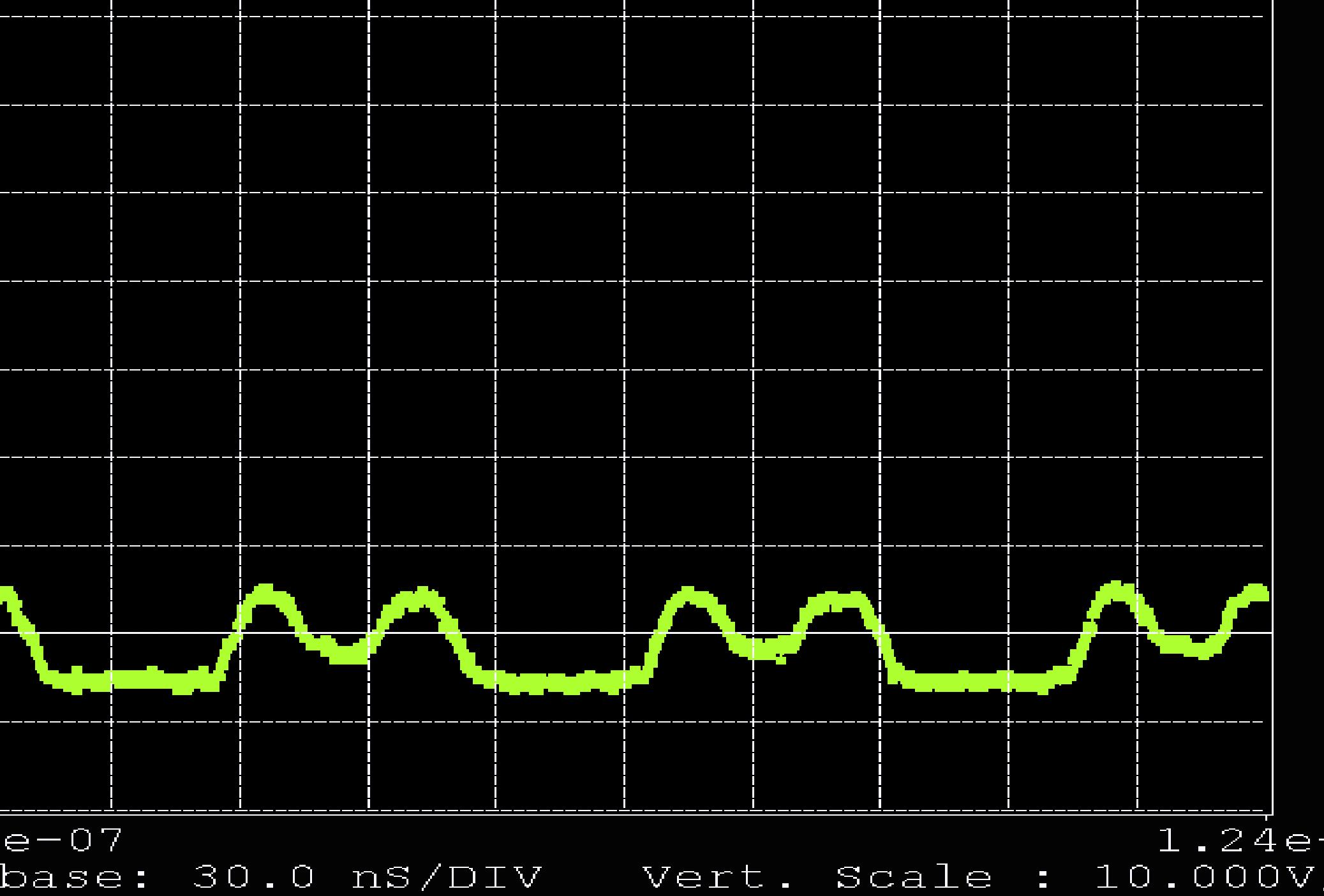


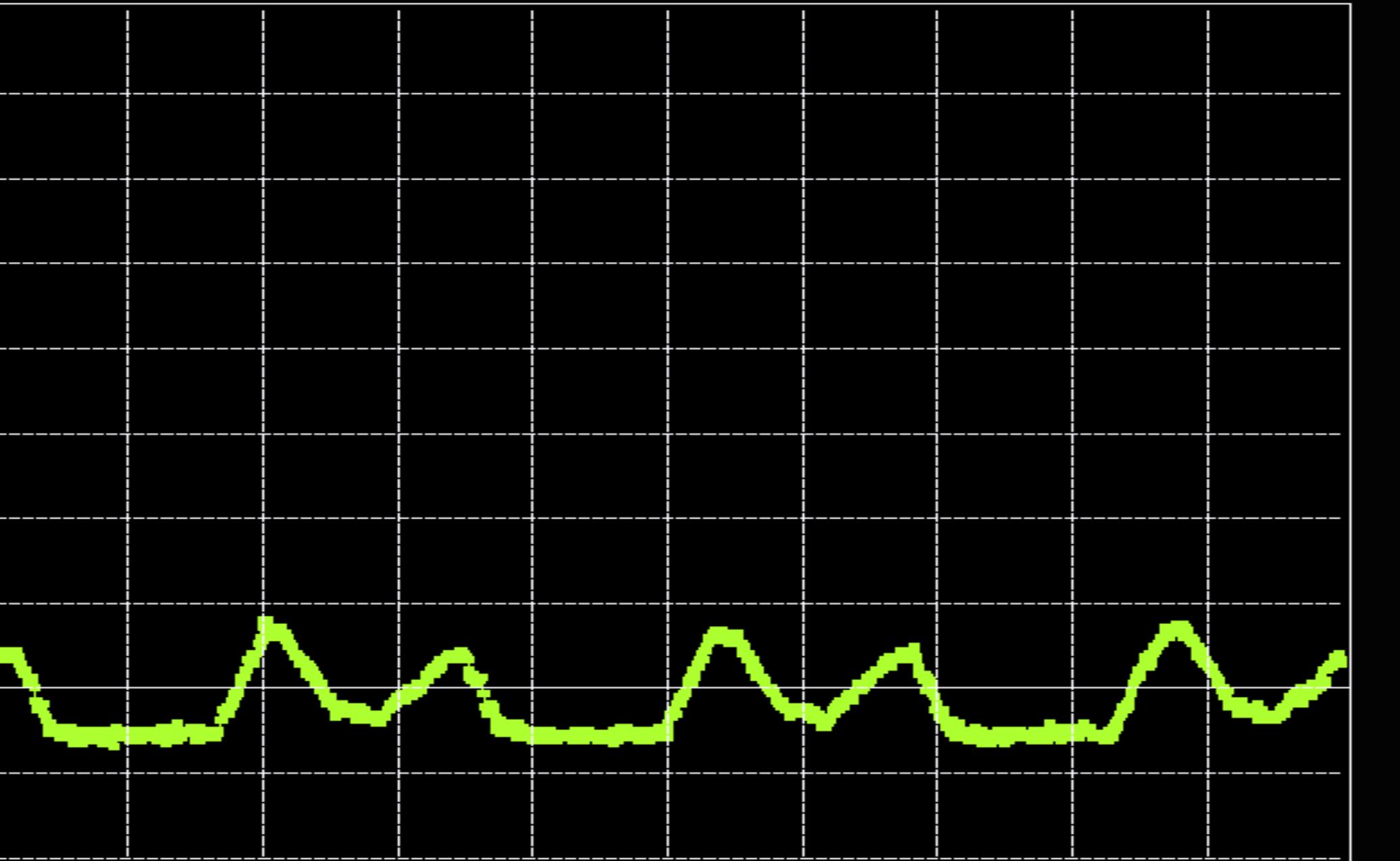
