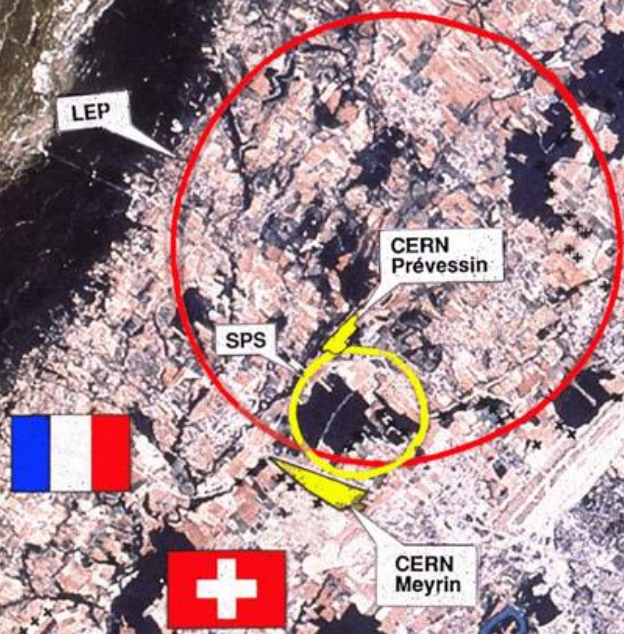


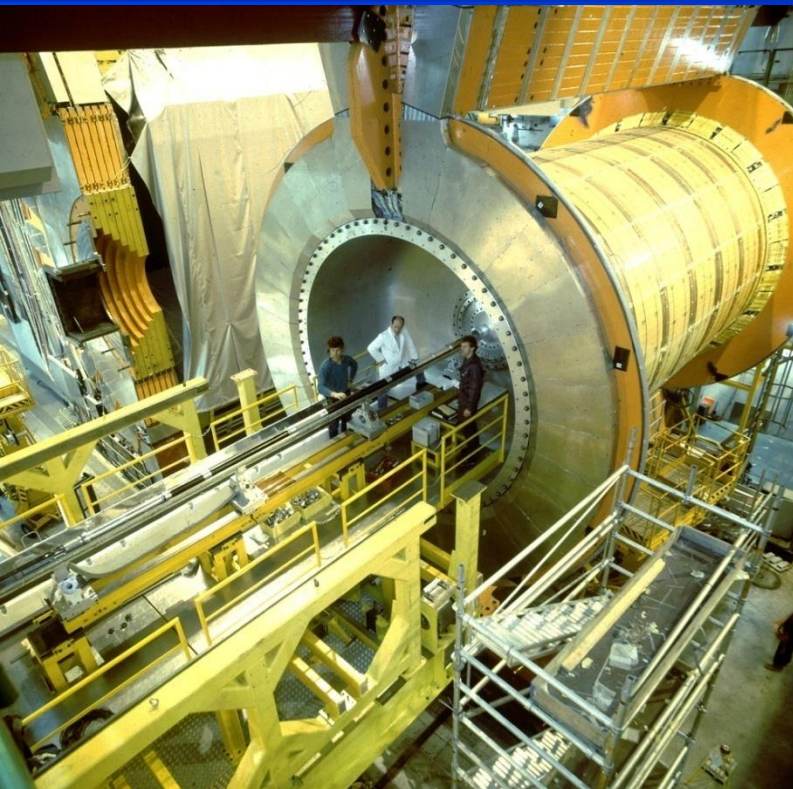
Introduction to accelerators

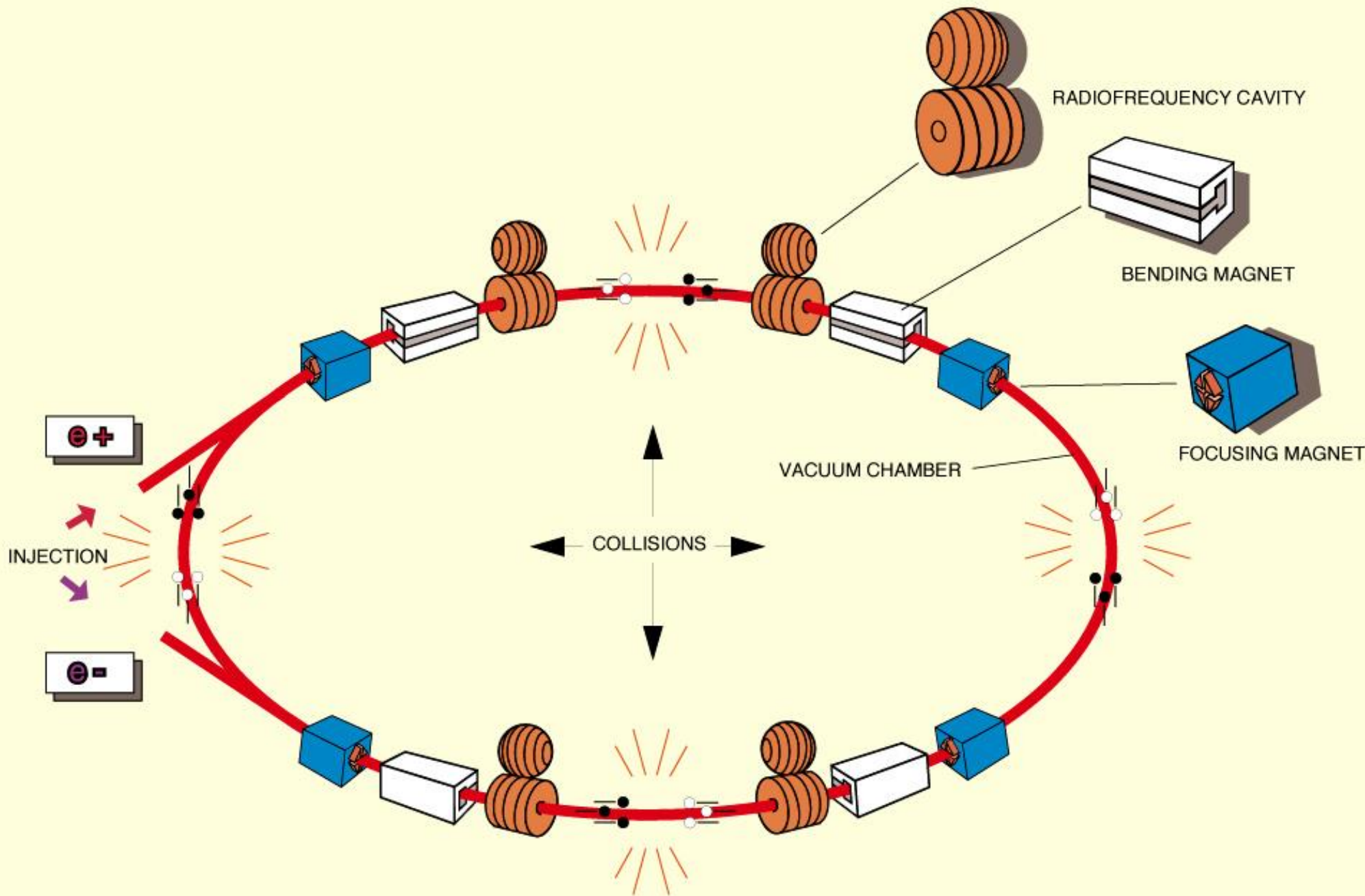
Django Manglunki
CERN/BE/OP



Tools for High Energy Physics

- Accelerators
- Detectors
- Computers

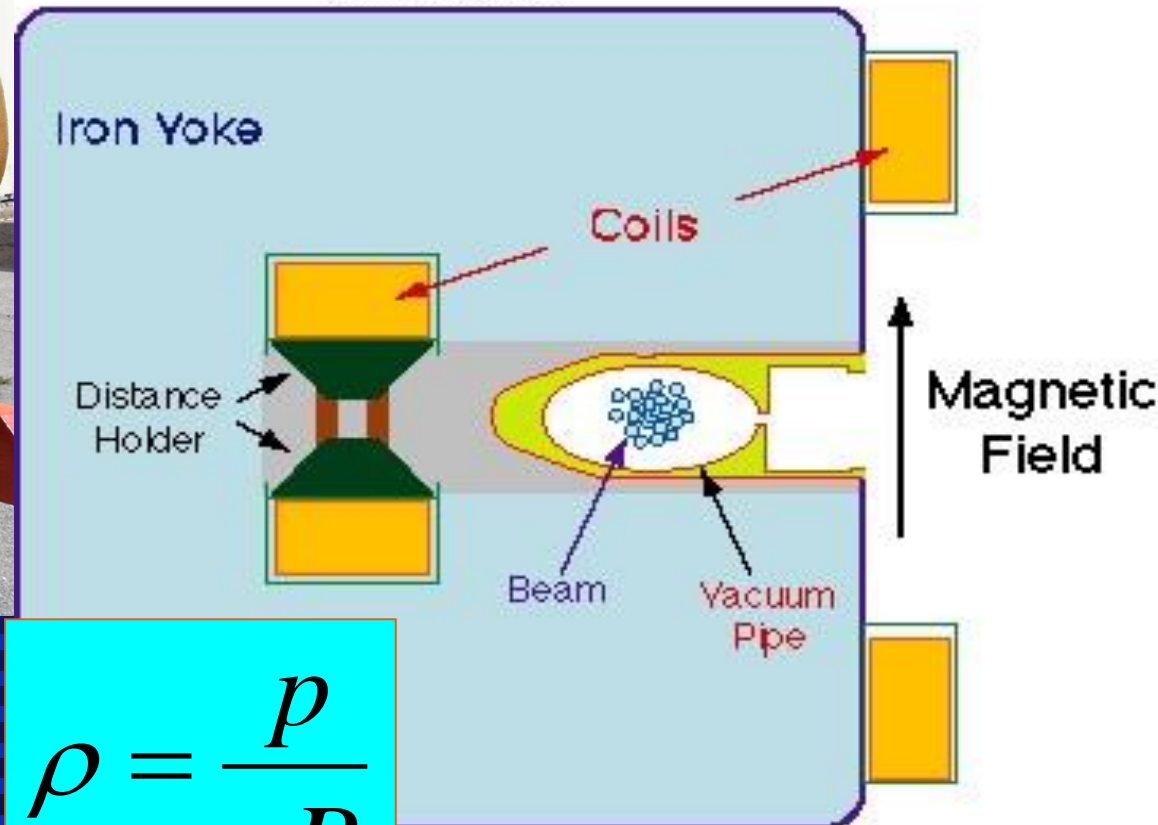




Bending magnets

- Bending by dipolar magnetic fields

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



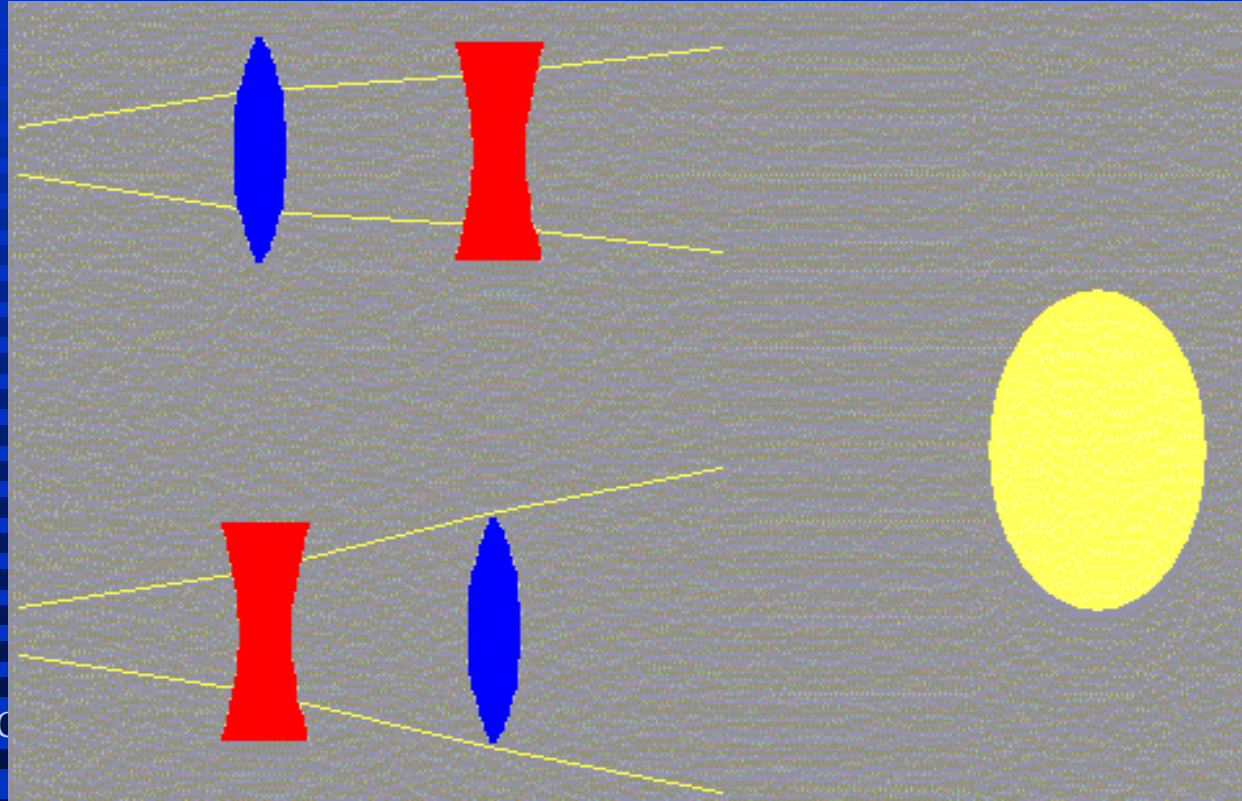
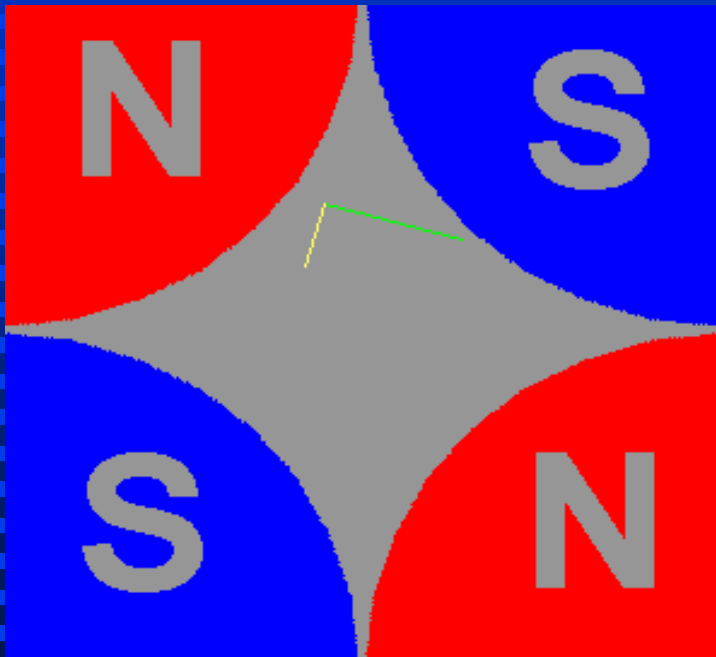
$$\rho = \frac{p}{qB}$$

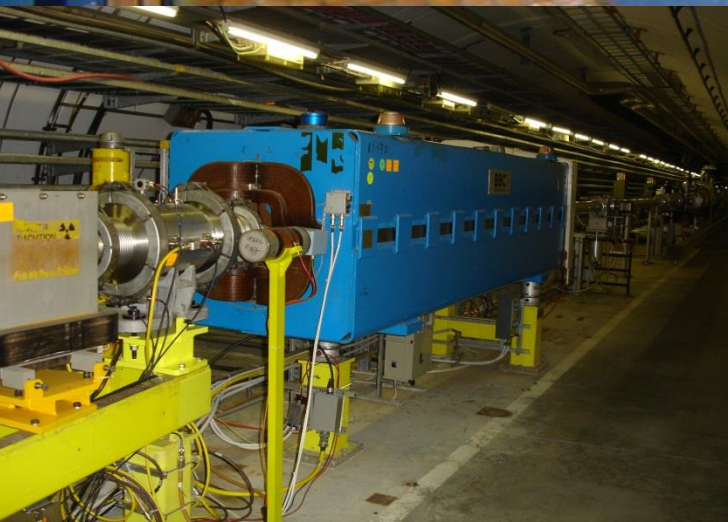
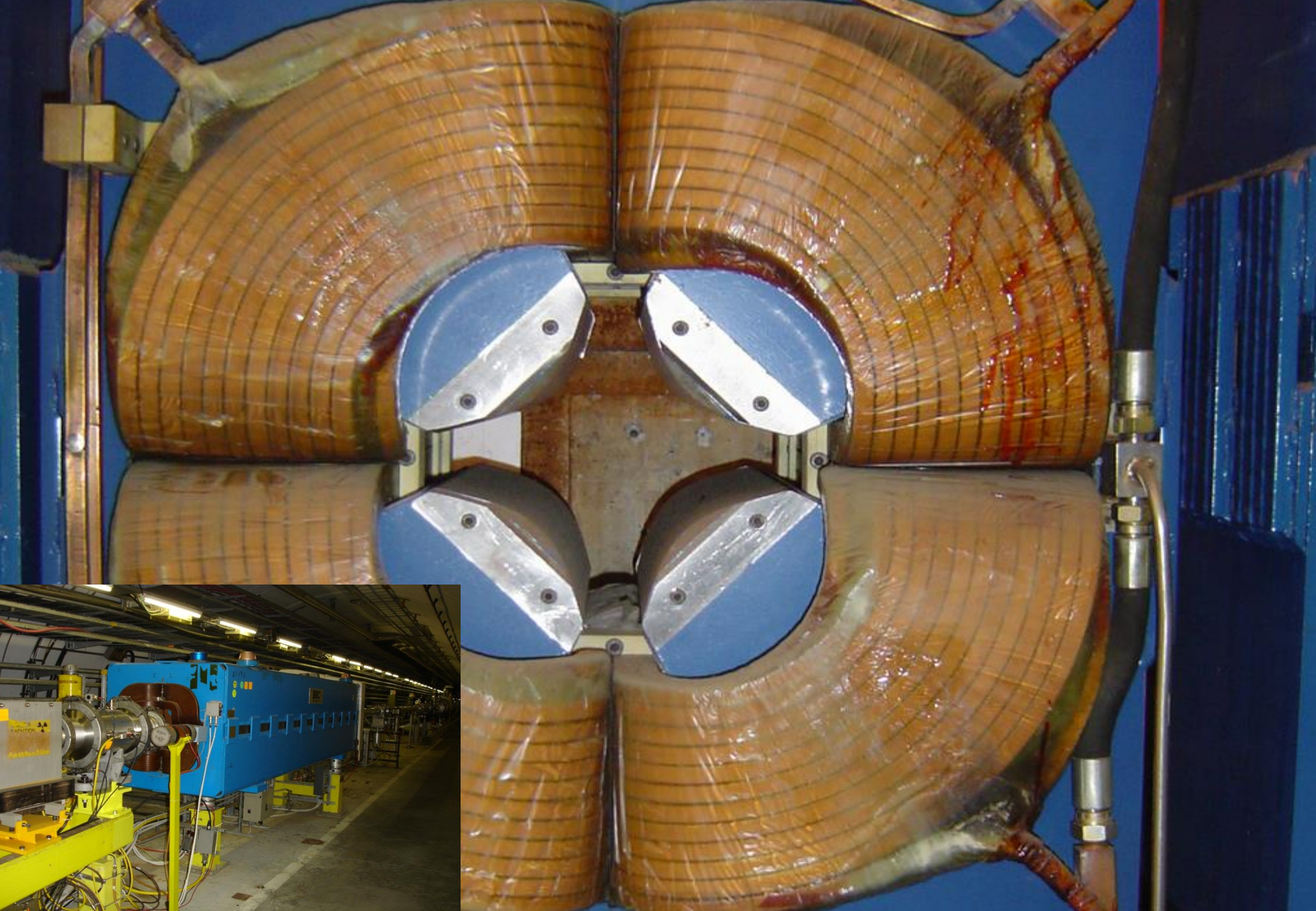
- The field must follow the energy (or, more exactly, the momentum)



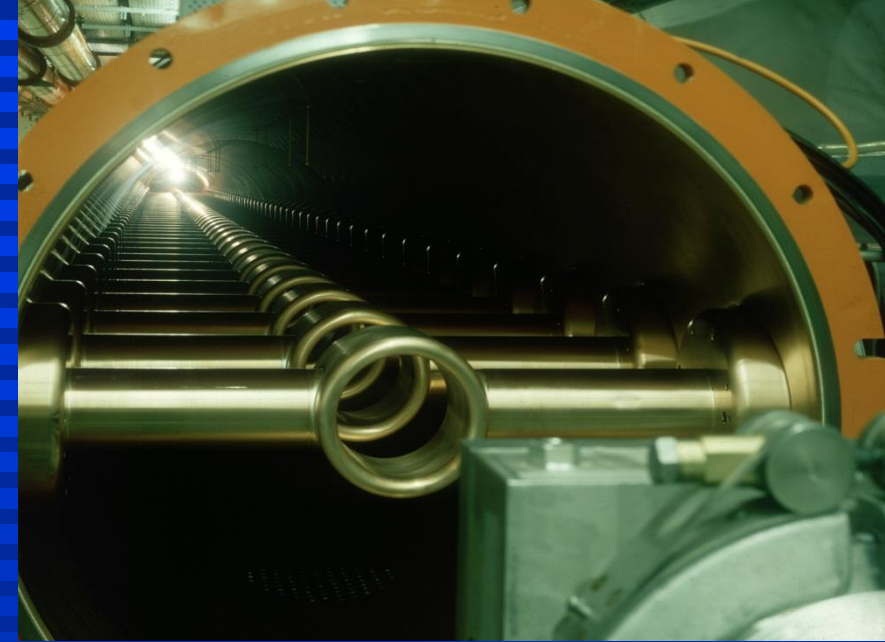
Focusing magnets

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

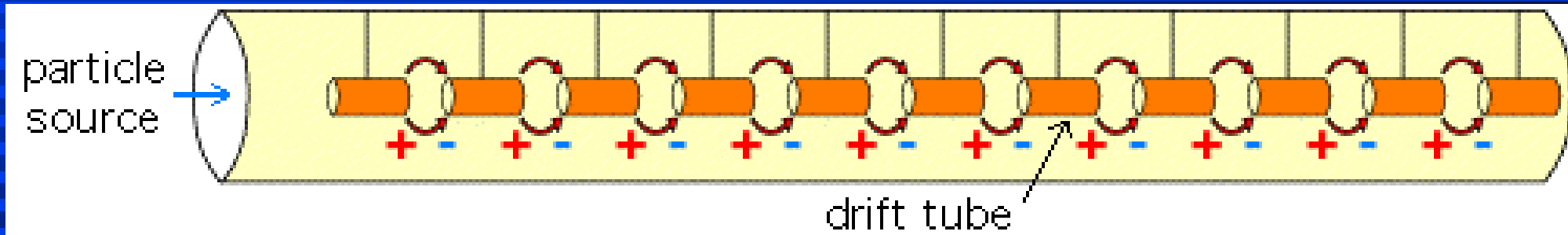




RF cavities



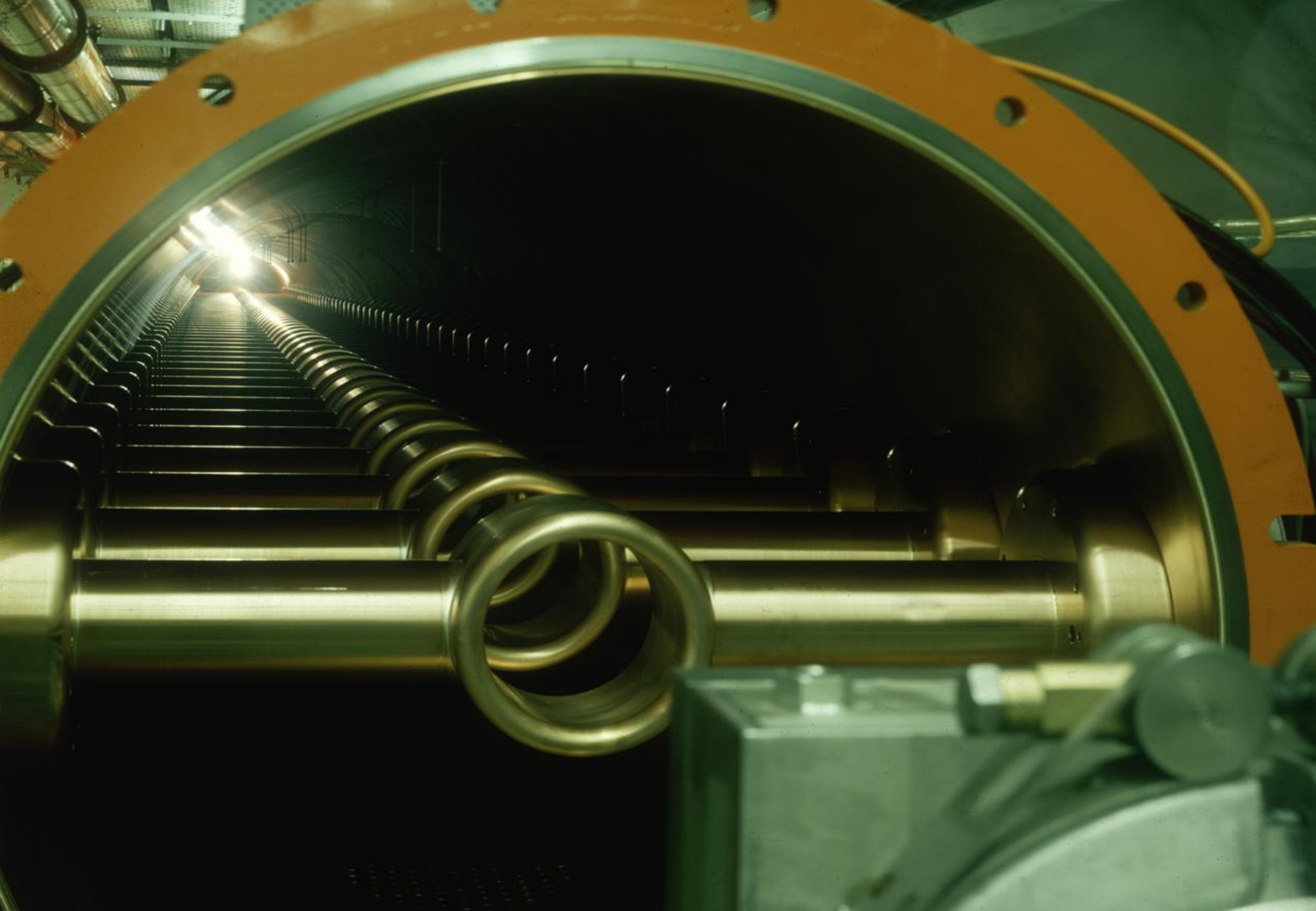
- Acceleration by electric fields



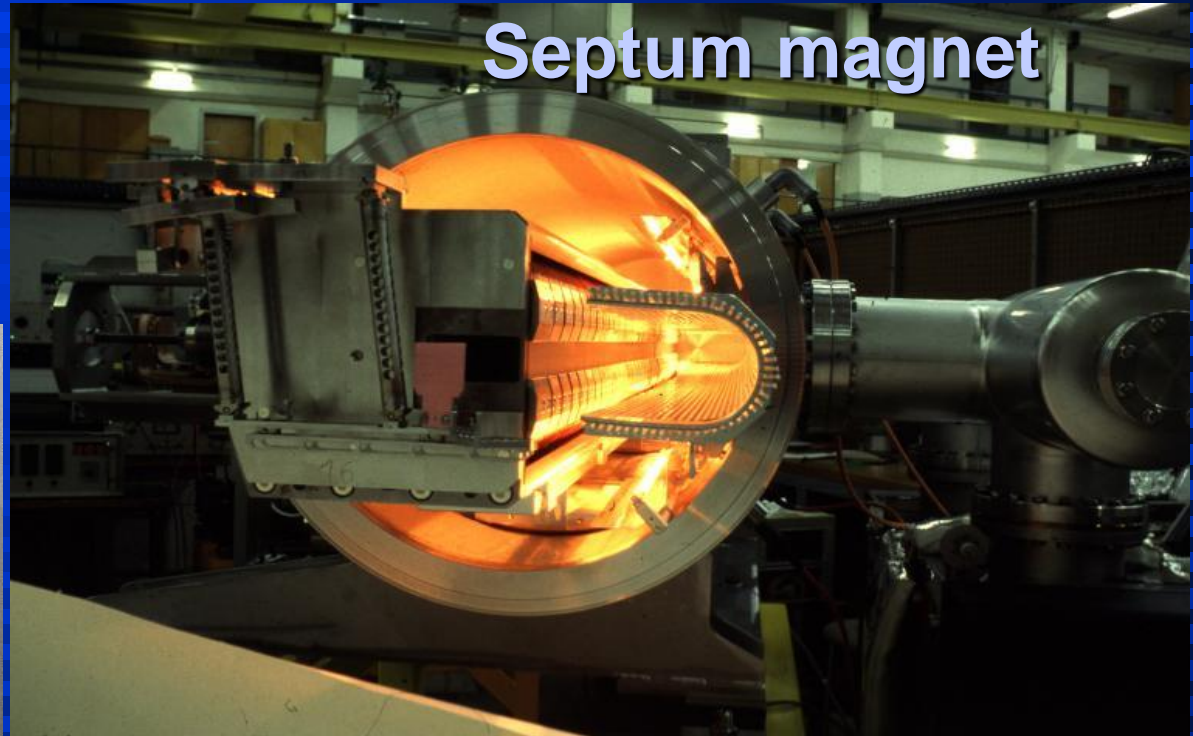
$$\vec{F}_{\parallel} = q\vec{E}$$

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

- 1 eV = 1 electron accelerated by 1 Volt



Injection/ejection systems

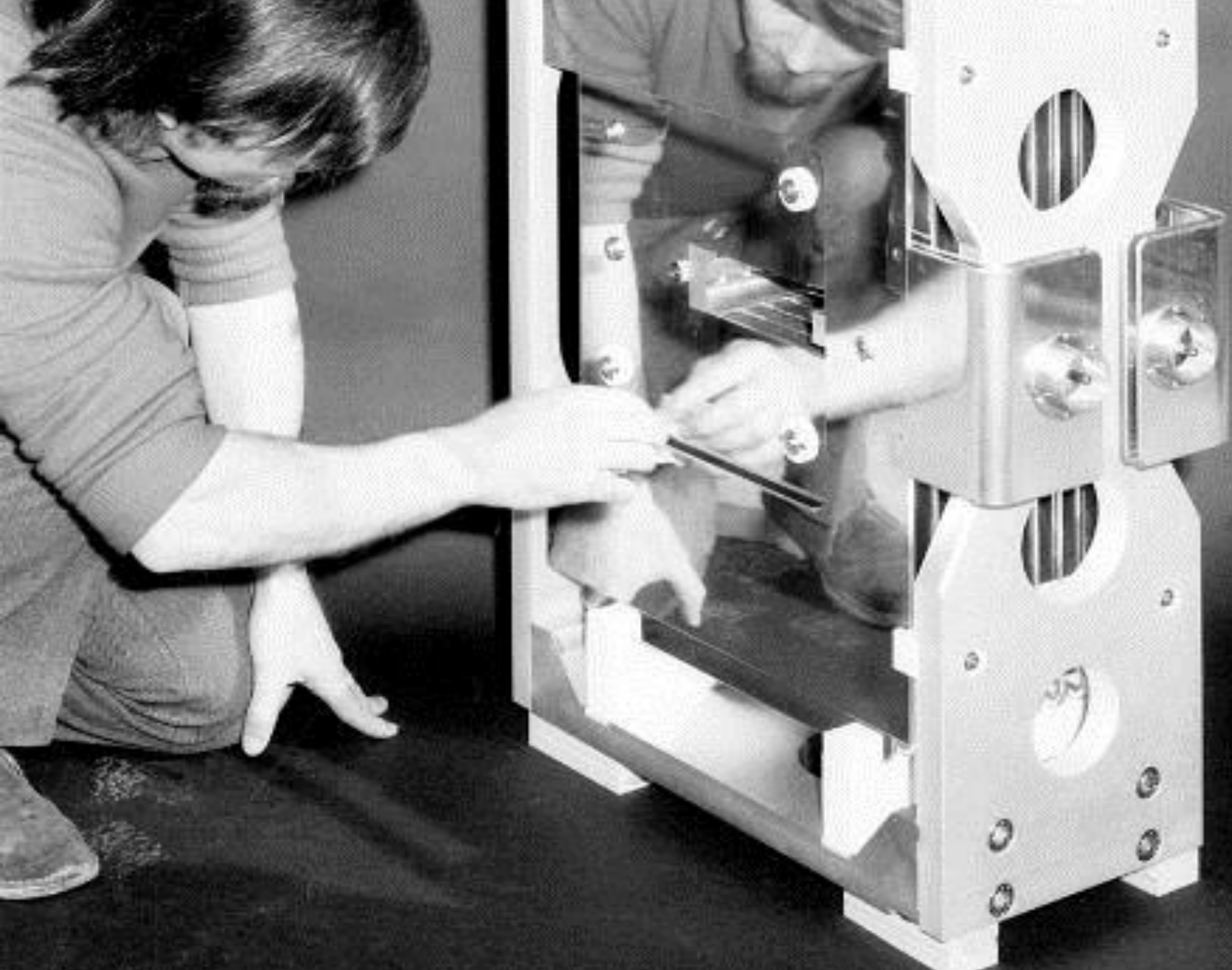


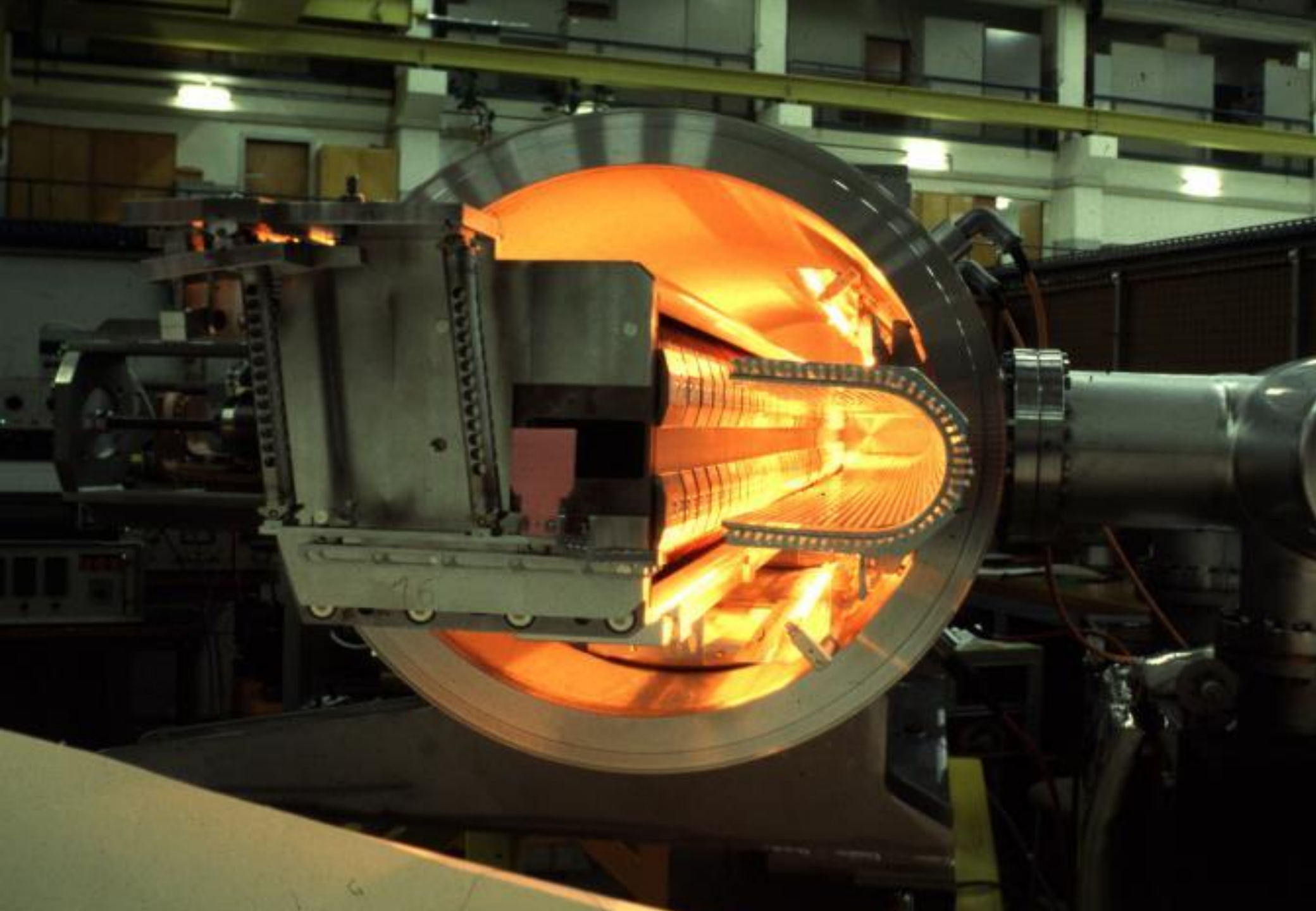
Septum magnet



Kicker magnet

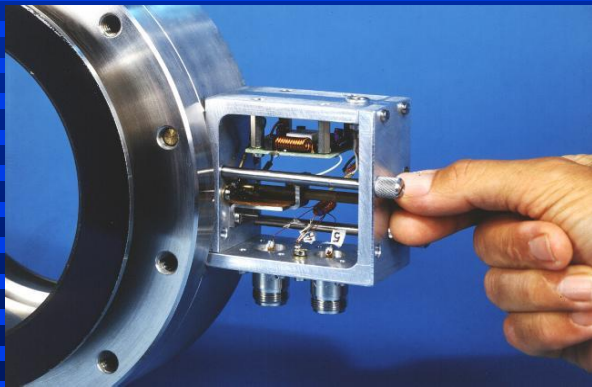
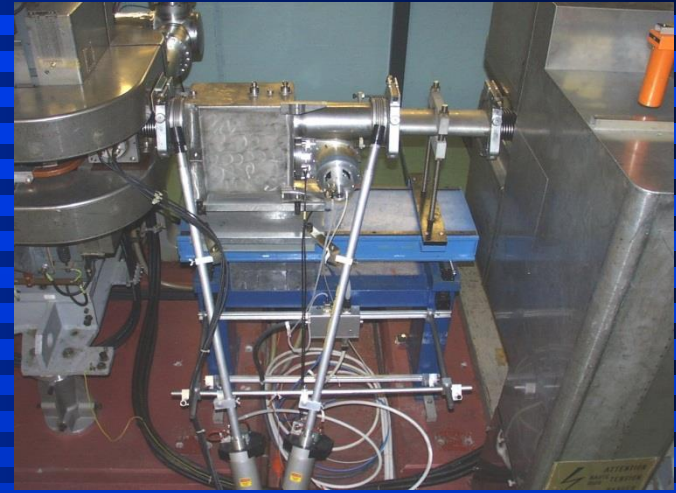
Note: there are other systems





Other components

- Vacuum pumps
- Instrumentation
- Corrector magnets
- Safety elements
- ...

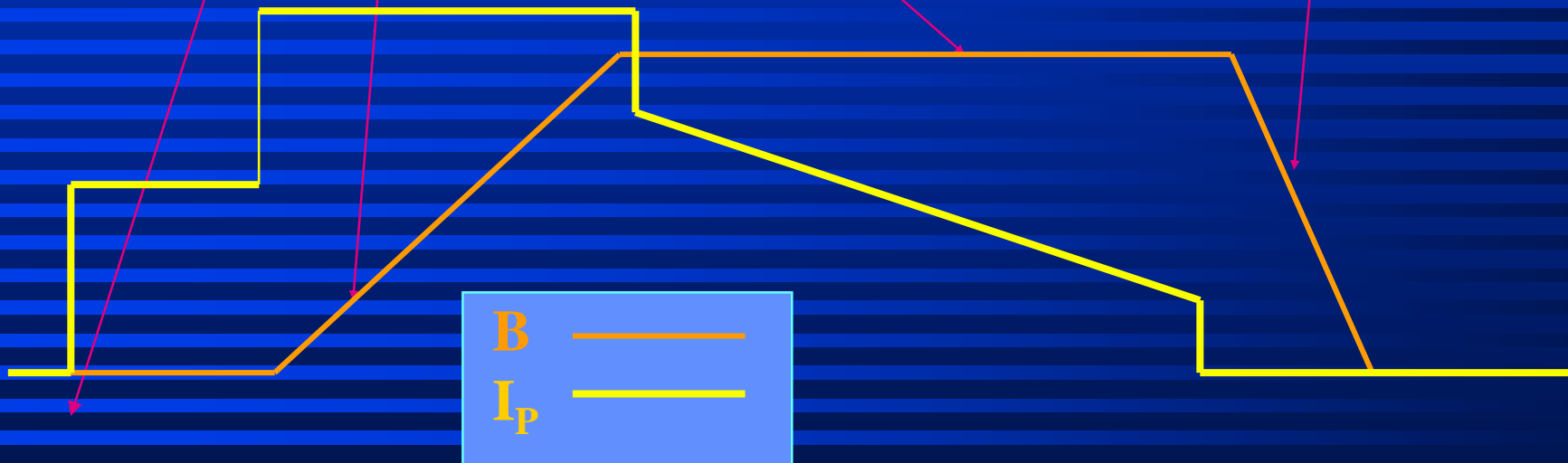




Cycles & Supercycles

- Cycle:

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

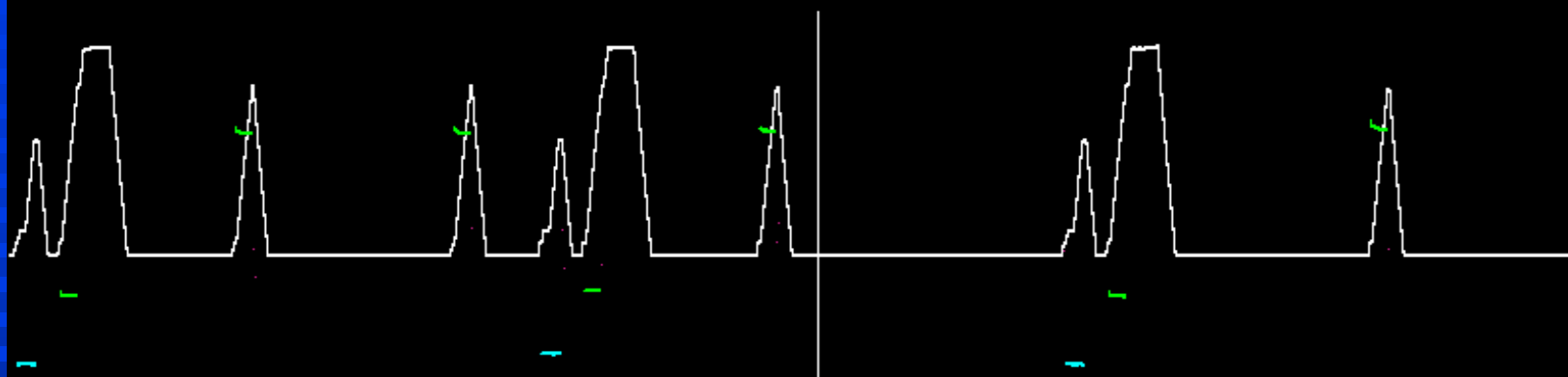


PS Supercycle

CPS Supercycle

supercycle length: 43.2 seconds (36 BP)

May 04 18:23:55



4 Colour range scale 0.1 - 0.49 0.49 - 9 9 - 225 225 - 4500 E10 Charges

ZERO

CPS User : TOF 175.95 E10 PROTON For: TT2_D3

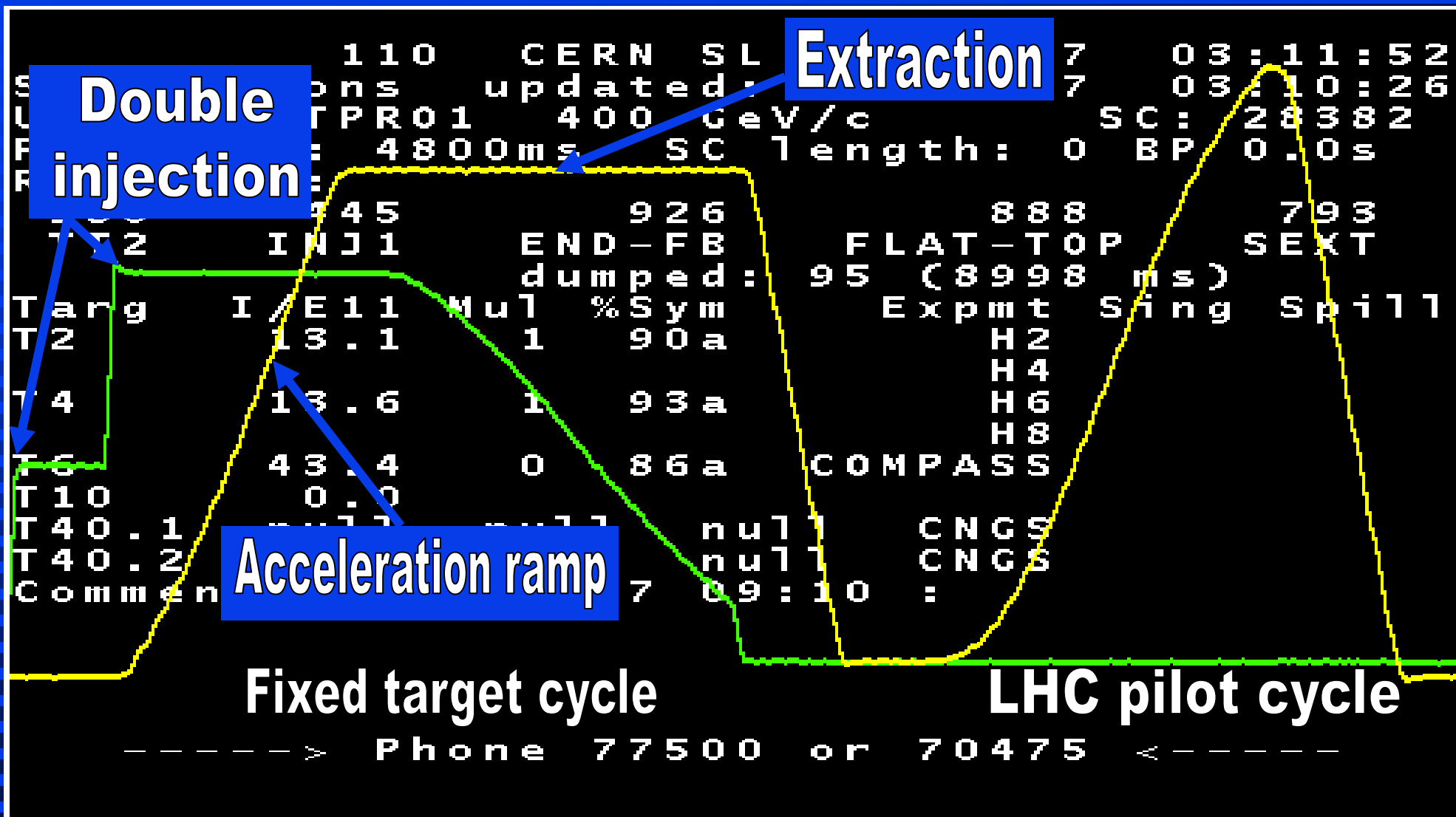
Beam for Isolde : 0 E10 BPNM = 19/36 MTG-level = 15

Comments: 04 May 2004 11:40:01

Energy, Intensity, Destination...