MeV





e-07 1.24e
base: 30.0 ns/DIV Vert. Scale : 10.000v



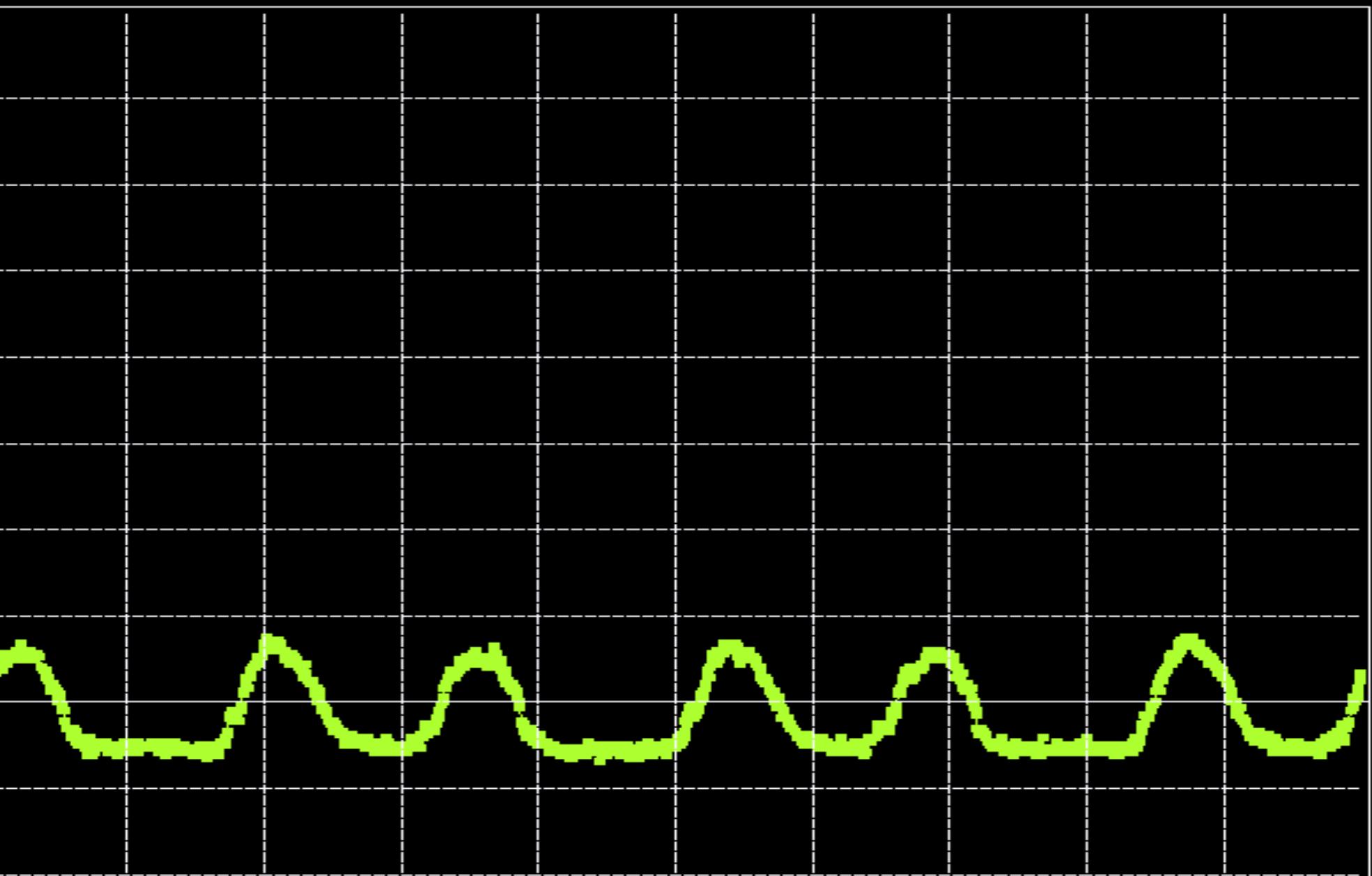