No Message

SPS supercycle



Cycles & Supercycles

▶▶ SPS



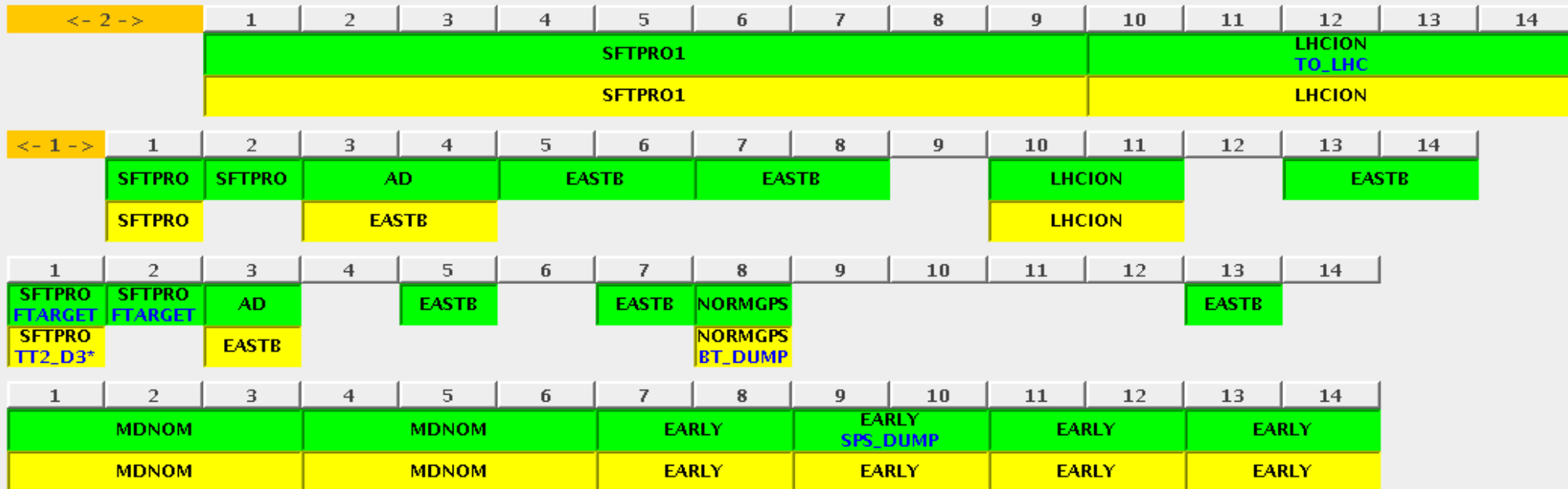
▶▶ CPS

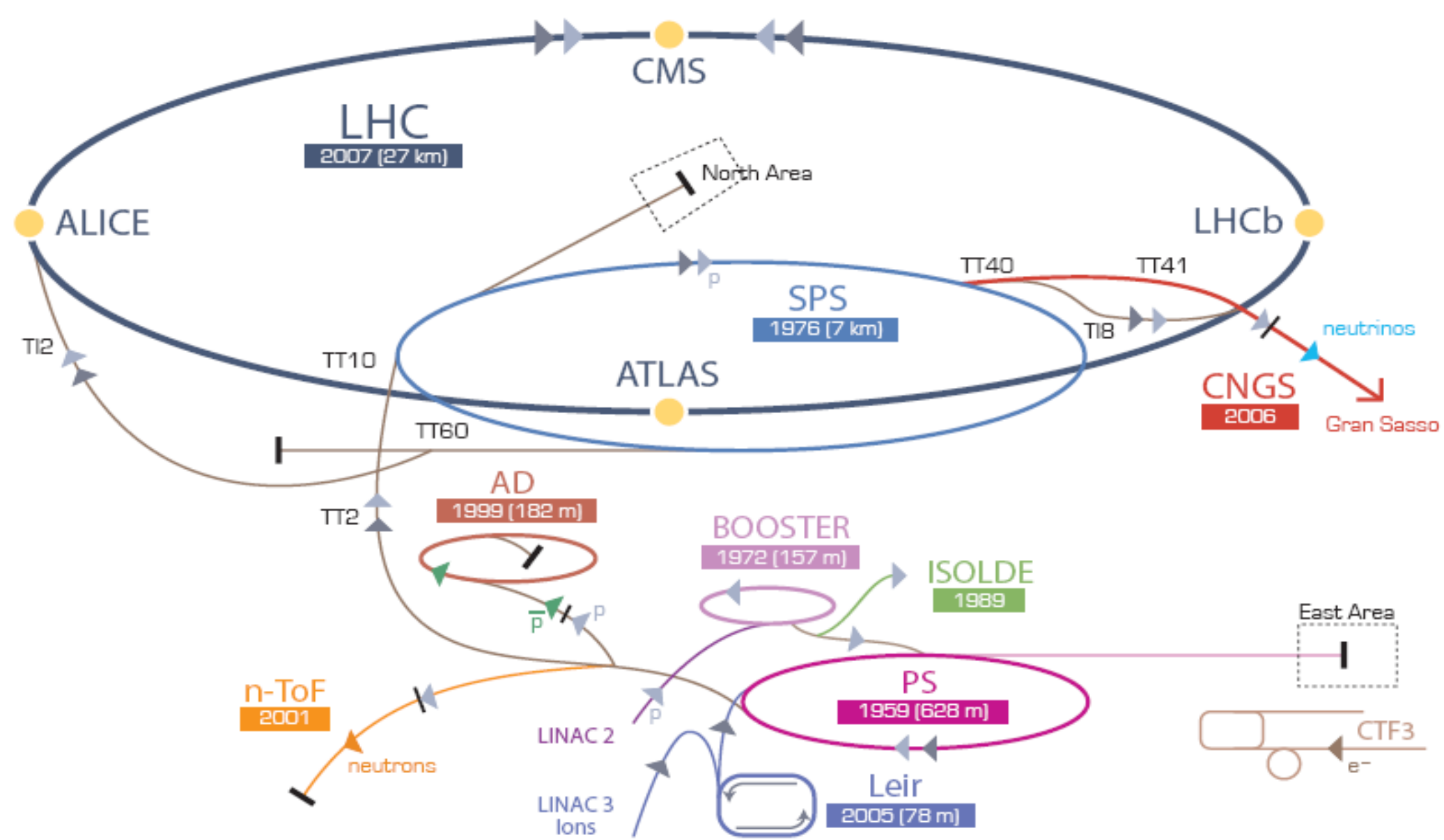


▶ PSB



Cycles & Supercycles





▶ p [proton] ▶ ion ▶ neutrons ▶ \bar{p} [antiproton] ↔ proton/antiproton conversion ▶ neutrinos ▶ electron

PREINJECTEUR
LINAC

ATTENTION
HAUTE TENSION
HIGH TENSION
100 KV DANGER

H₂

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

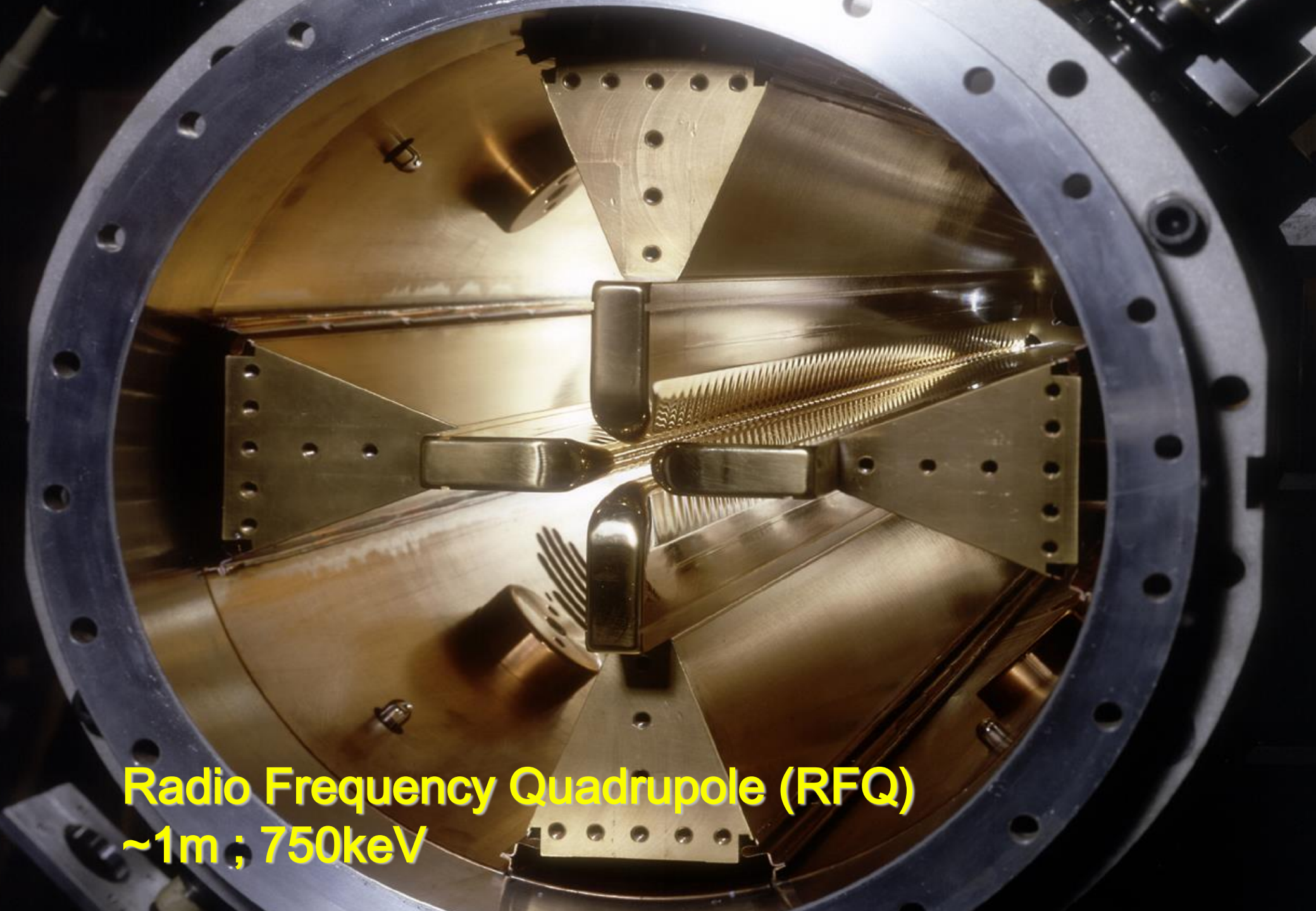
A PROTON SOURCE

Duoplasmatron proton source
90keV ; 500mA

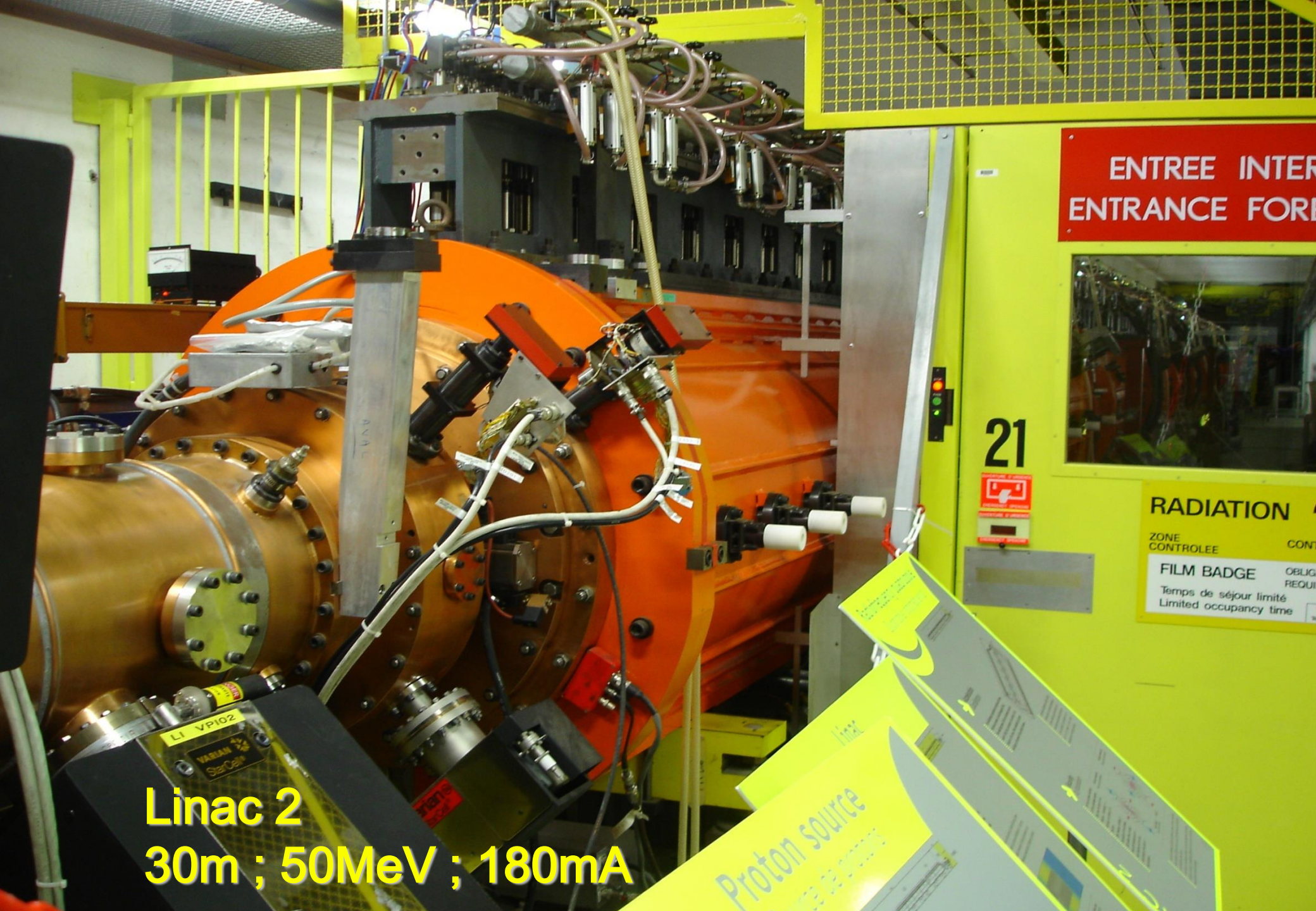
Proton source
source de protons

Linac

Radiofréquence quadrupole
Radio Frequency Quadrupole



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



ENTREE INTER
ENTRANCE FOR



21

RADIATION

ZONE
CONTROLEE

CONT

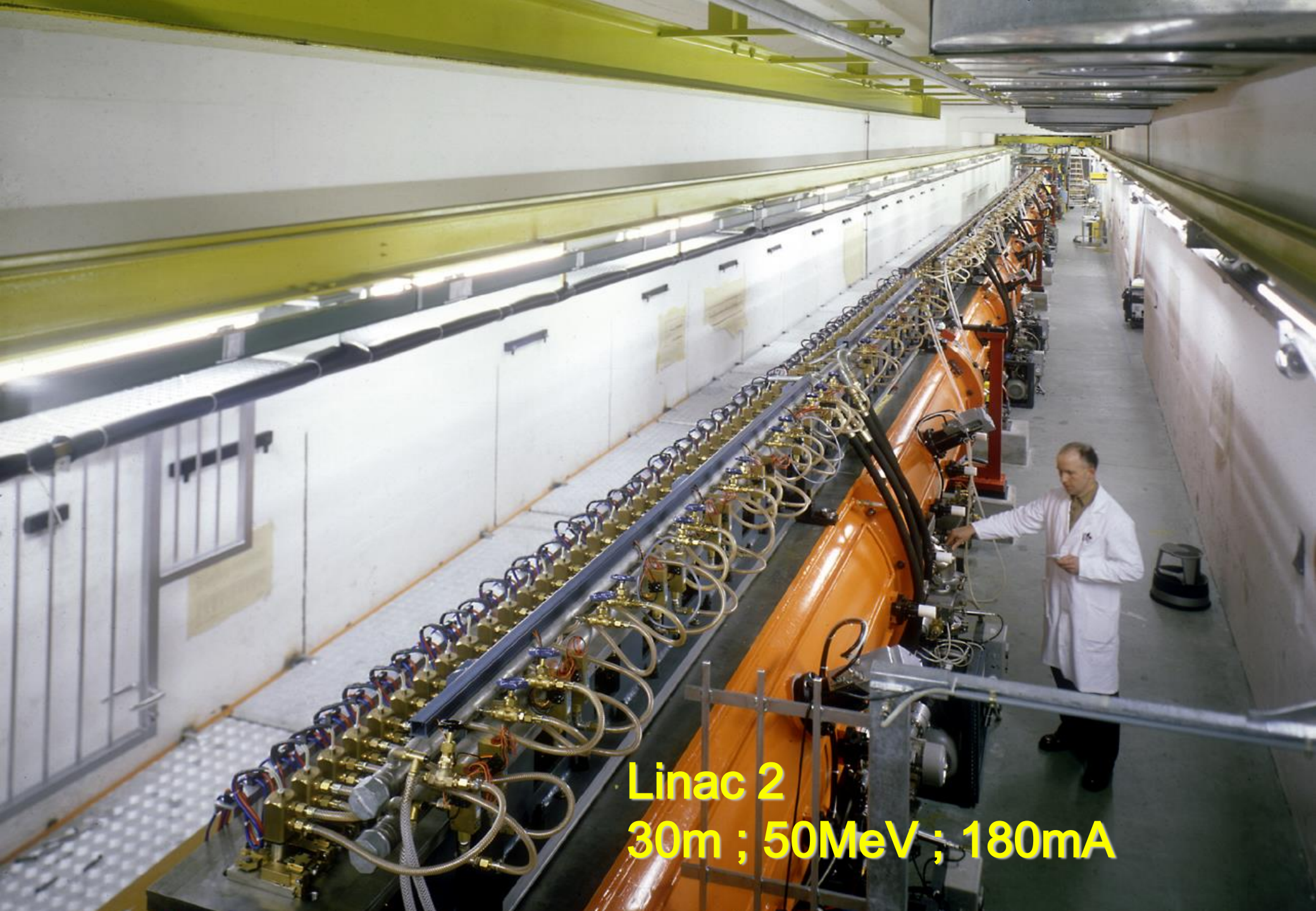
FILM BADGE

OBLIG
REQUI

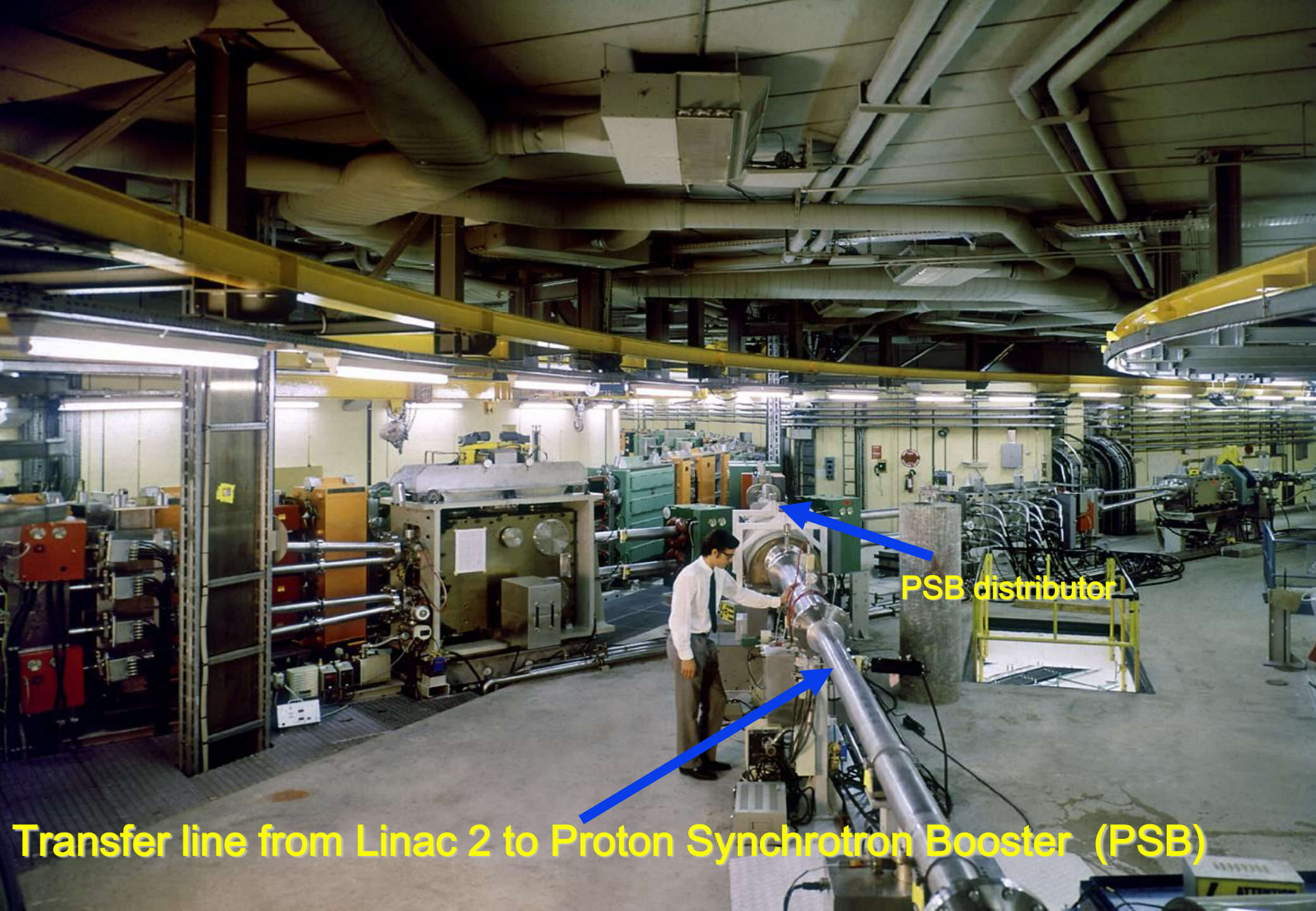
Temps de séjour limité
Limited occupancy time