5e-07

base: 30.0 nS/DIV

1.24e-

vert. Scale : 10.000V

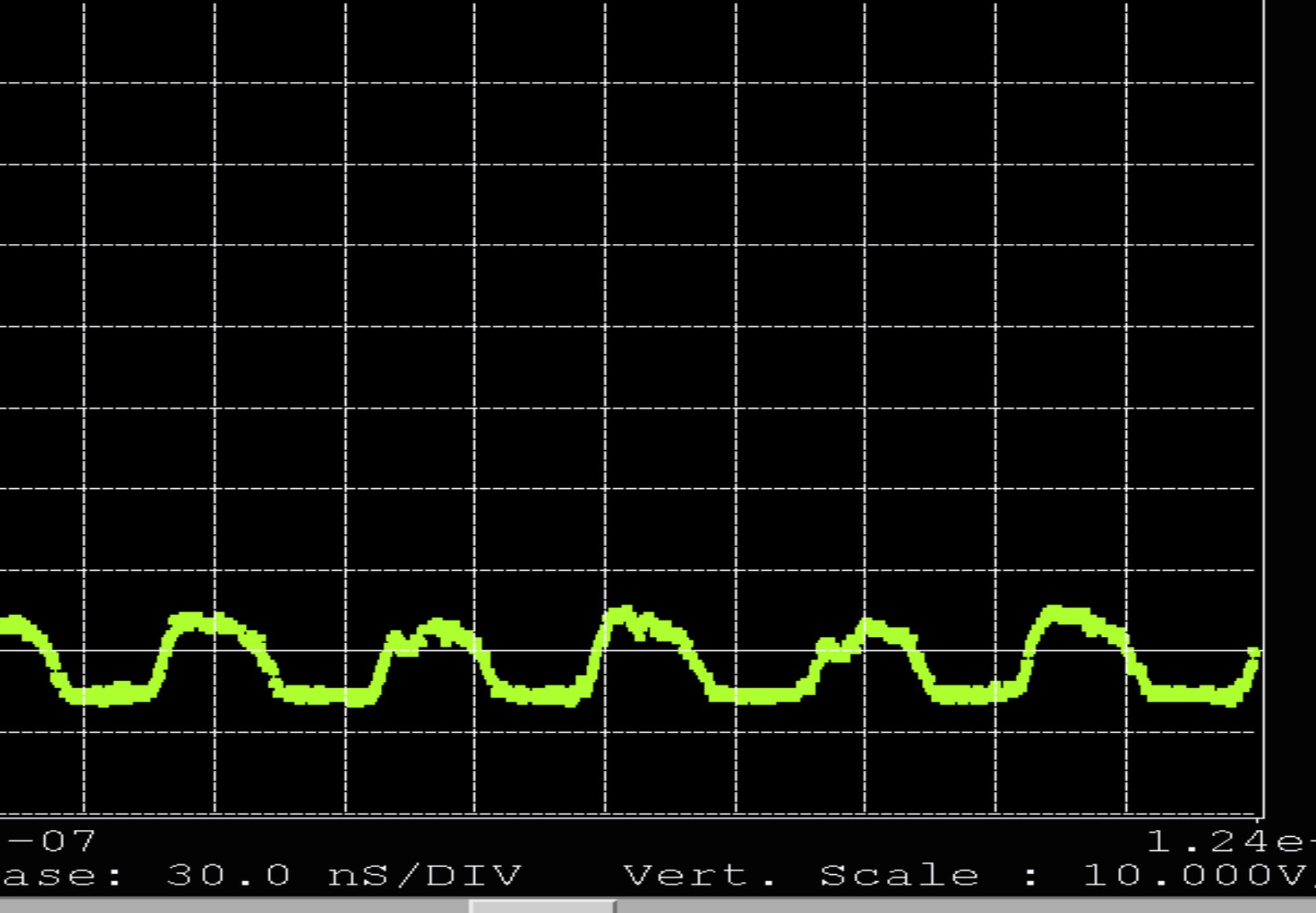


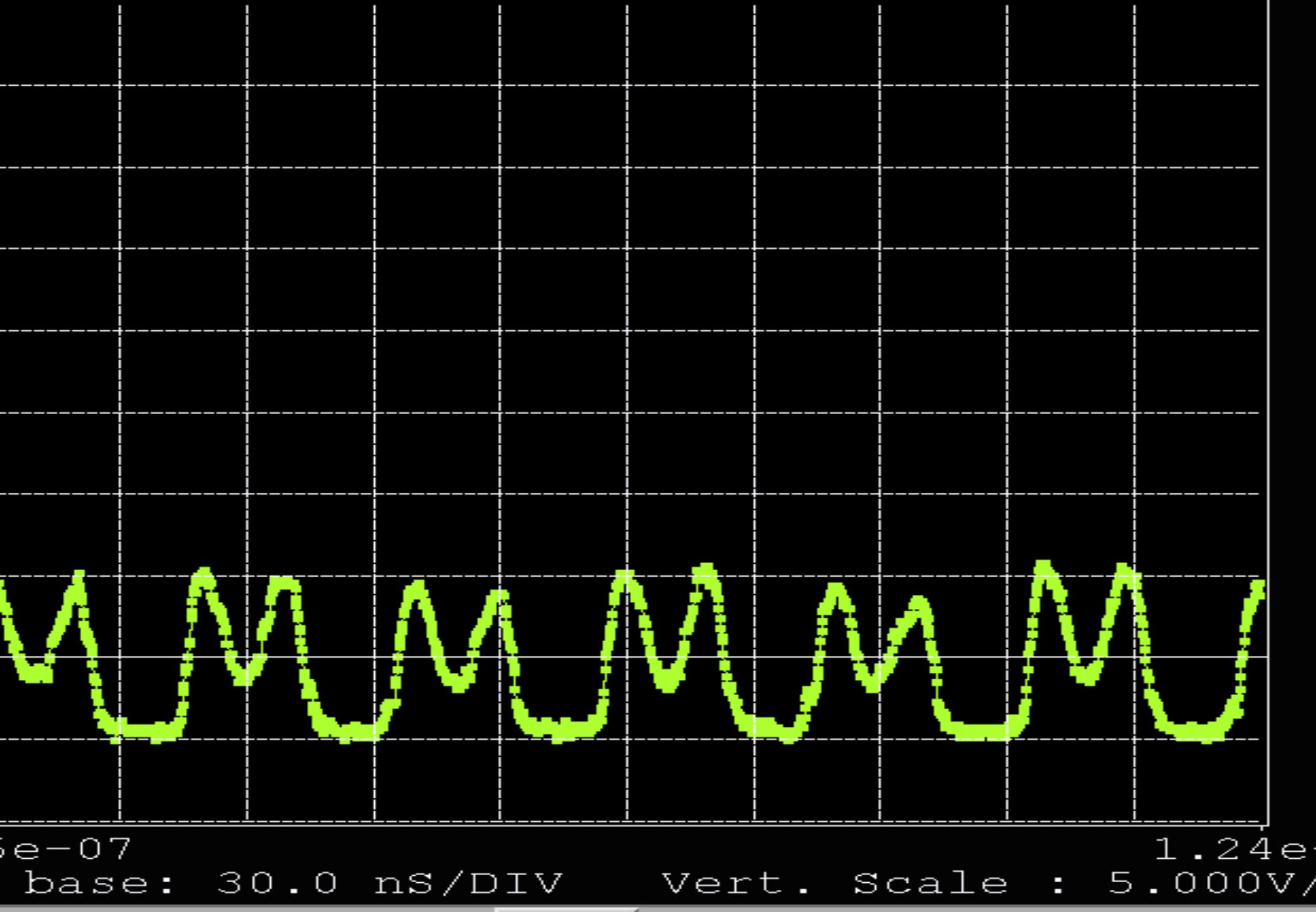
e-07