Linac 2
30m ; 50MeV ; 180mA

Proton source



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

**DANGER
RADIATION**

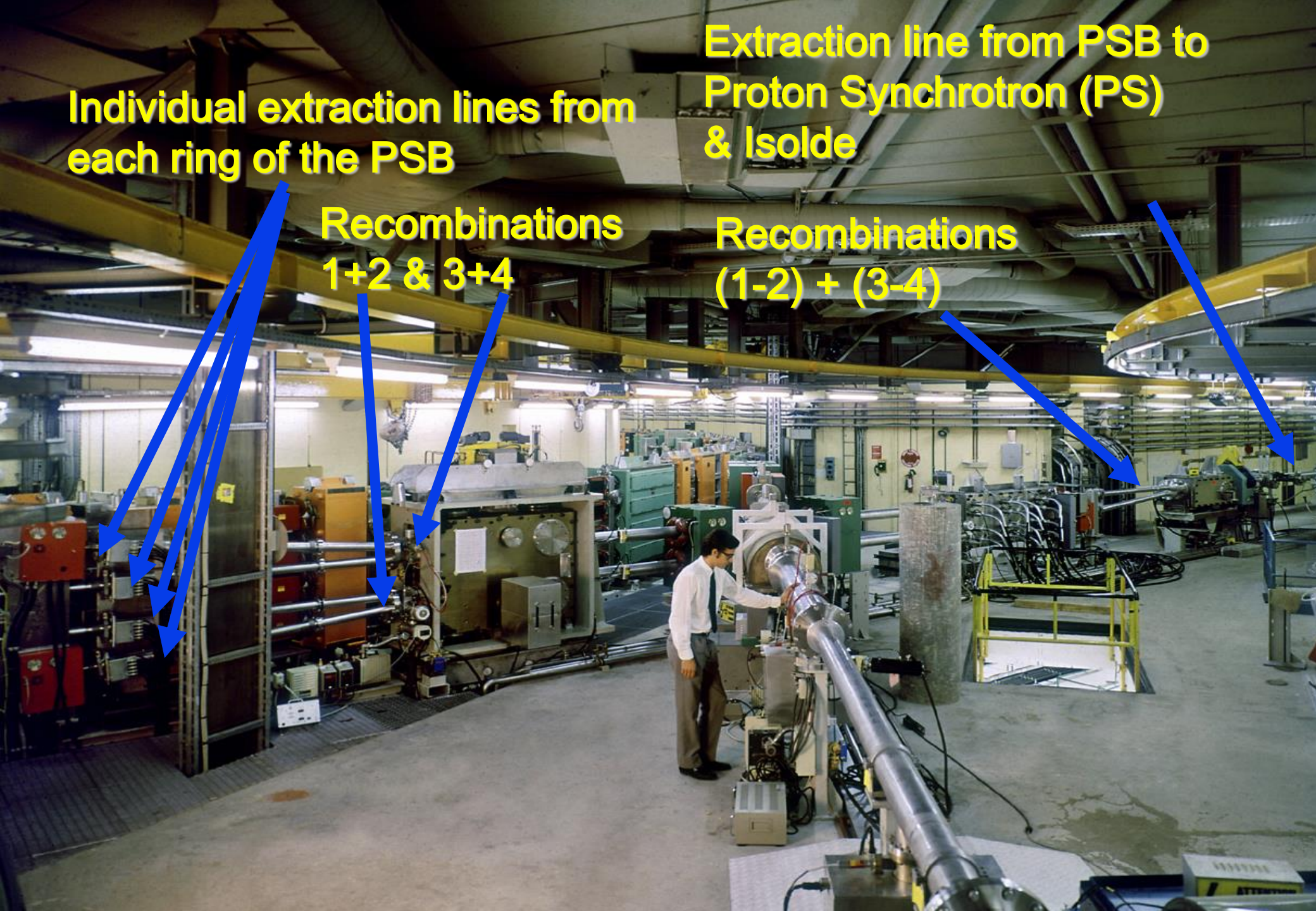


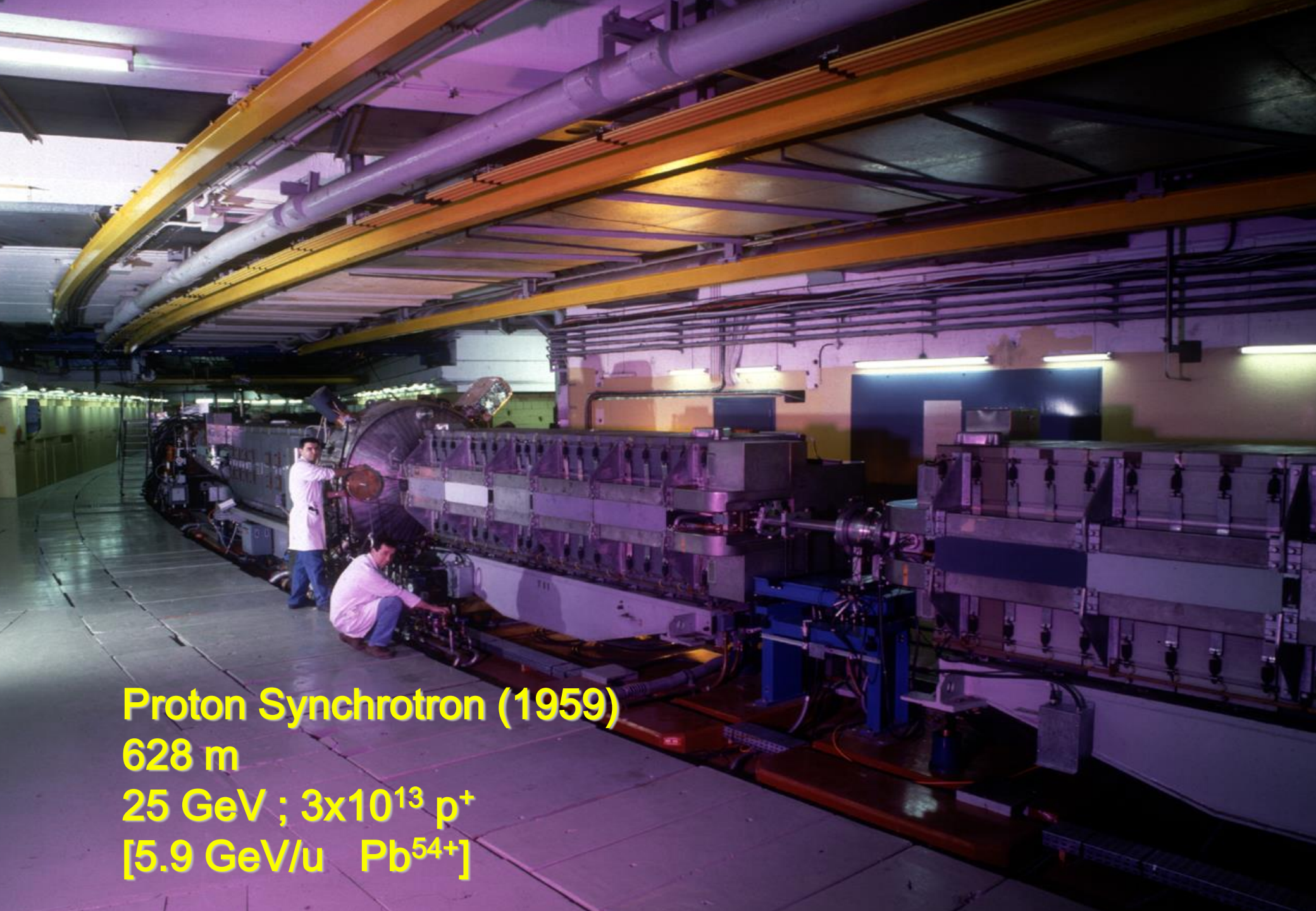
Individual extraction lines from each ring of the PSB

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⁺]



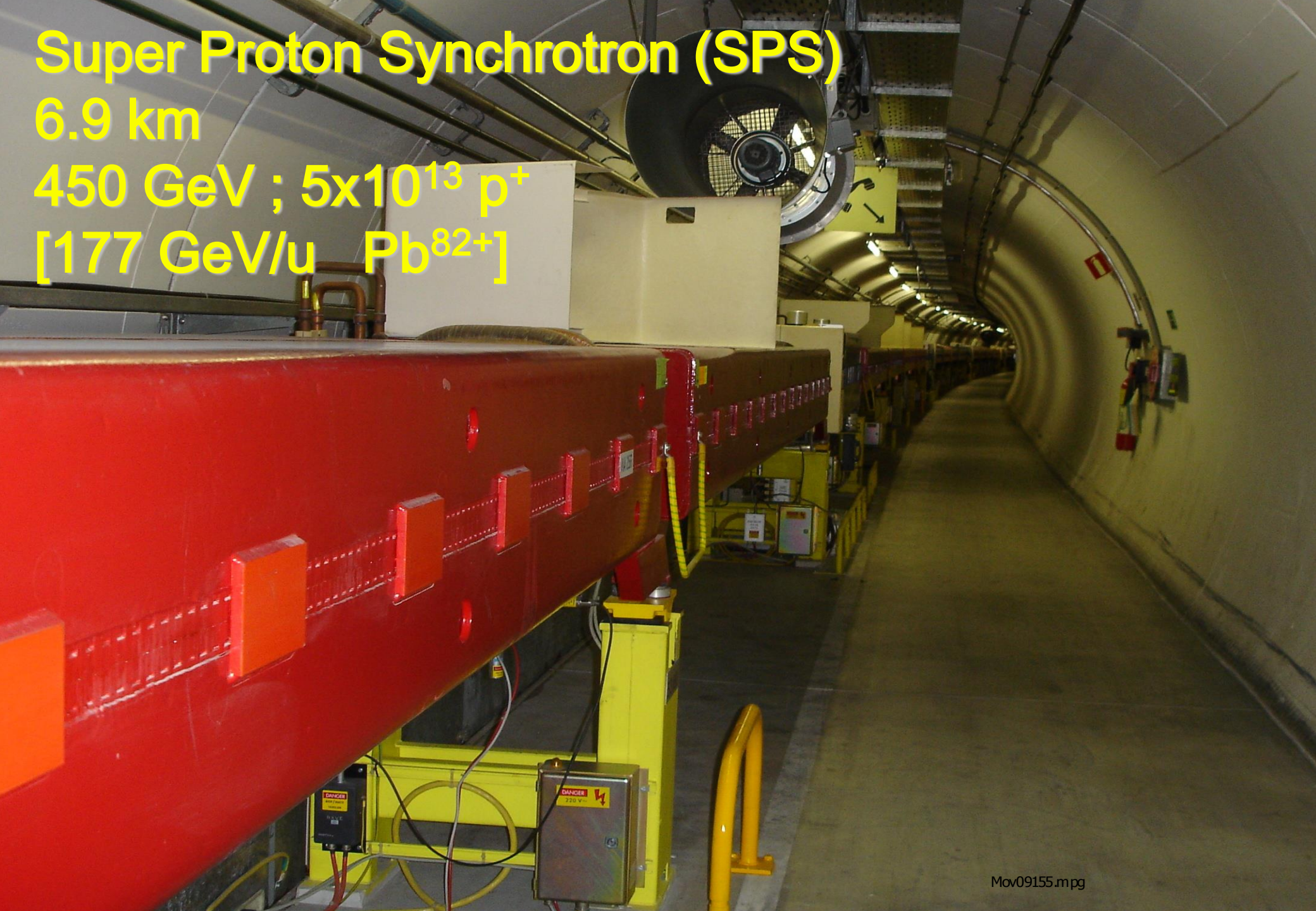
TT2 transfer line from PS to SPS, AD,
nTOF, and D3 dump

Super Proton Synchrotron (SPS)

6.9 km

450 GeV ; 5×10^{13} p⁺

[177 GeV/u Pb⁸²⁺]

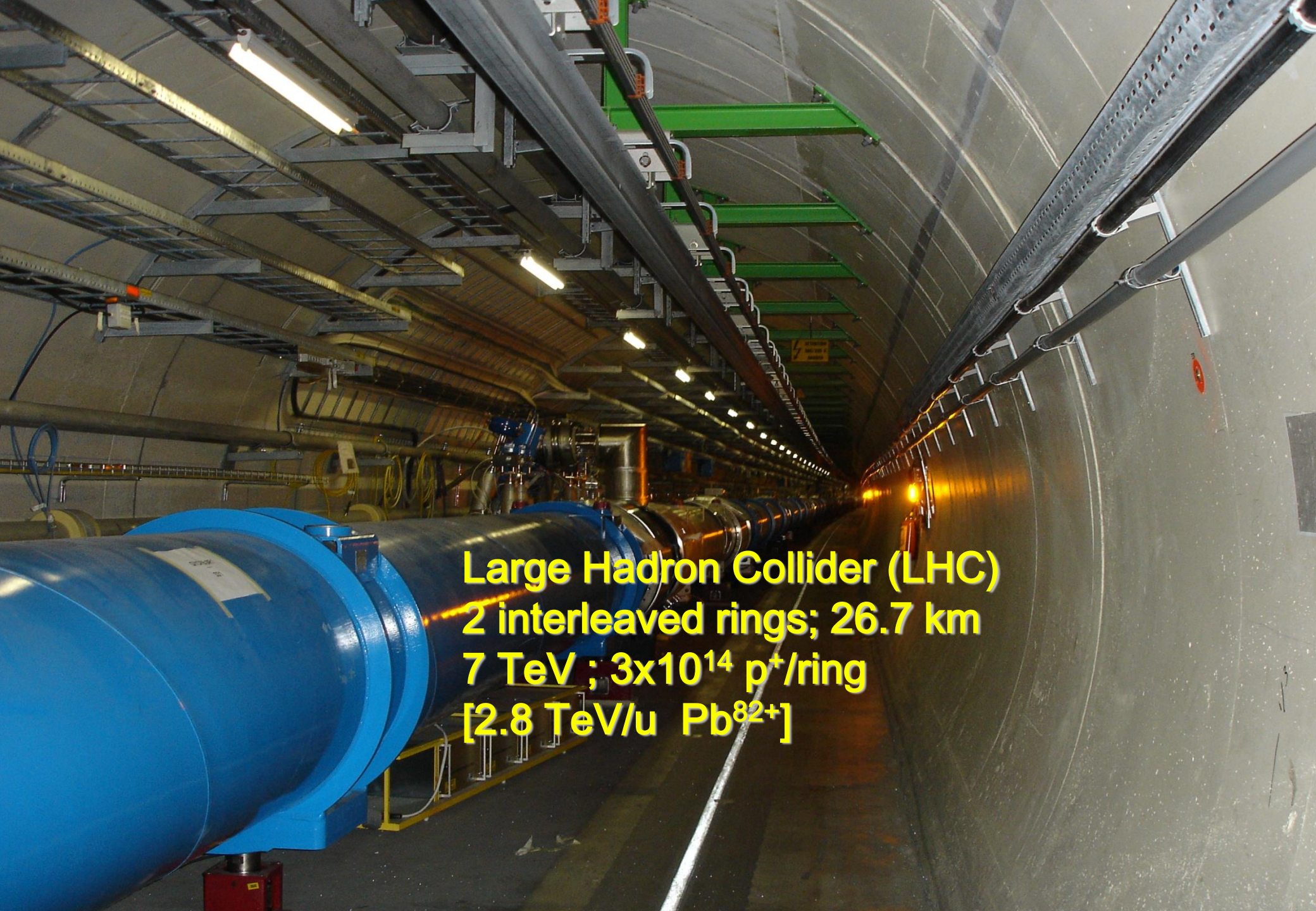




T18 counter-clockwise transfer line from SPS to LHC

ATTENTION
EMPLACEMENT RESERVE
POUR LA POSE DES AIMANTS
VEUILLEZ RESPECTER CET ESPACE
POUR TOUT ENTRETIENMENT, REPARATION, MODIFICATION A
PARLER AVEC LE SERVICE T18-1000, 1000