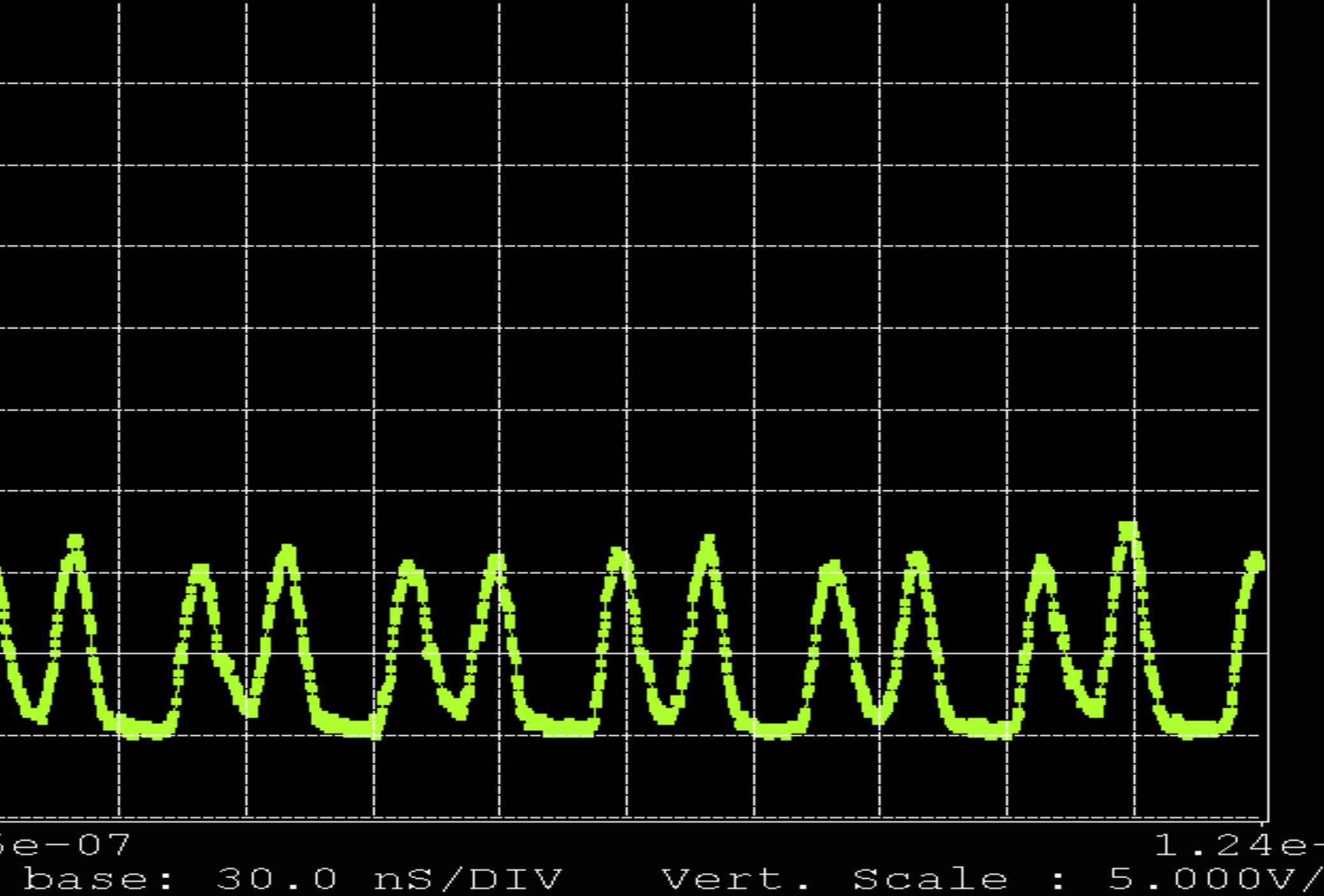
base: 30.0 nS/DIV

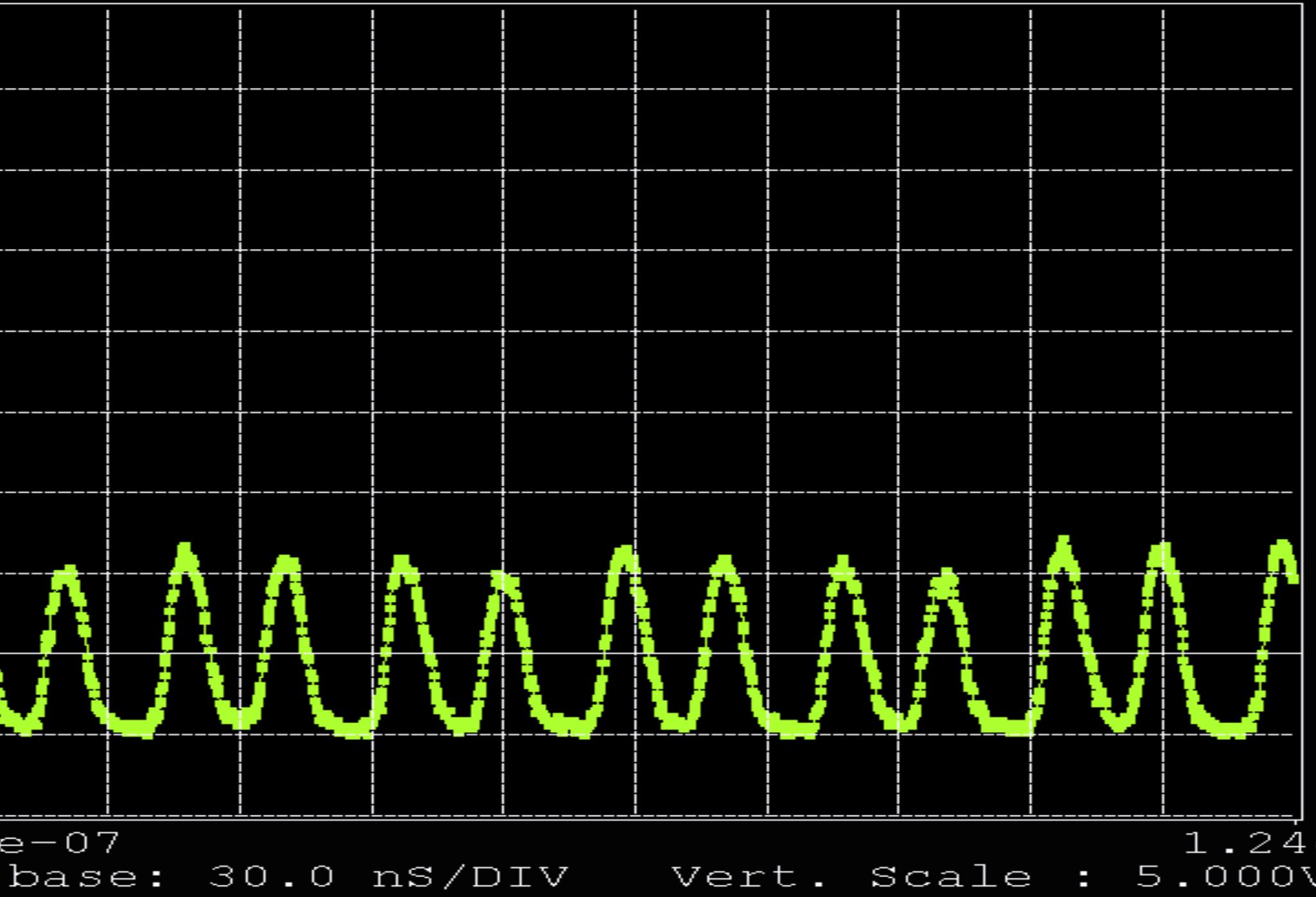