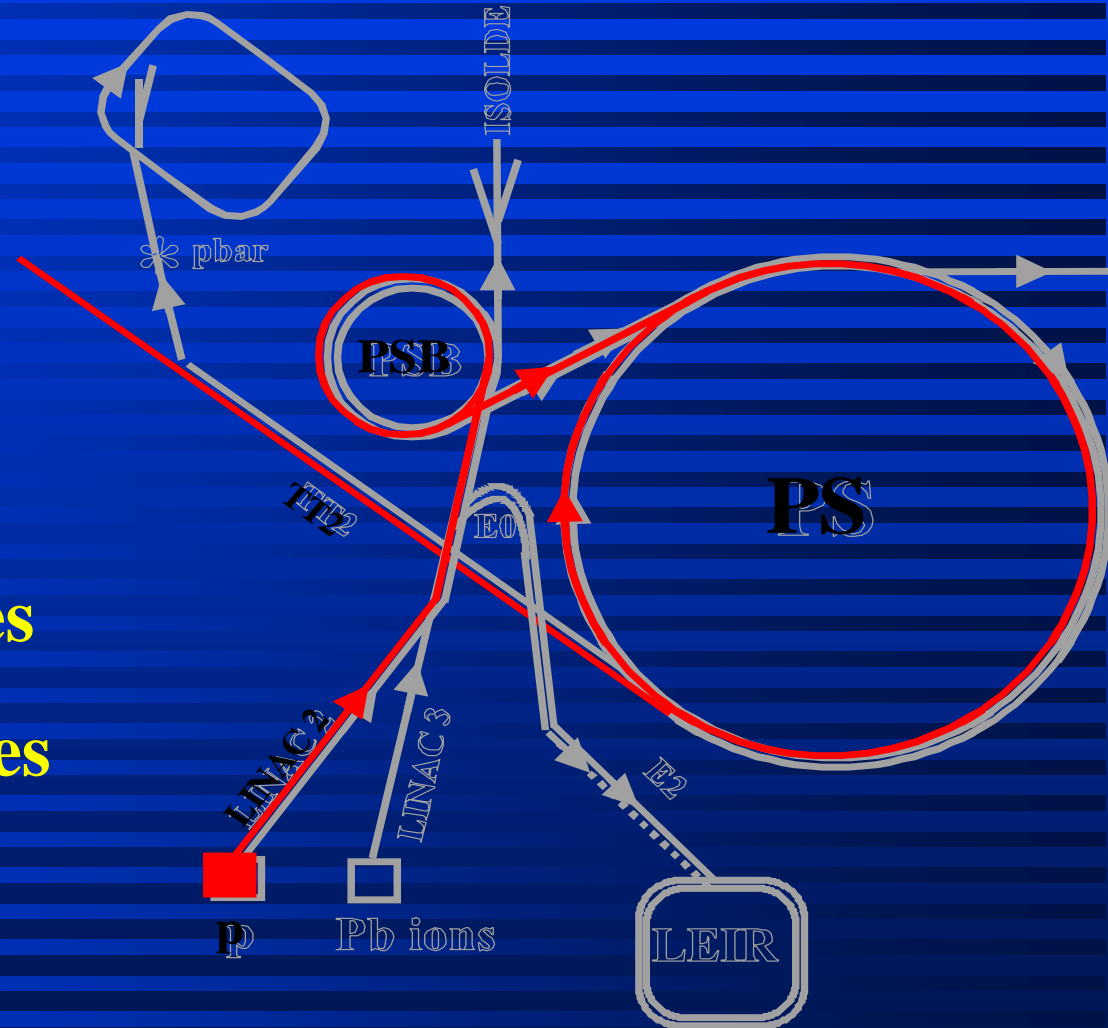
MINIAT

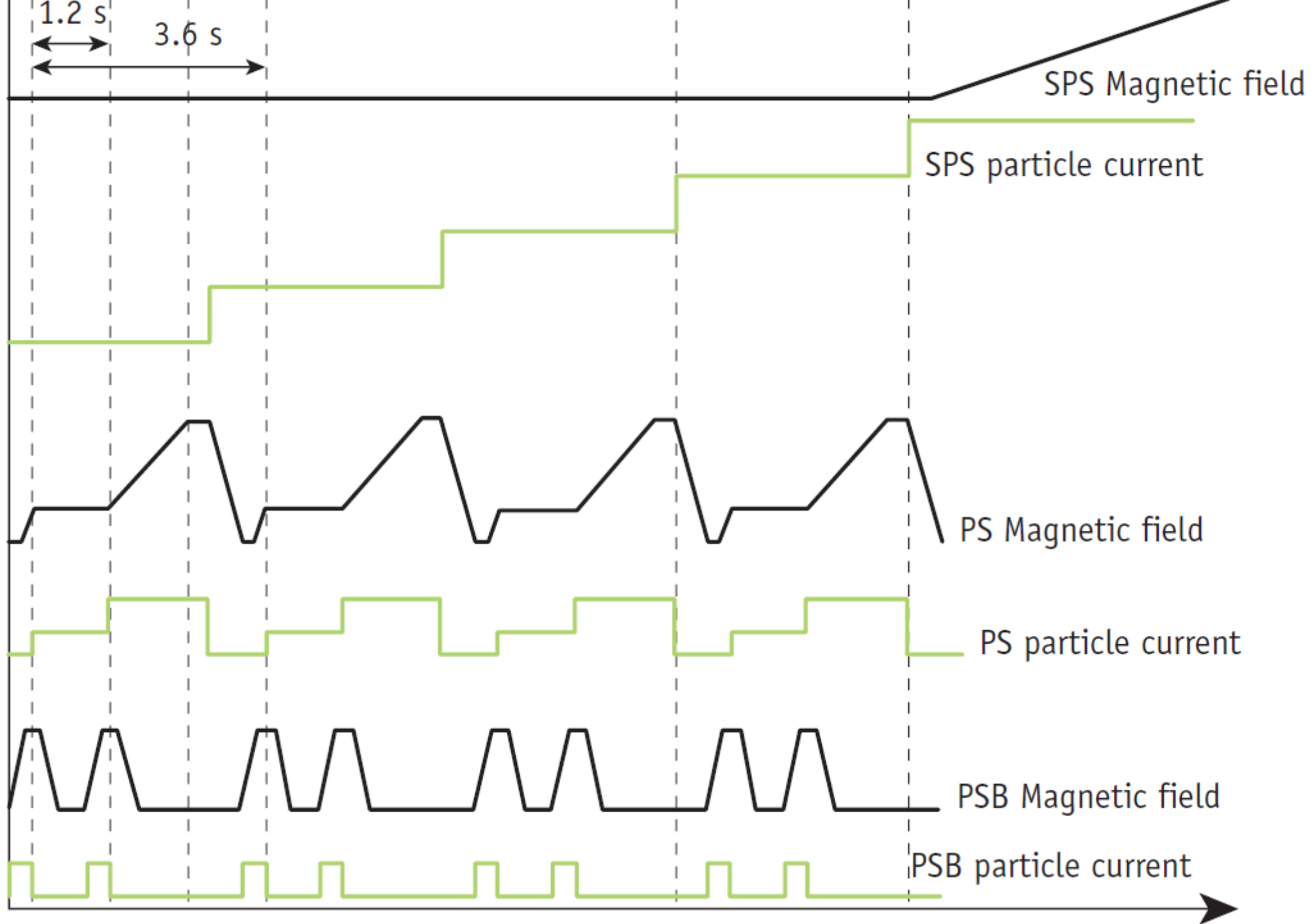


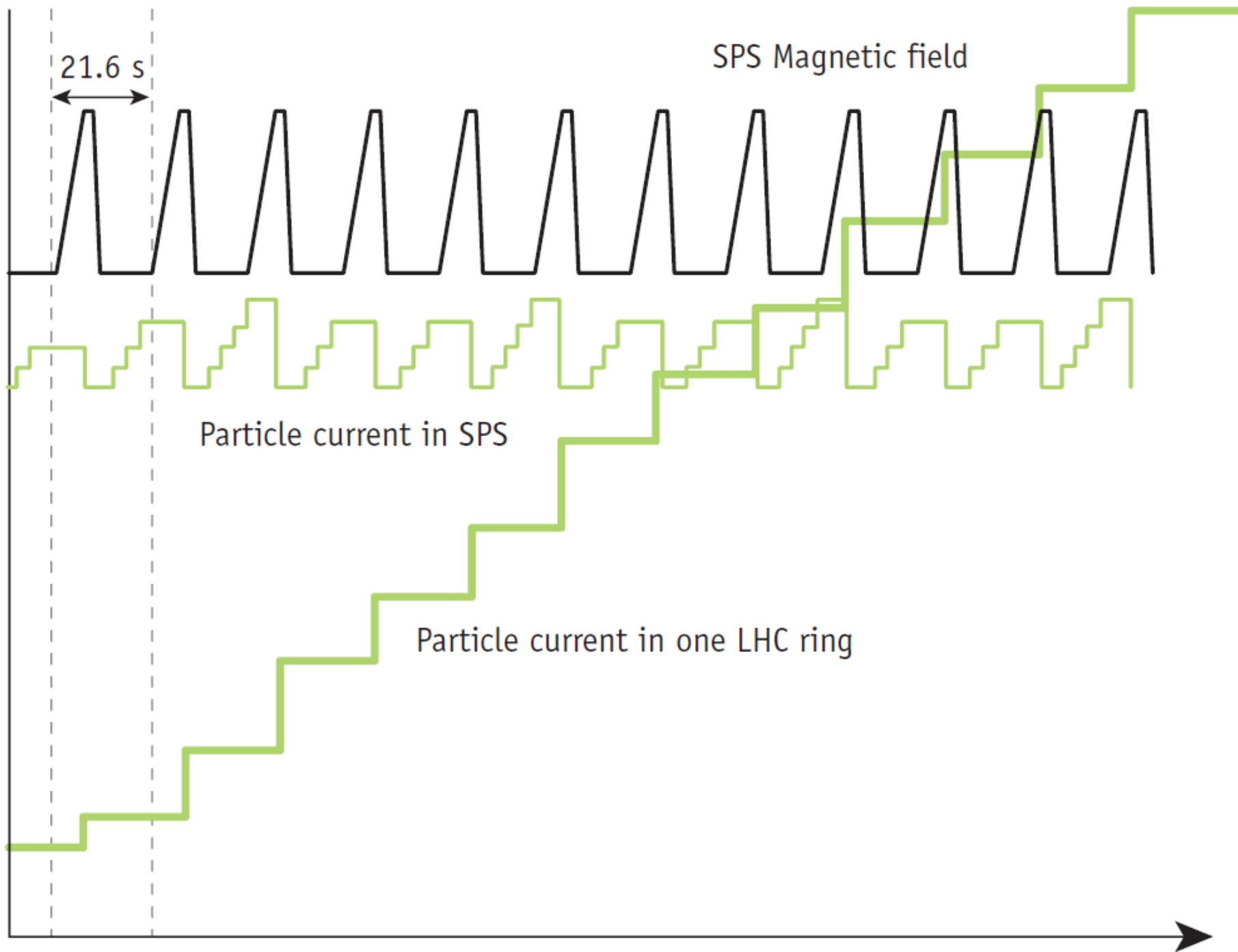
Large Hadron Collider (LHC)
2 interleaved rings; 26.7 km
7 TeV ; 3×10^{14} p⁺/ring
[2.8 TeV/u Pb⁸²⁺]

Proton beam production for LHC

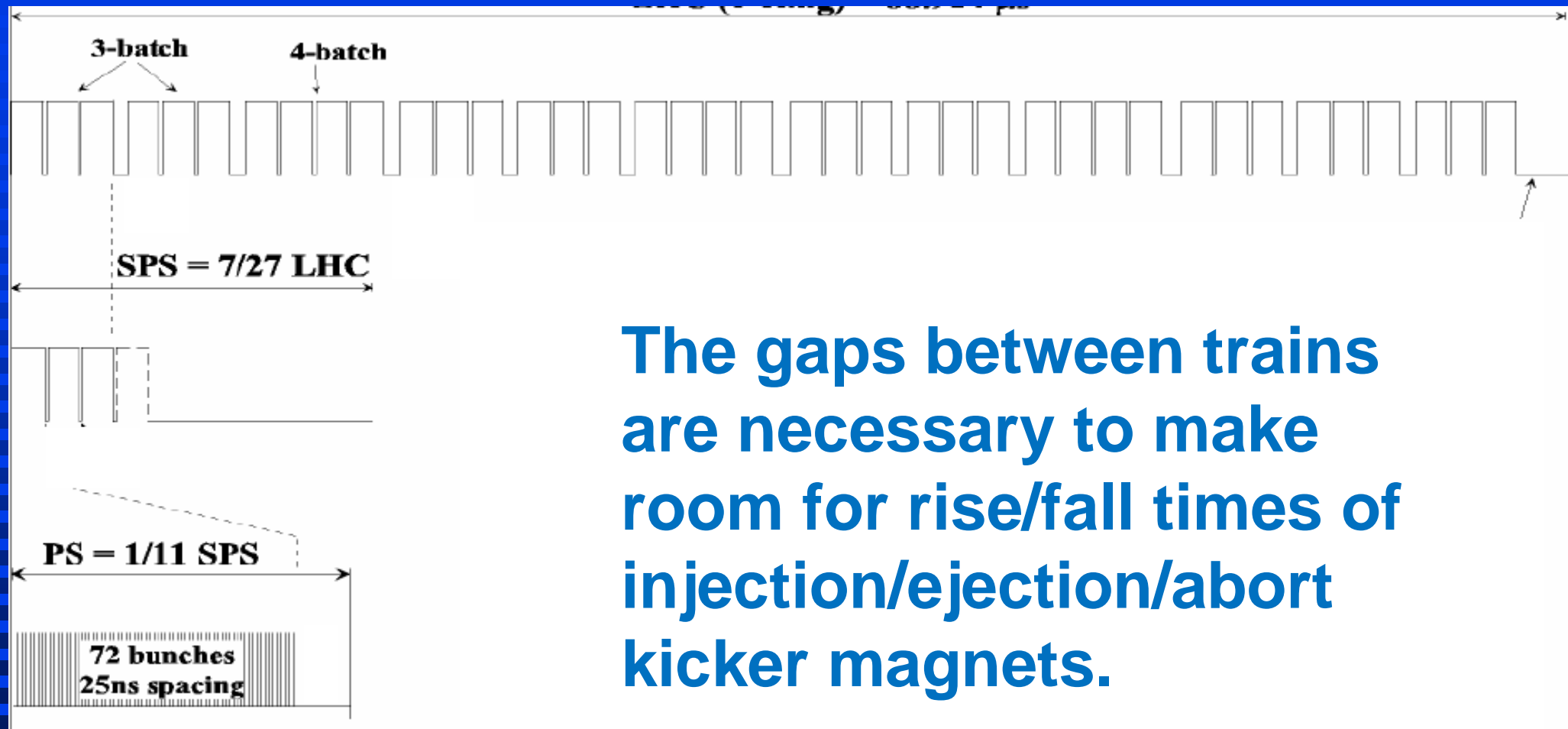
- Linac2 (50MeV)
- PSB (1.4GeV) 4+2 bunches
- PS (25GeV) 72 bunches
- SPS (450 GeV) 4 x 72 bunches
- LHC (7 TeV) 2 x 2808 bunches





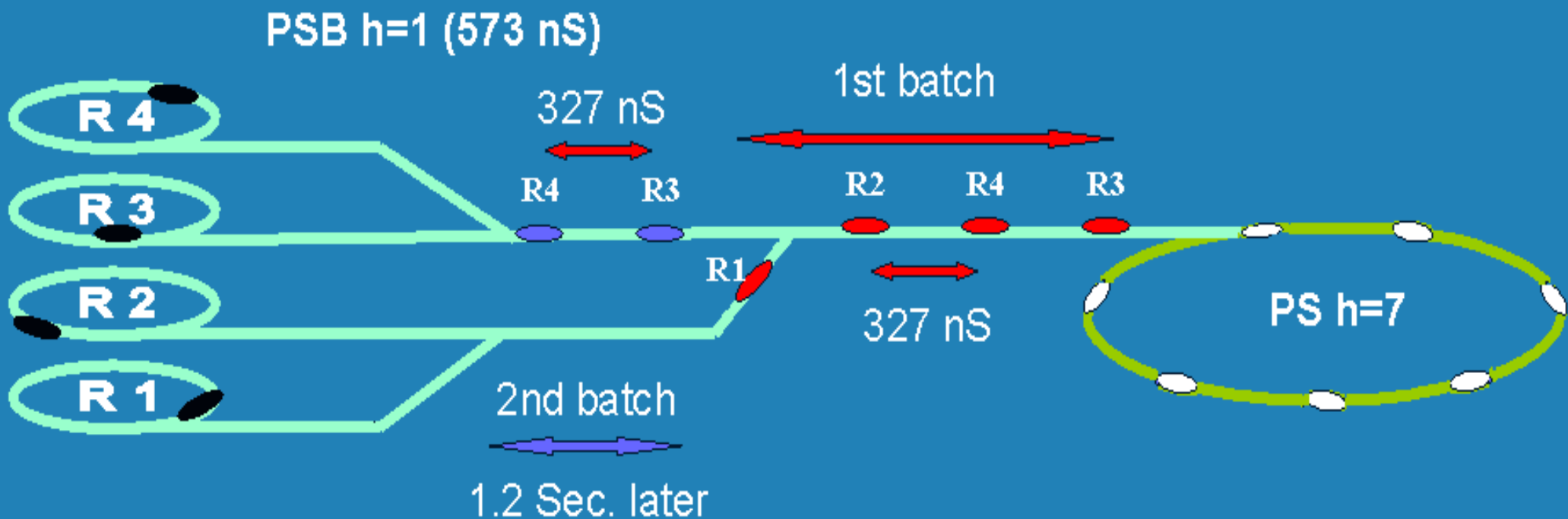


12 injections from SPS to LHC



The gaps between trains are necessary to make room for rise/fall times of injection/ejection/abort kicker magnets.

Double batch injection from PSB to PS

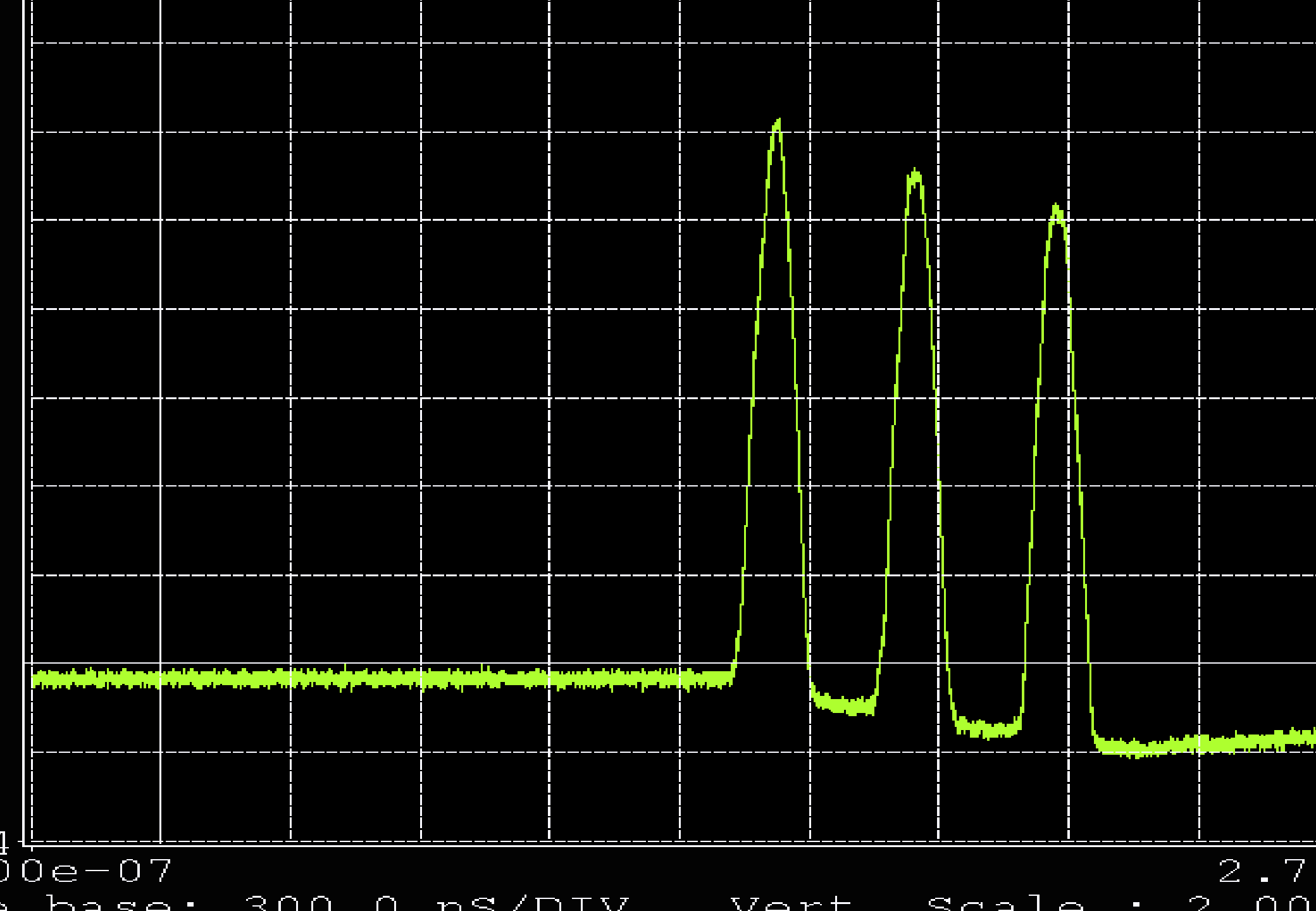


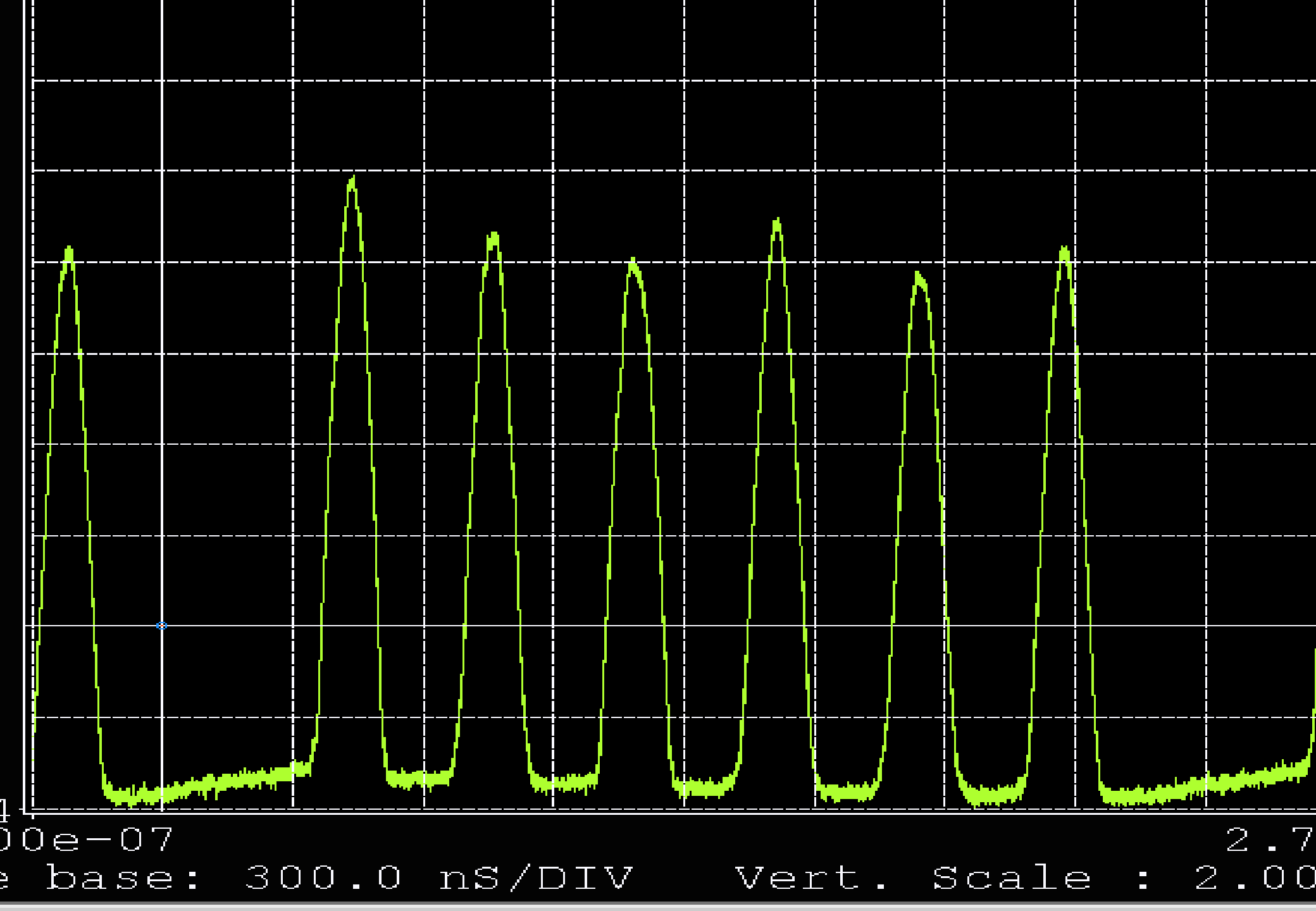
PS cycle: 3.6 S

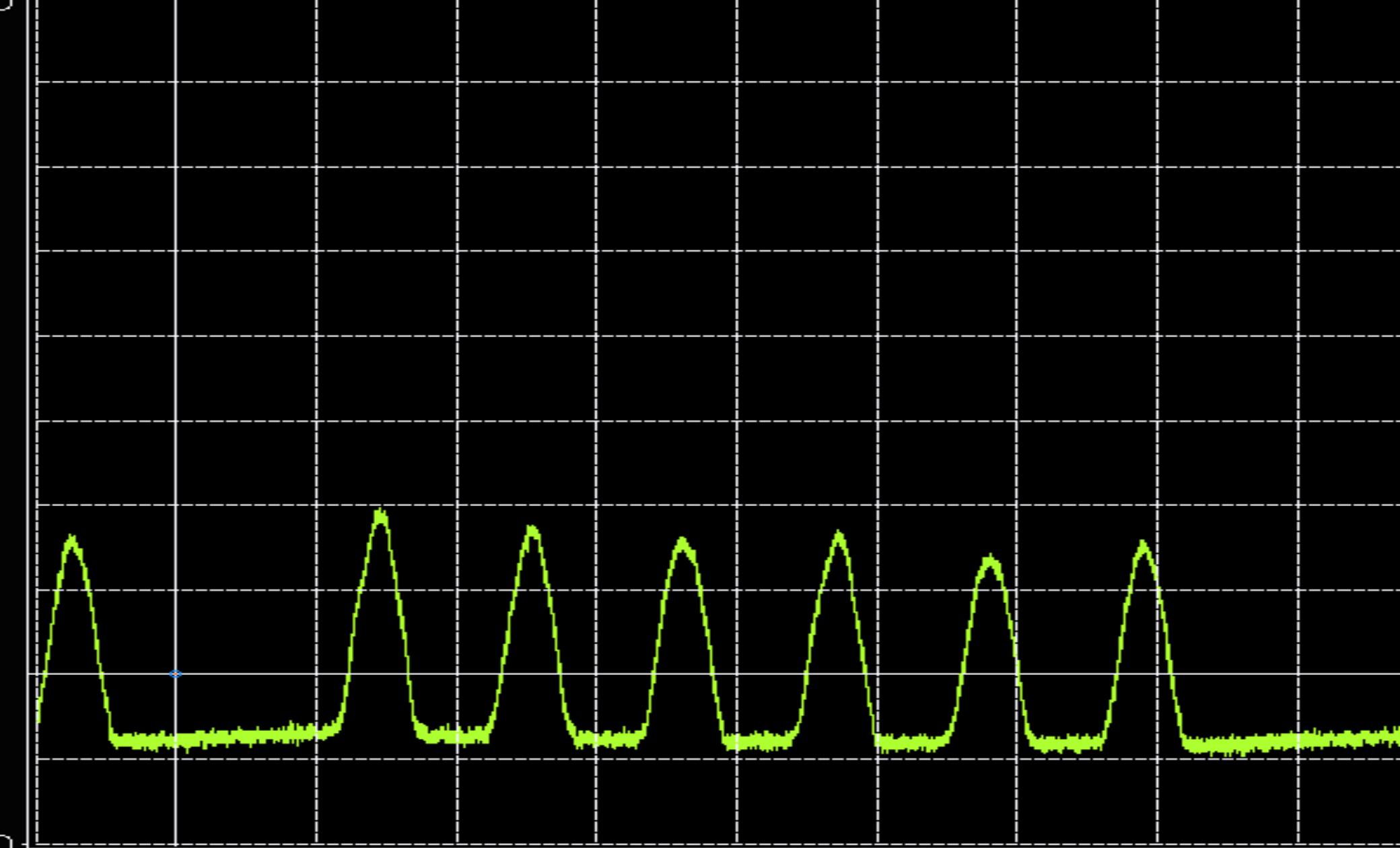
LHC mode 2 batch filling PSB h1, PS h7

After 3 splitting--->PS ejection =
72 bunches and 84 buckets

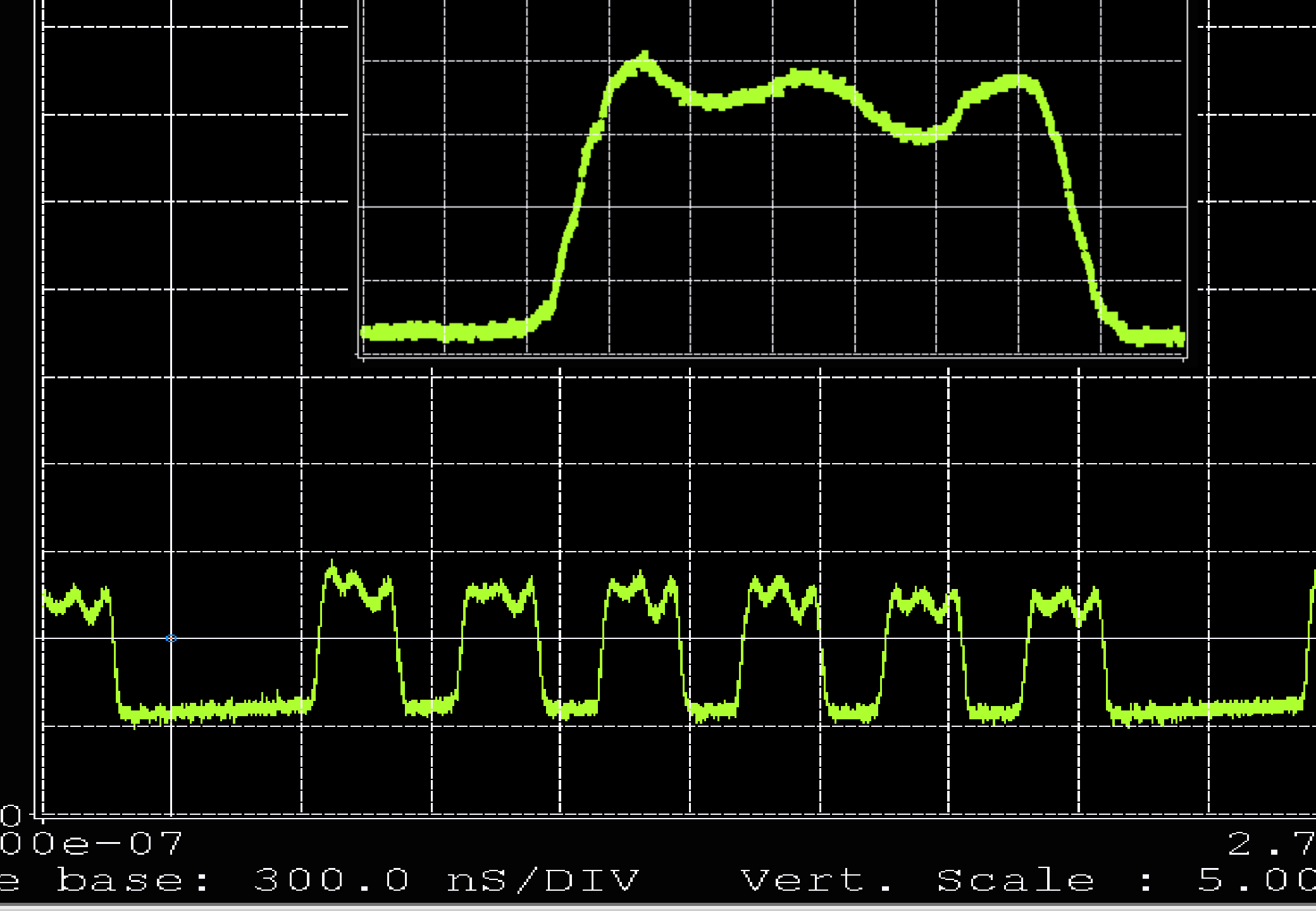
[M.Lindroos]

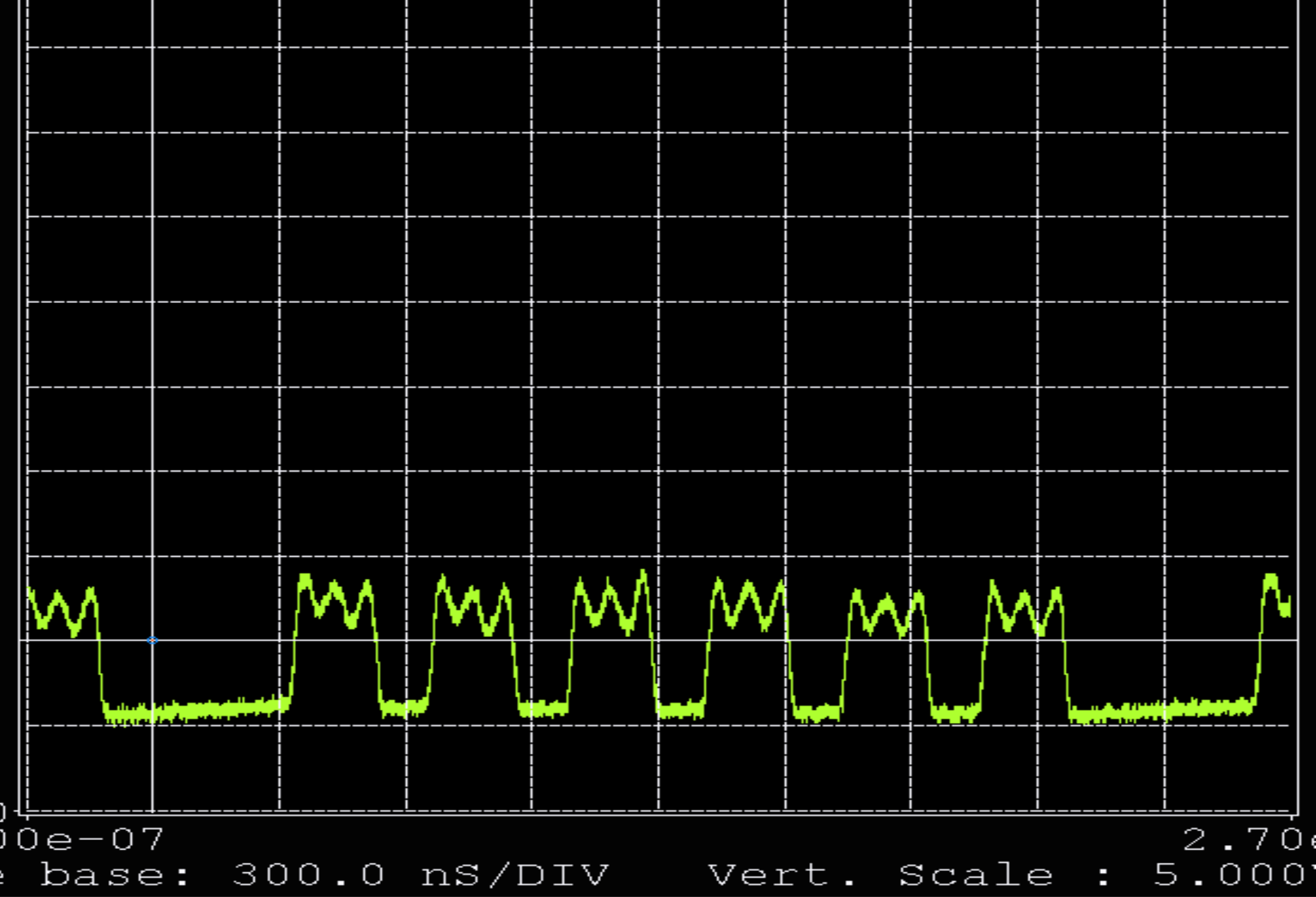


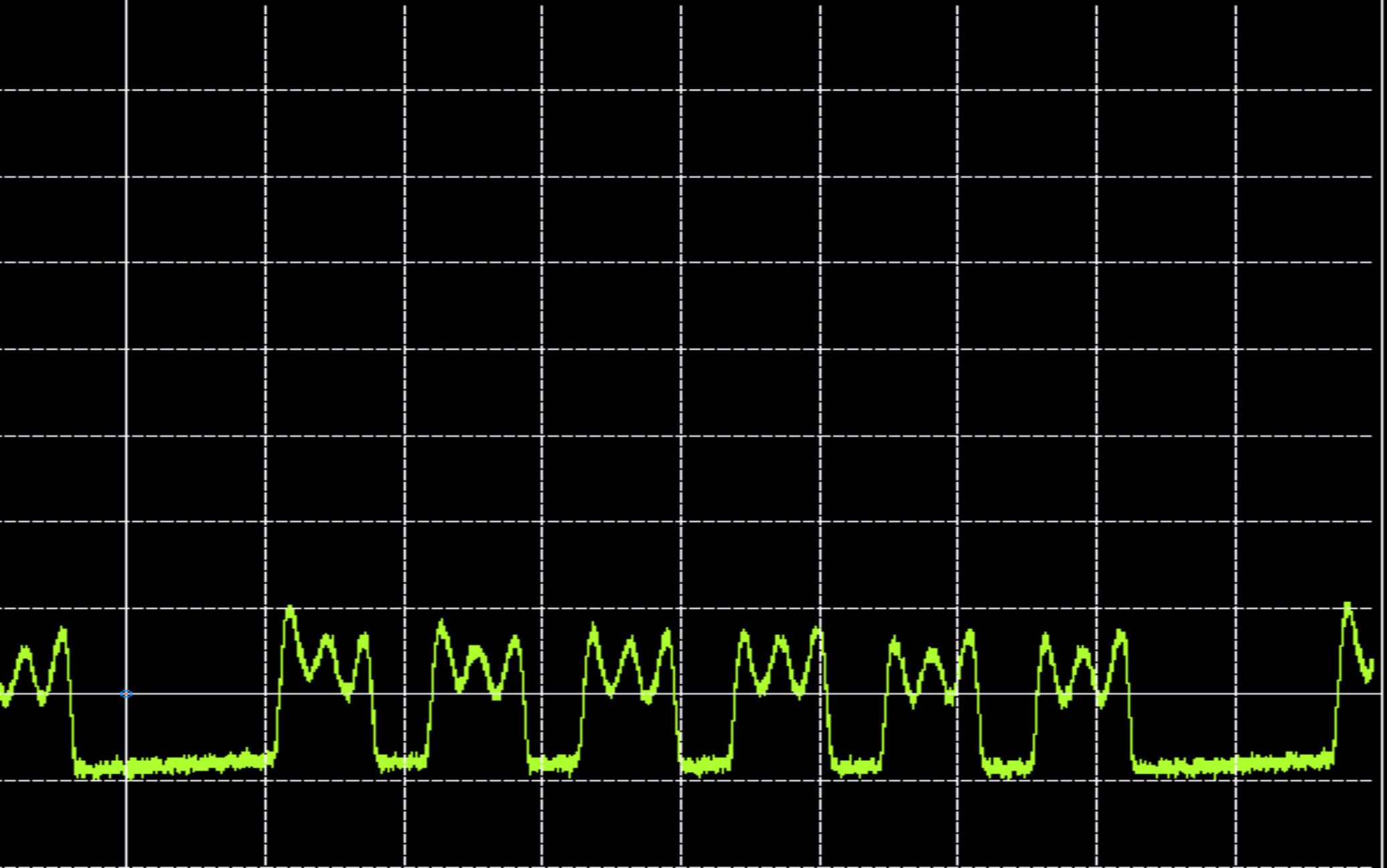




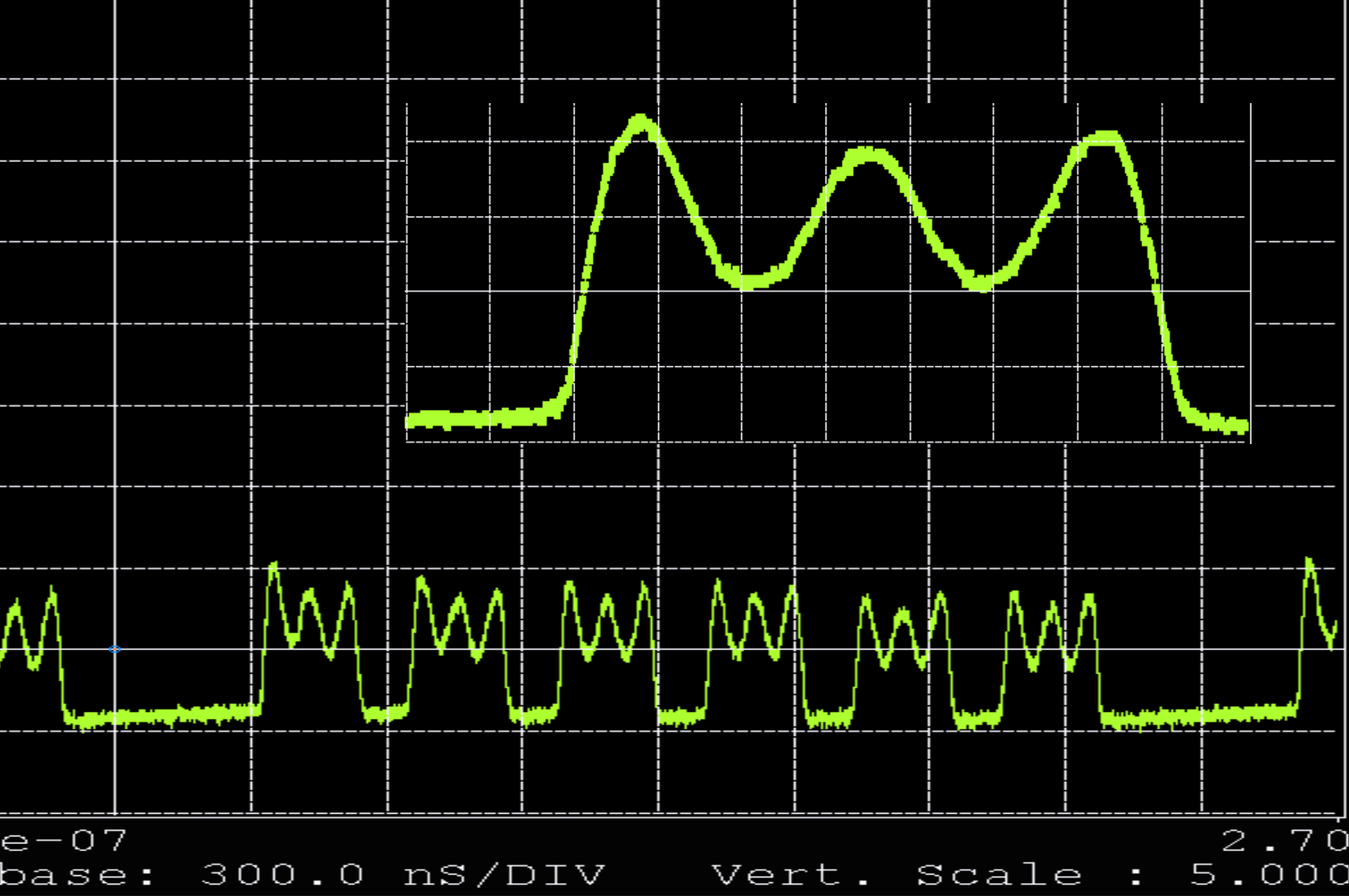
00e-07
e base: 300.0 nS/DIV Vert. Scale : 5.00