Vert. Scale : 10.000V/

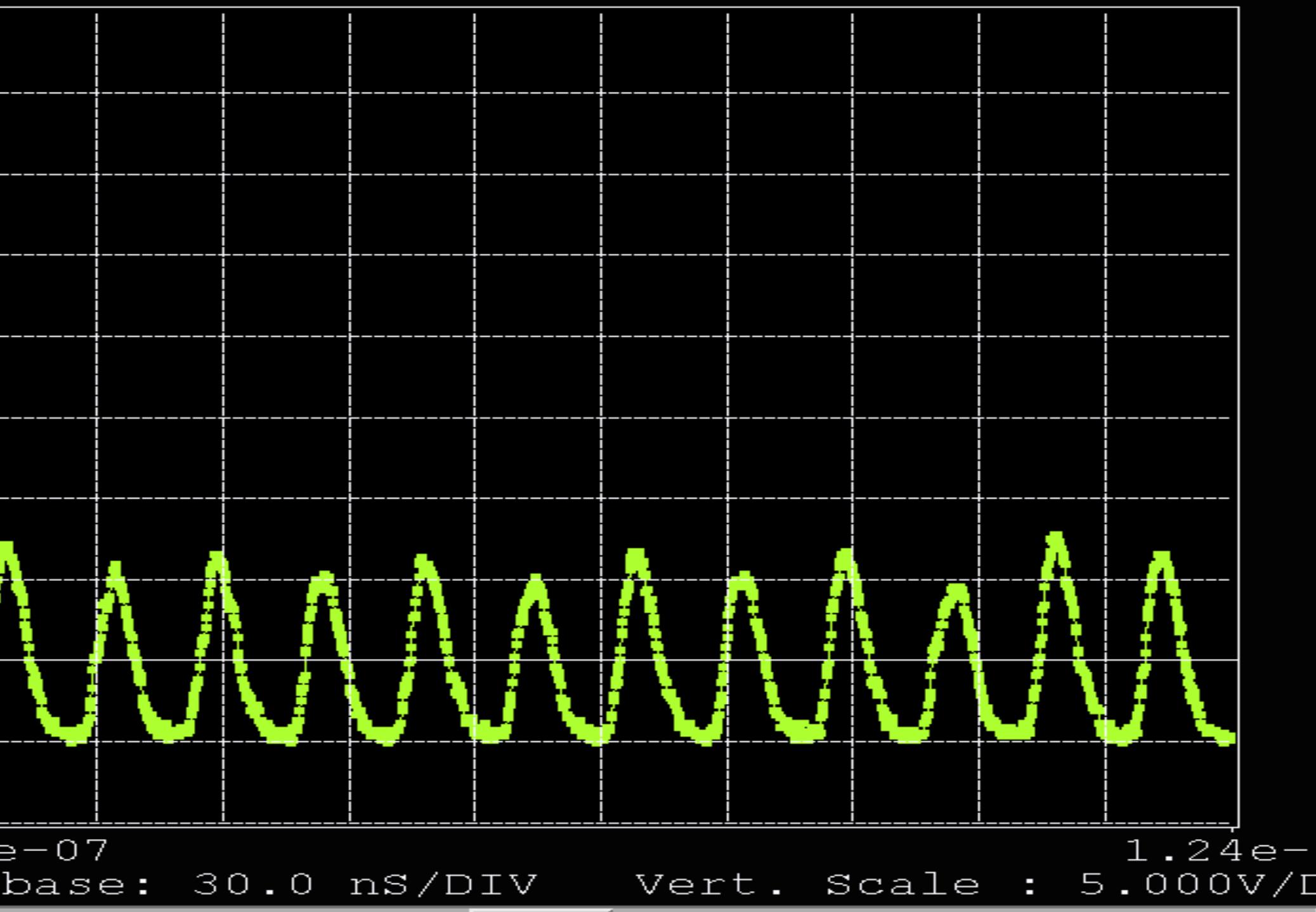
1.24e-