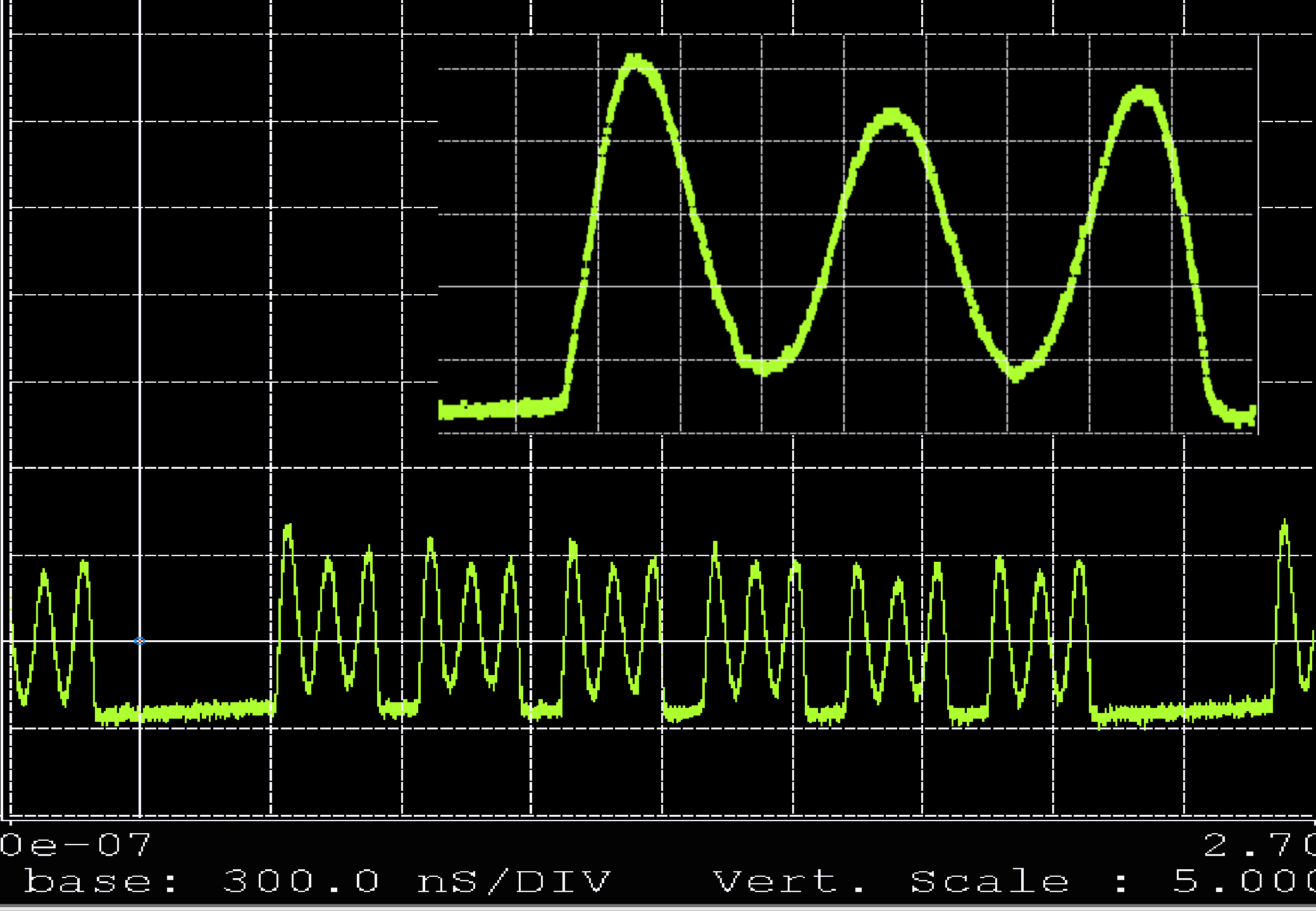


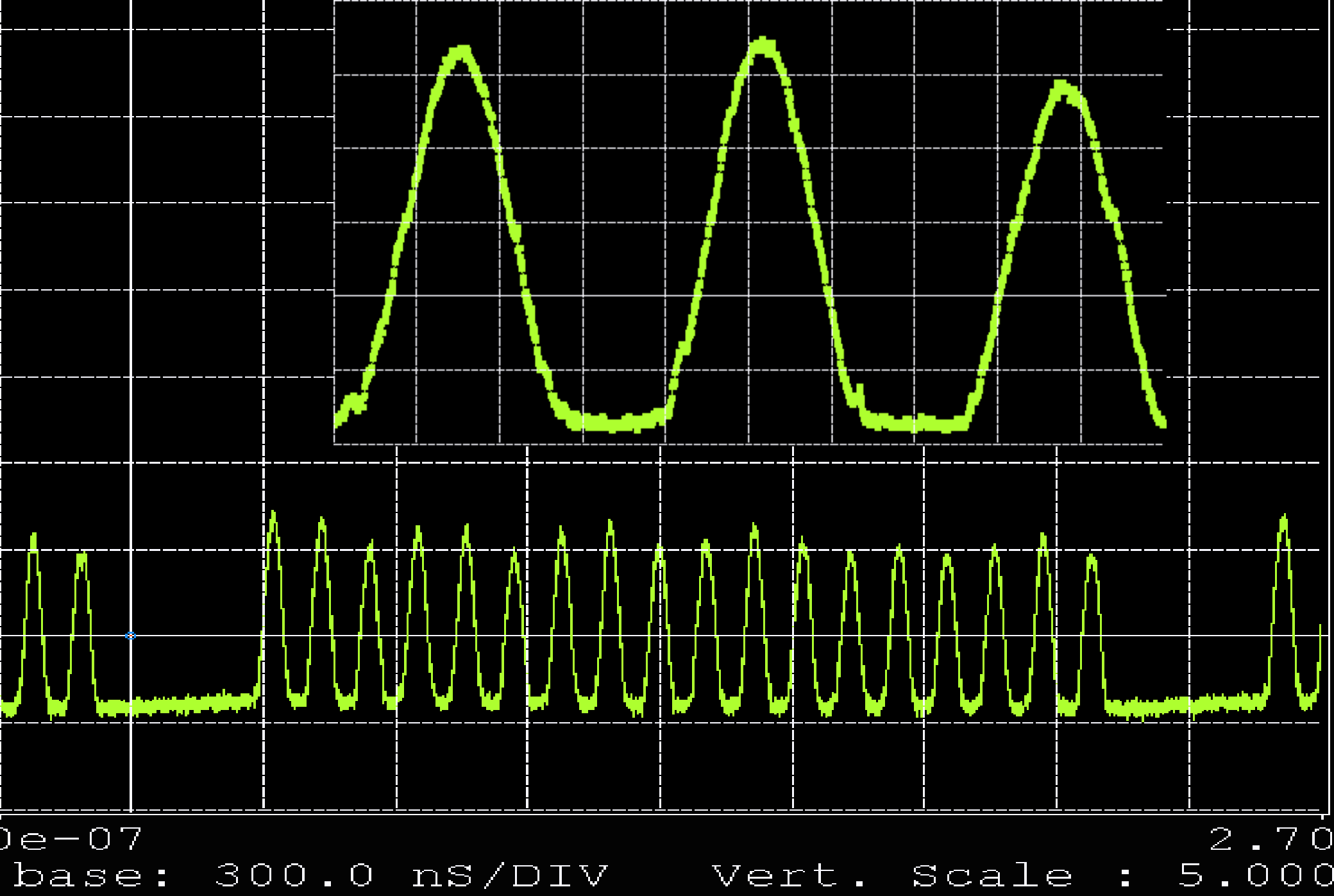




e-07 2.70
base: 300.0 nS/DIV Vert. Scale : 5.000







0e-07

base: 300.0 nS/DIV

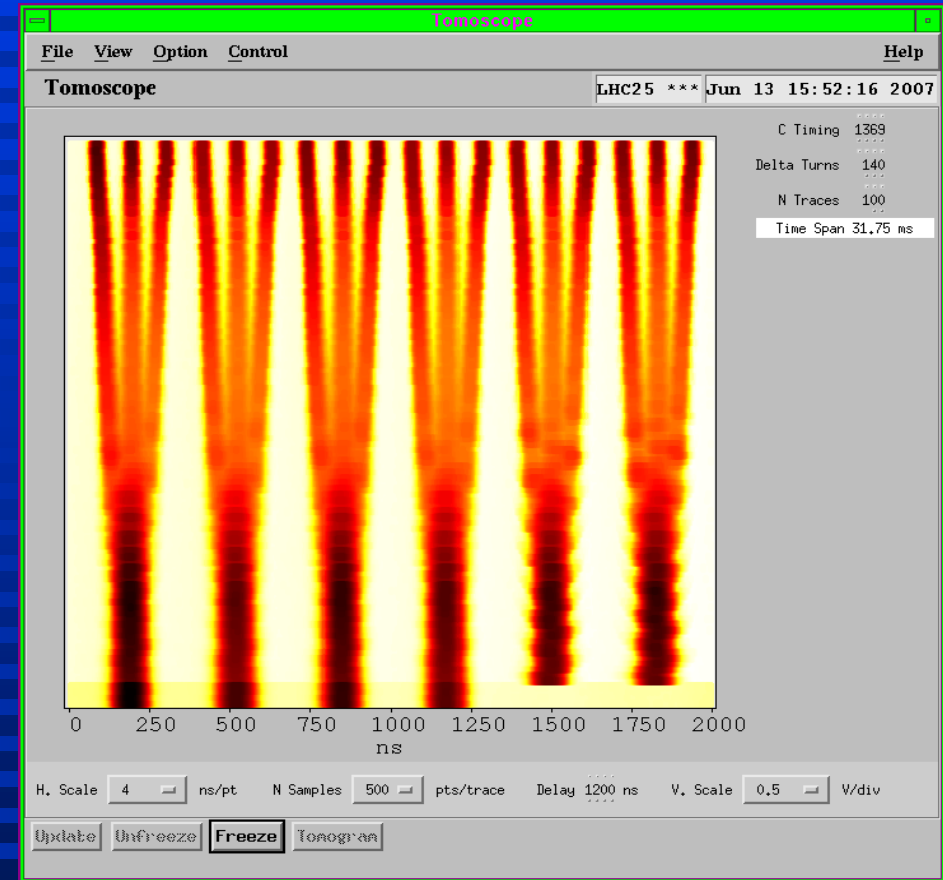
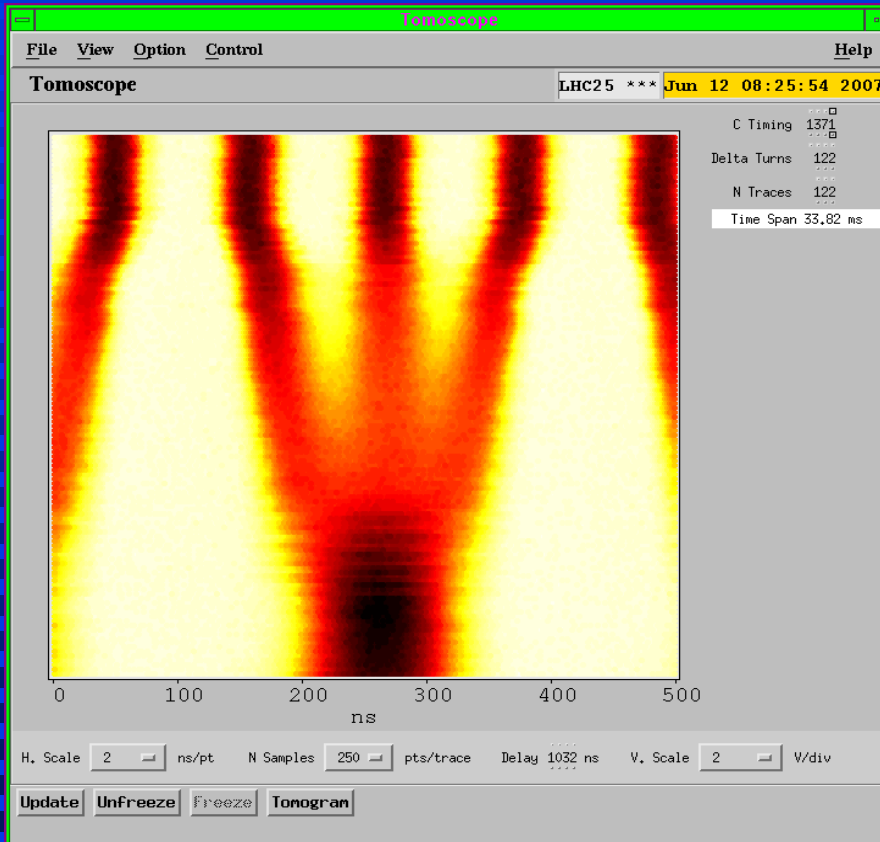
Vert. Scale : 5.000

2.70

Triple bunch splitting in PS

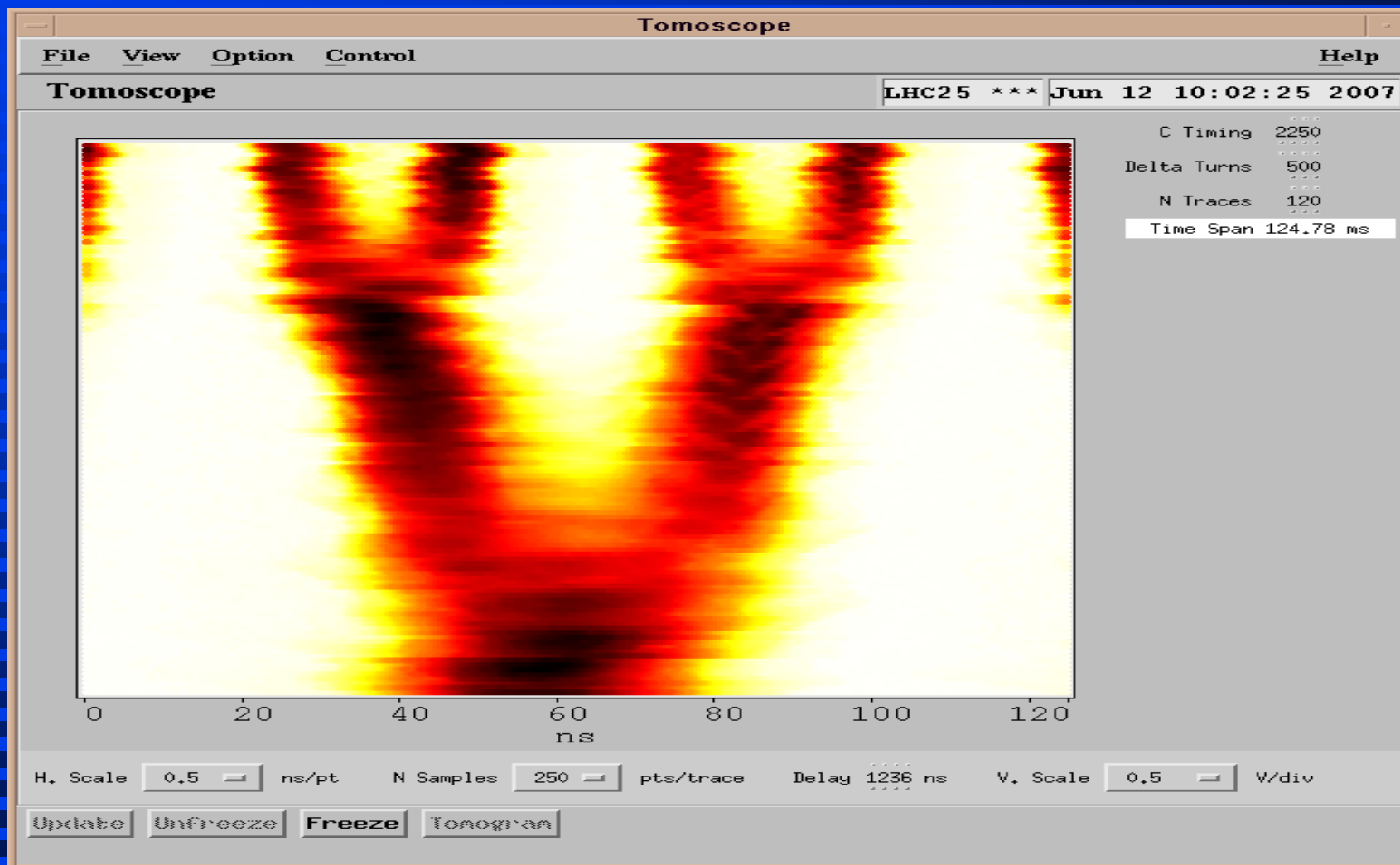
“Waterfall” representation: V=time, H=position, colour=density