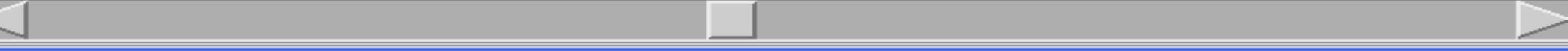
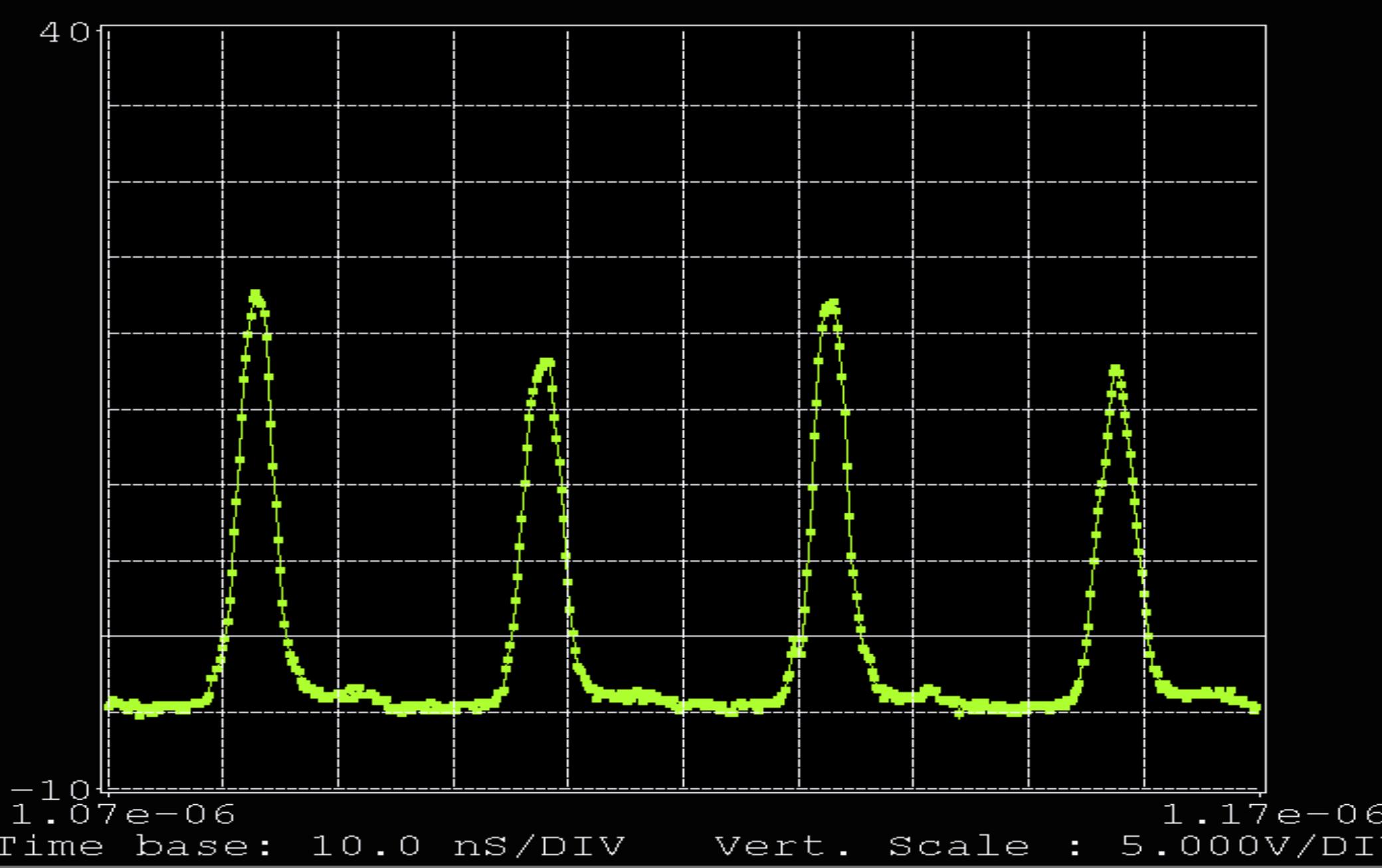




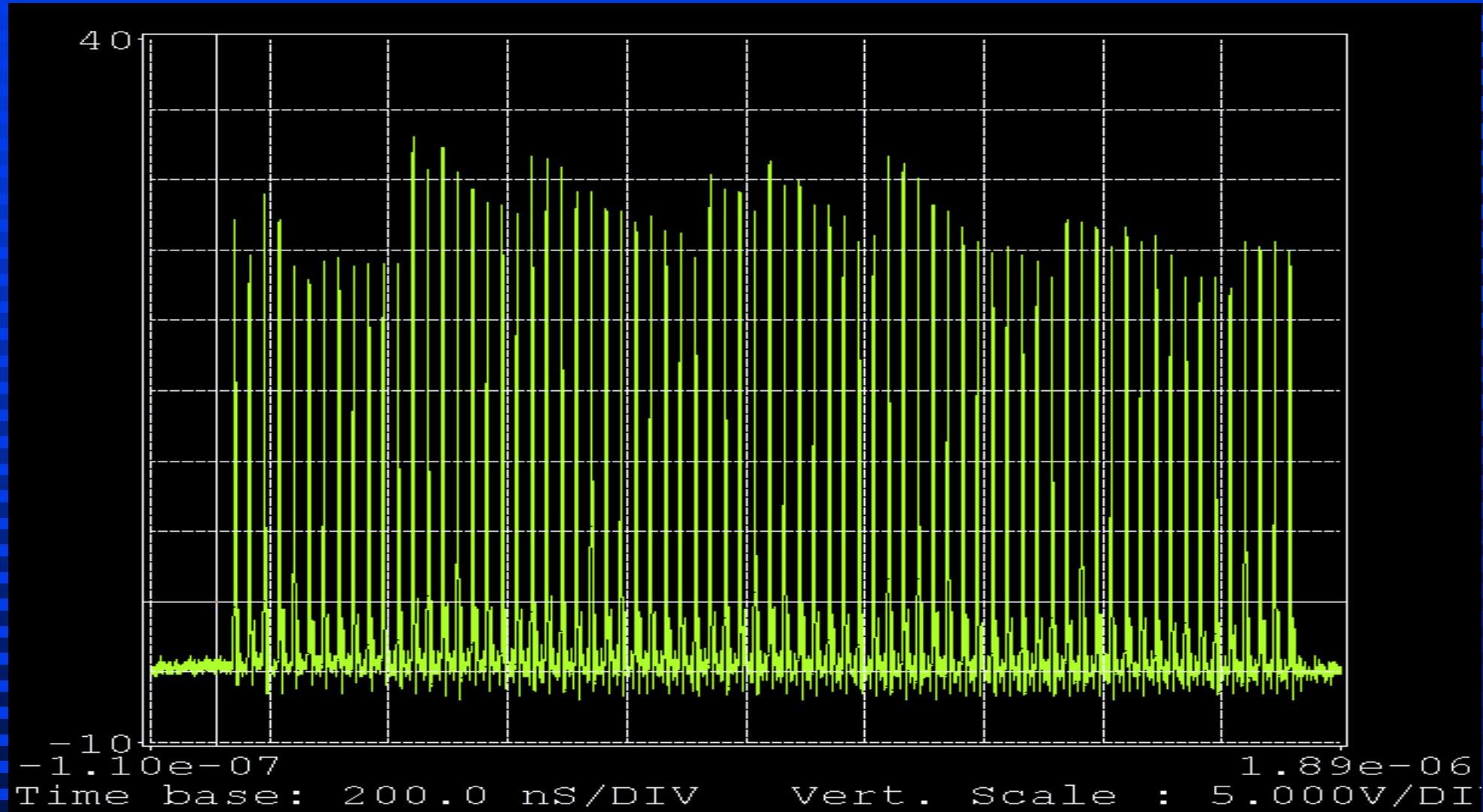








72-bunch train ready to be sent to SPS



Thanks for your attention!



Questions ? ...

LHC Accelerator Diagram:

The diagram illustrates the LHC accelerator complex. The LHC ring (2007, 27 km) is at the top. Inside it is the Super Proton Synchrotron (SPS, 1976, 7 km). Various detectors are shown: CMS, ALICE, ATLAS, and LHCb. Other facilities include TT40, TT41, TT10, TT60, TT2, TT12, CNGS (2006), Gran Sasso, ISOLDE (1989), BOOSTER (1972, 157 m), PS (1959, 628 m), LINAC 2, LINAC 3 (ions), Leir (2005, 79 m), and CTF3. A legend defines symbols for particles: p (proton), ion, neutrinos, p-bar (antiproton), and proton/antiproton.

Control Room Display:

A screenshot of a control room software interface. The plot shows a signal with a peak around 1.0e-06. The parameters listed are:

- Train C : 850
- counter: Train C2 850
- RFB : 2
- Hct 2 : 0.93
- Fitting: Gaussian
- Nb = 3.64e+12
- dt = 5.05 ns
- D1: 15.000, Robot: 1.447/s
- D2: 1.411, Freq: 30.000Hz
- Wf: 10.19V, h = 8
- p : 26. GeV/c
- RL : 6.813 eVs/u
- Bm : 1.59e-3
- Em : 1.41e-3
- E1 : 2.11 eVs/u
- dE/dP (2s) = 0.94e-3

Selection: Channel 1

Experimental Hall:

Two photographs of the experimental hall. The left photo shows a long blue cylindrical detector component in a tunnel. The right photo shows a person in a white lab coat and hard hat working on a large red and blue detector assembly.

Data Analysis and Simulation:

Two plots. The left plot shows a heatmap of particle distribution with axes from -75 to 75. The right plot shows a red line graph of a signal over time.

Results for V75

At C Pulse :	195
e (2s) (mm.mrad)	8.05
e (2s) (normalized)	18.22