time

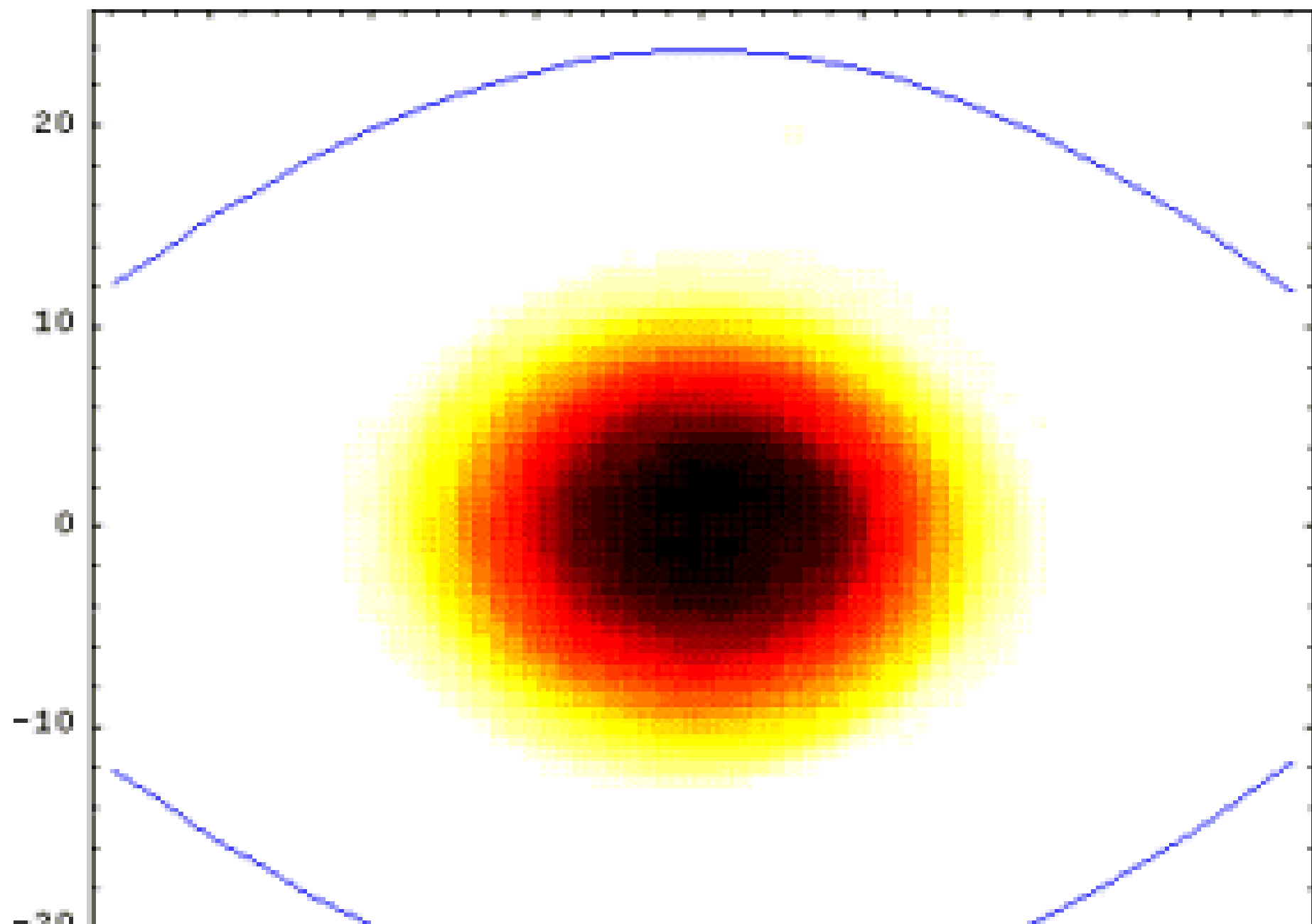


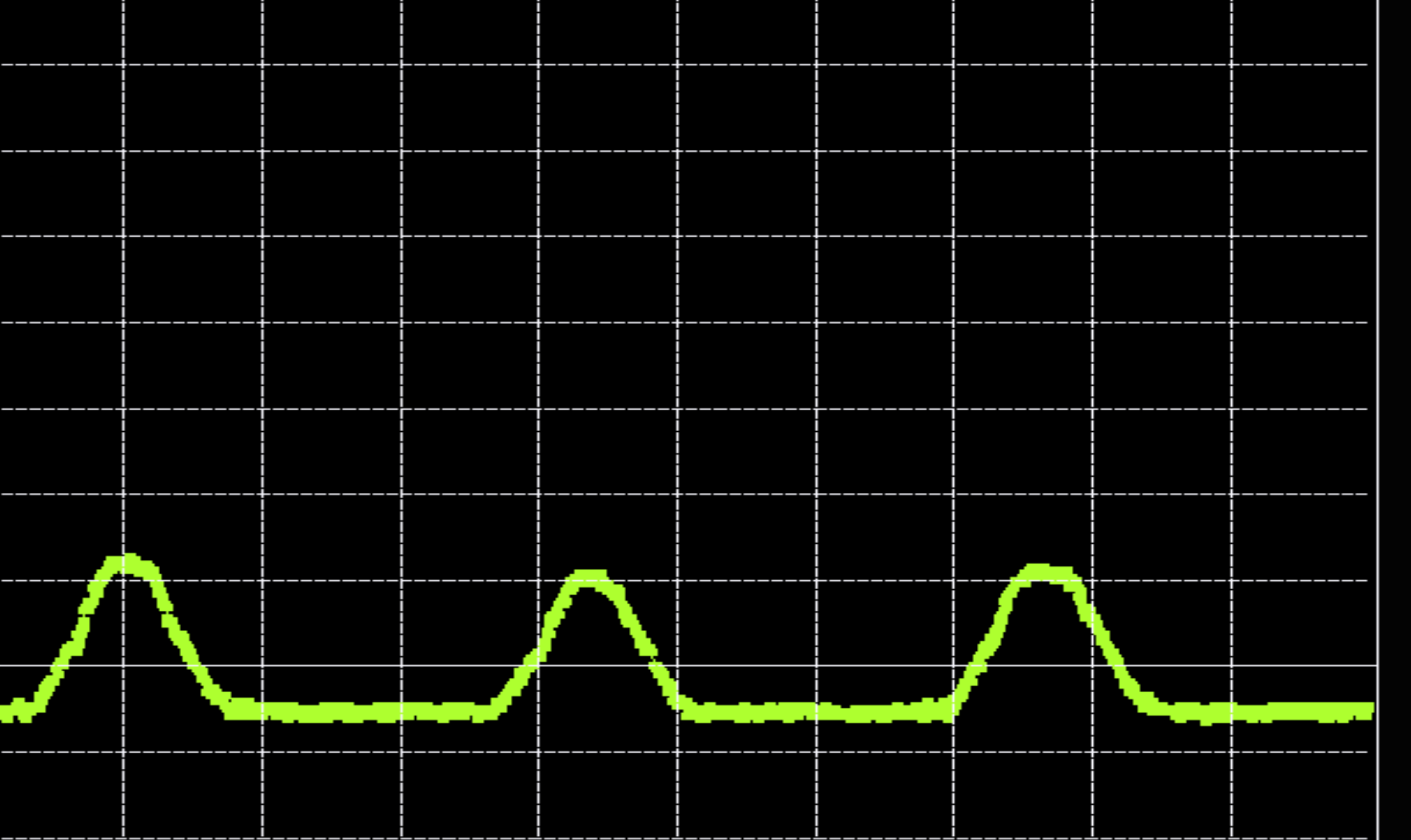
position

Two more bunch splittings in PS

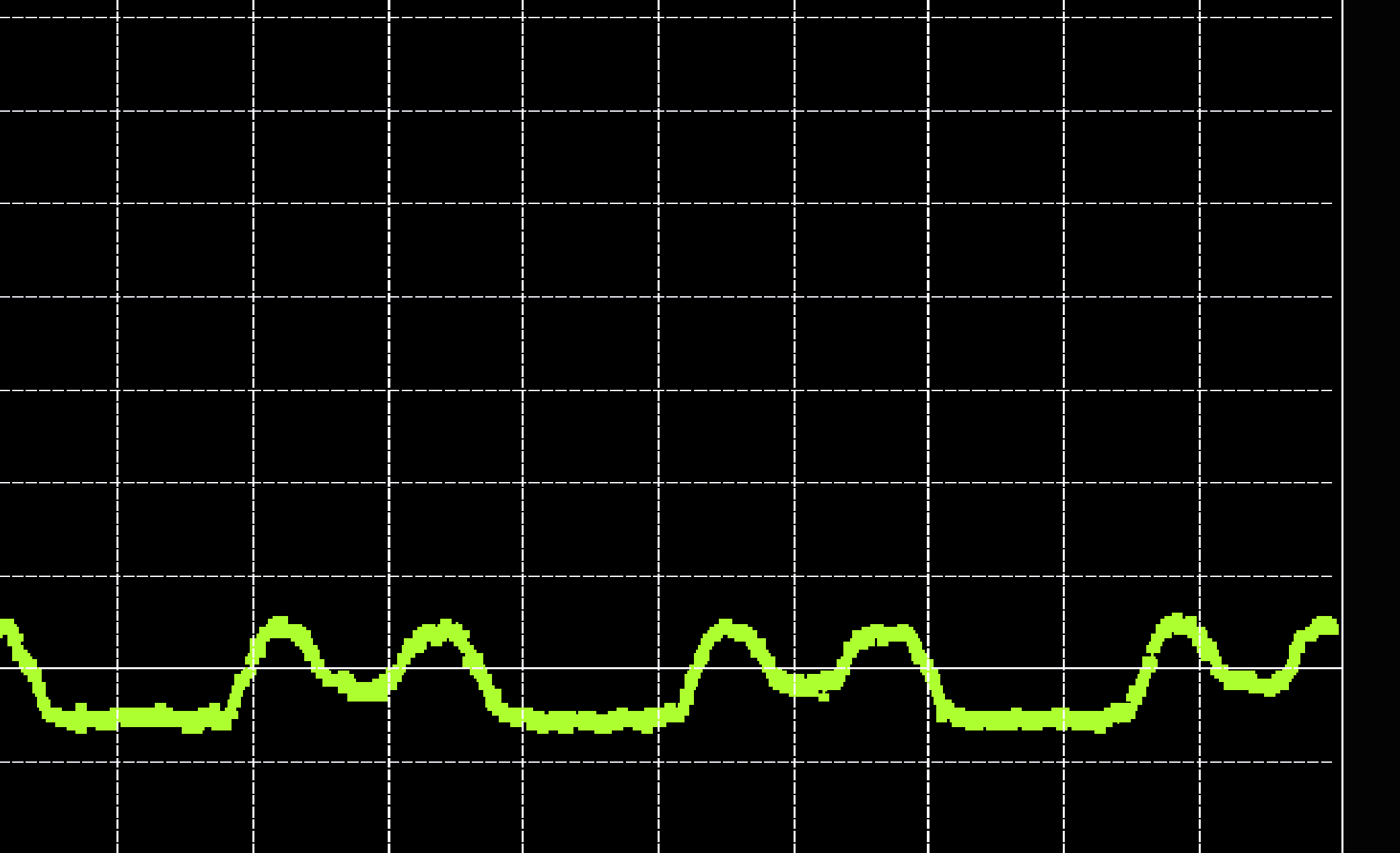


MeV

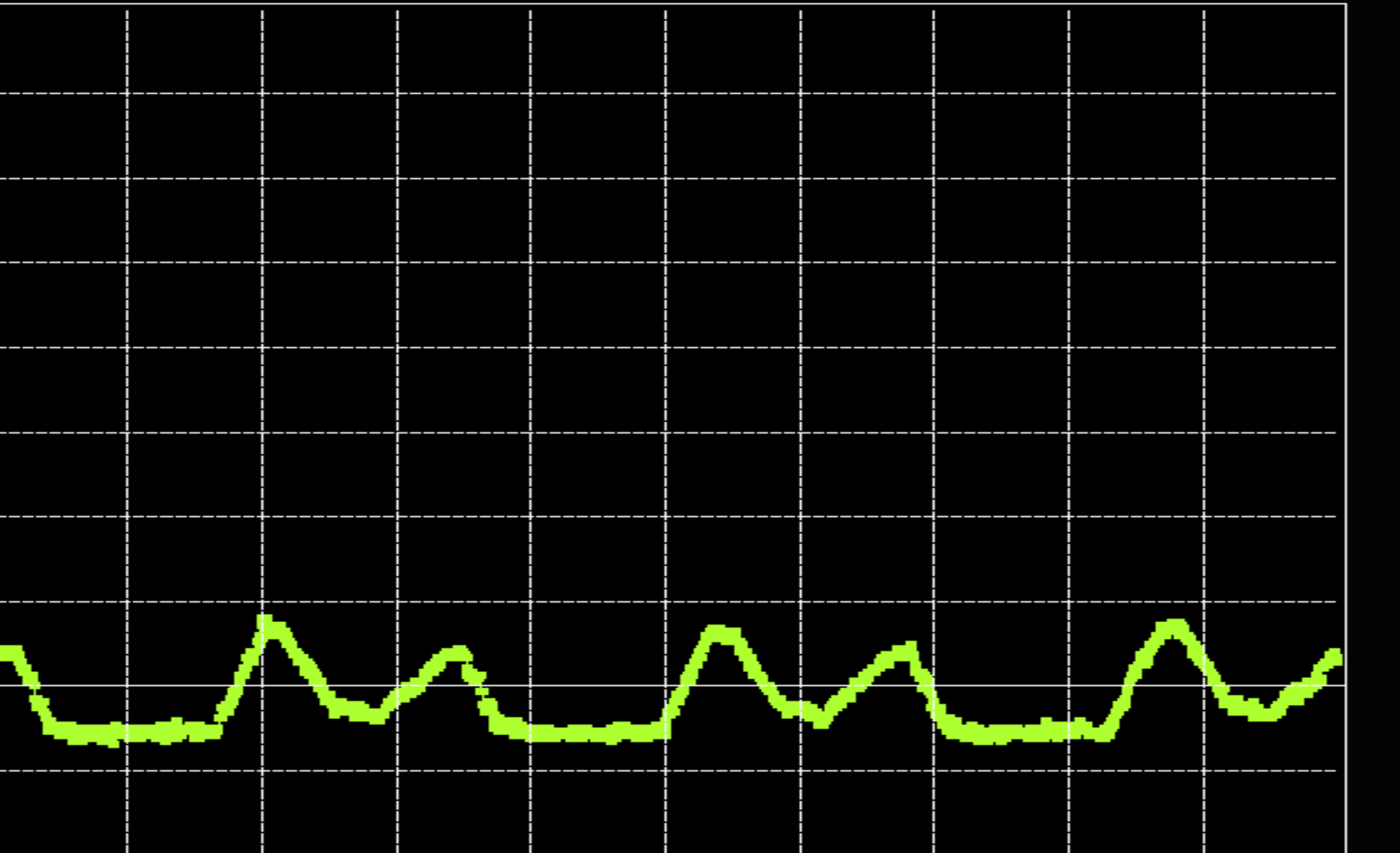




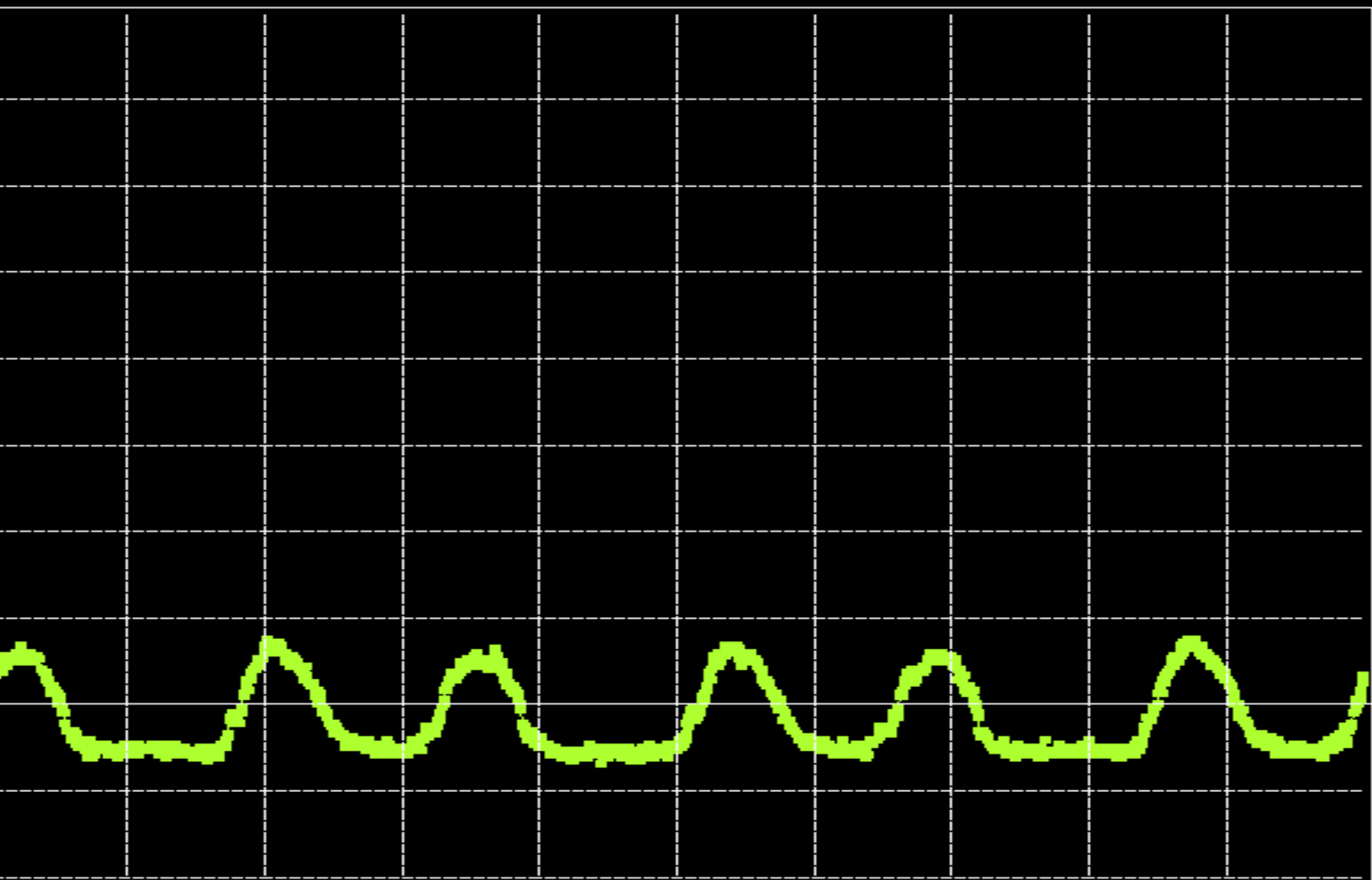
e-07 1.24e
base: 30.0 ns/DIV Vert. Scale : 10.000V



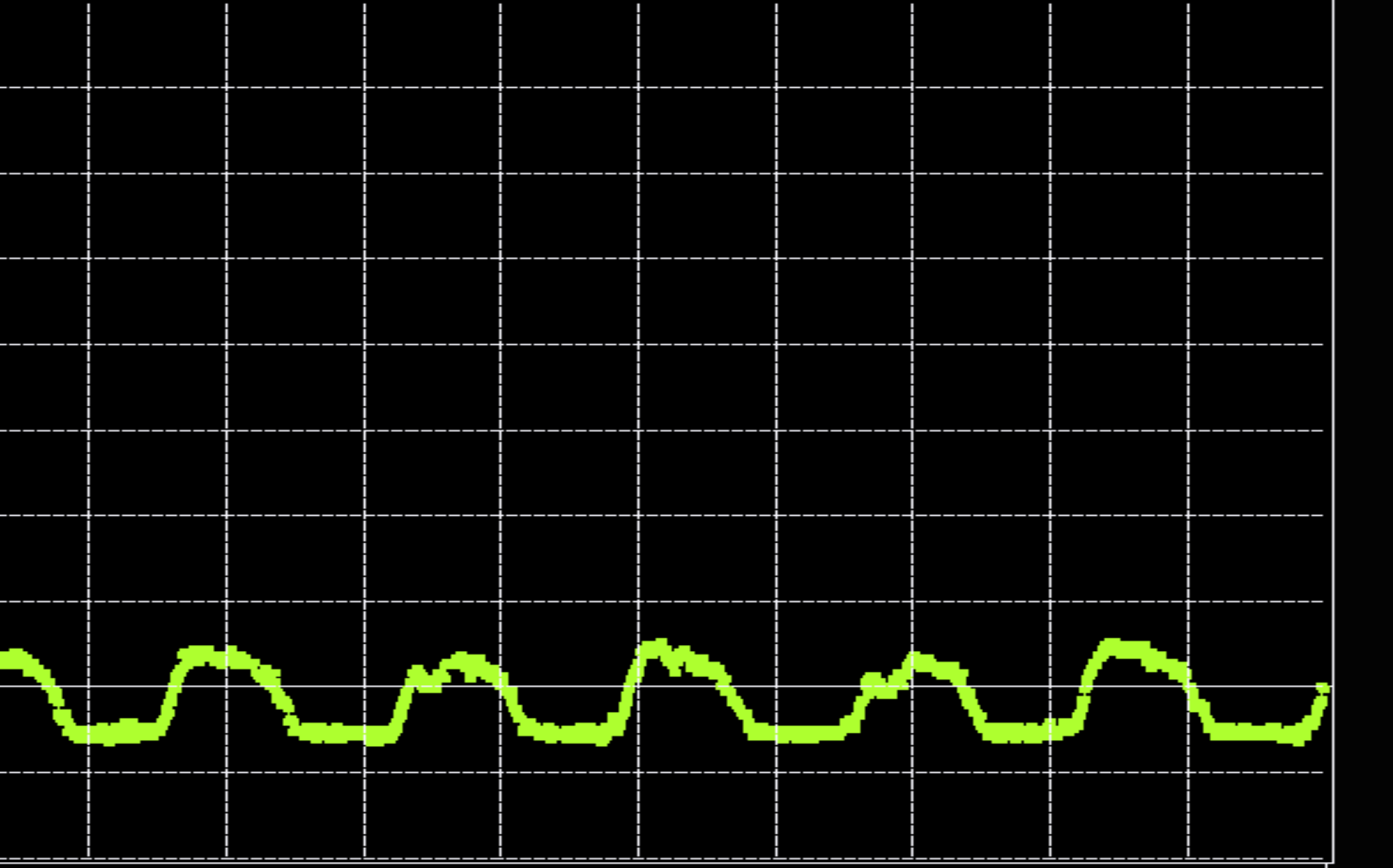
e-07 1.24e-
base: 30.0 nS/DIV Vert. Scale : 10.000V



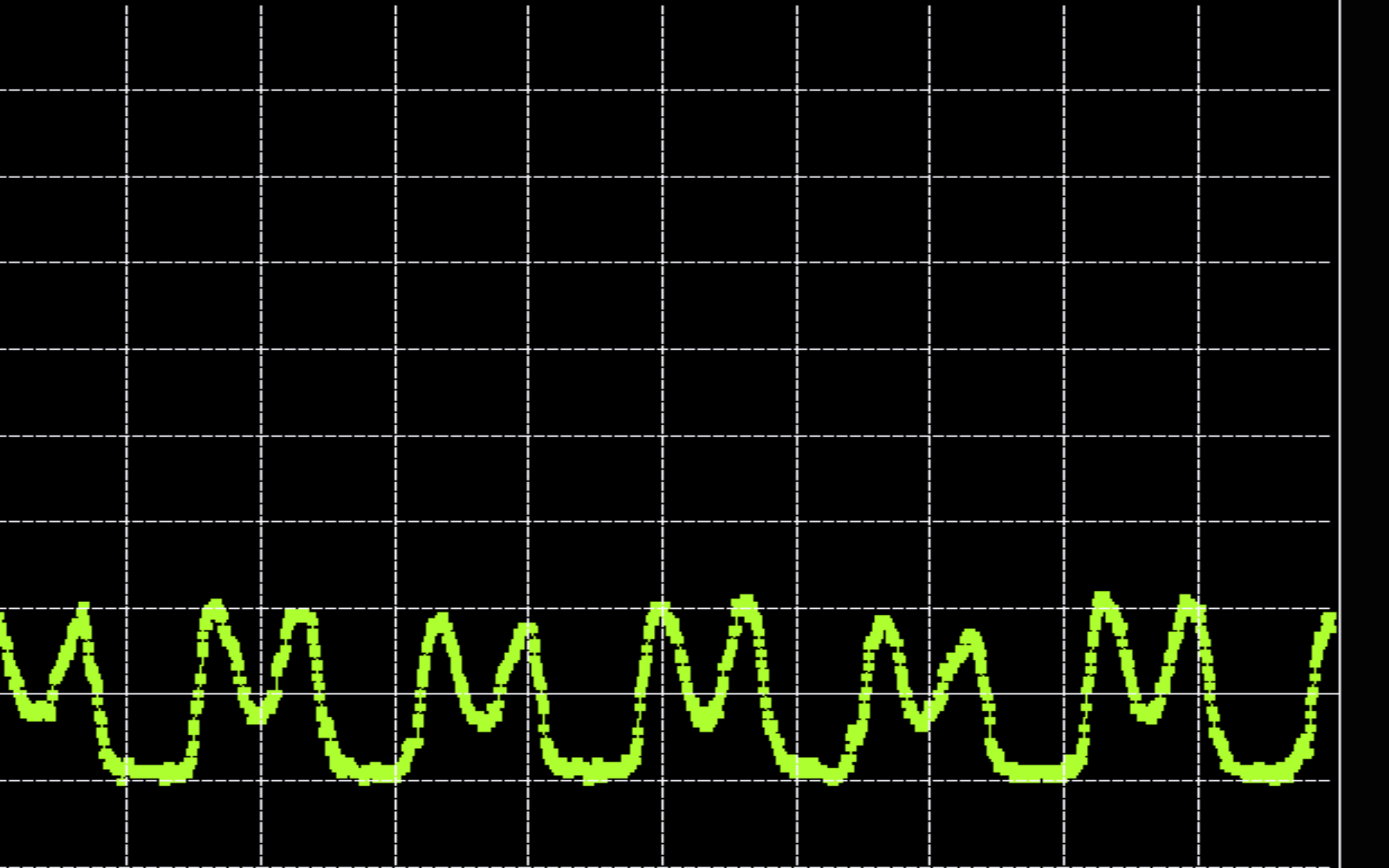
5e-07
base: 30.0 ns/DIV Vert. Scale : 1.24e-
10.000V



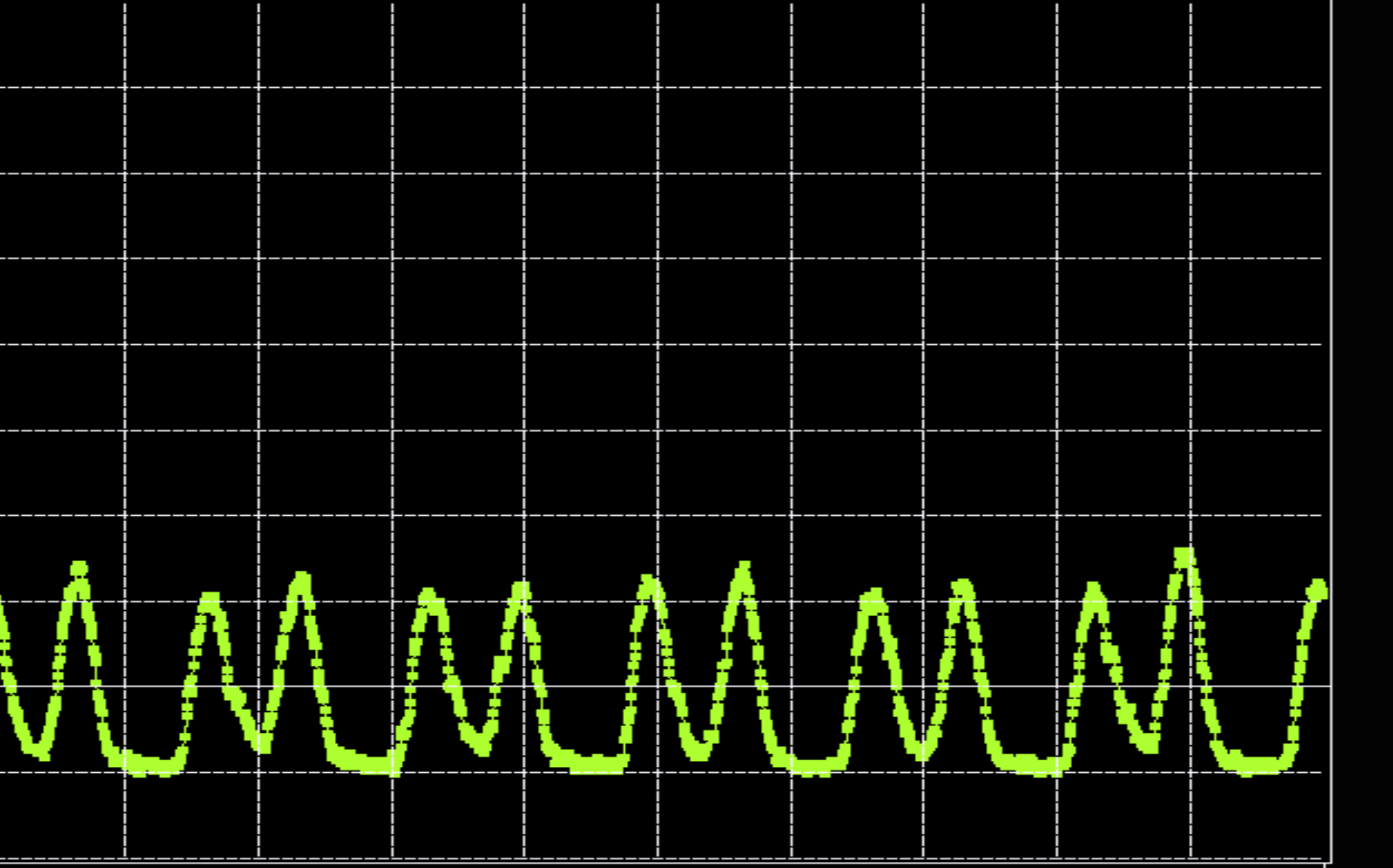
1.24e-
base: 30.0 ns/DIV Vert. Scale : 10.000V/
e-07



-07
ase: 30.0 ns/DIV Vert. Scale : 10.000V, 1.24e-

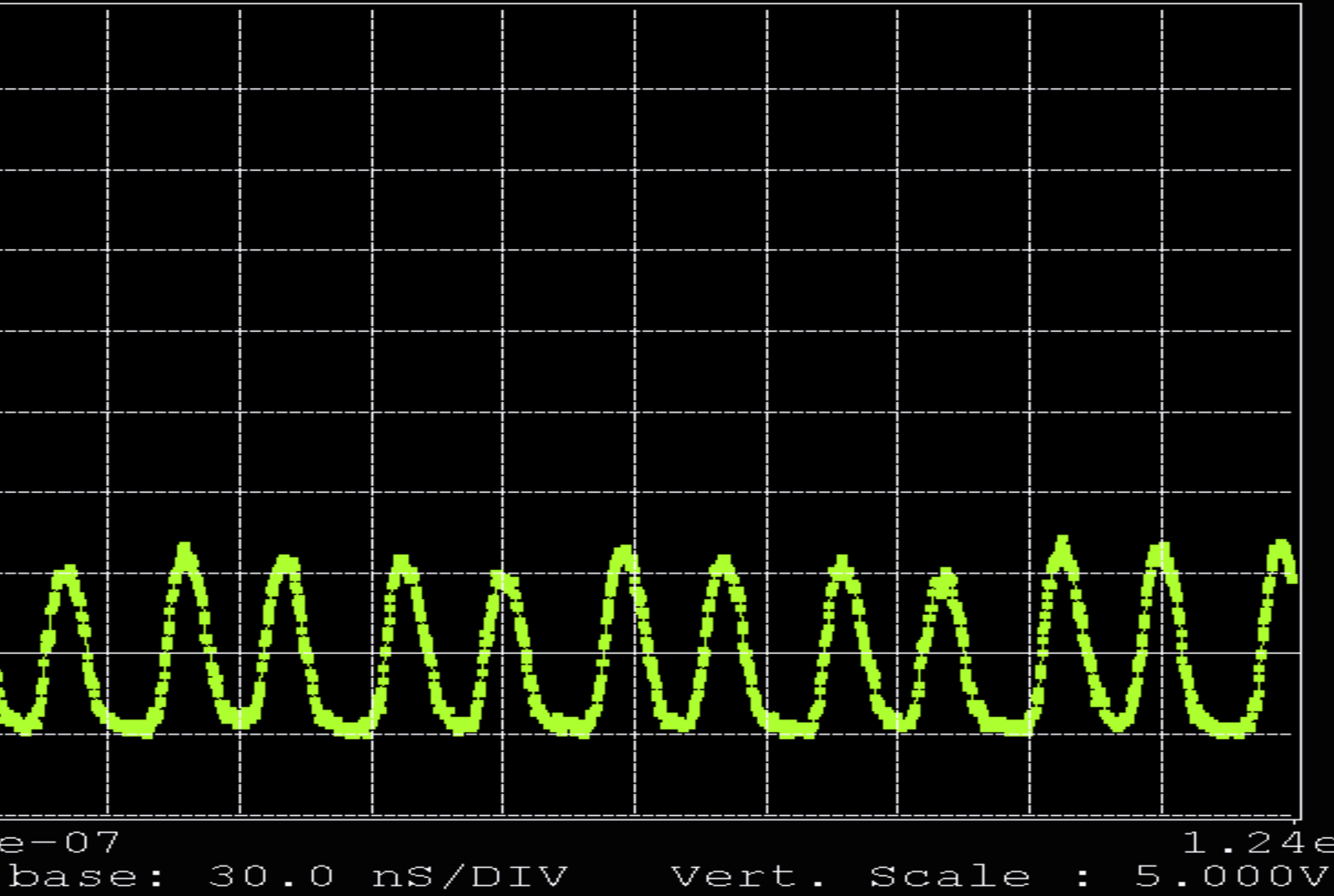


5e-07 1.24e-
base: 30.0 ns/DIV Vert. Scale : 5.000V/

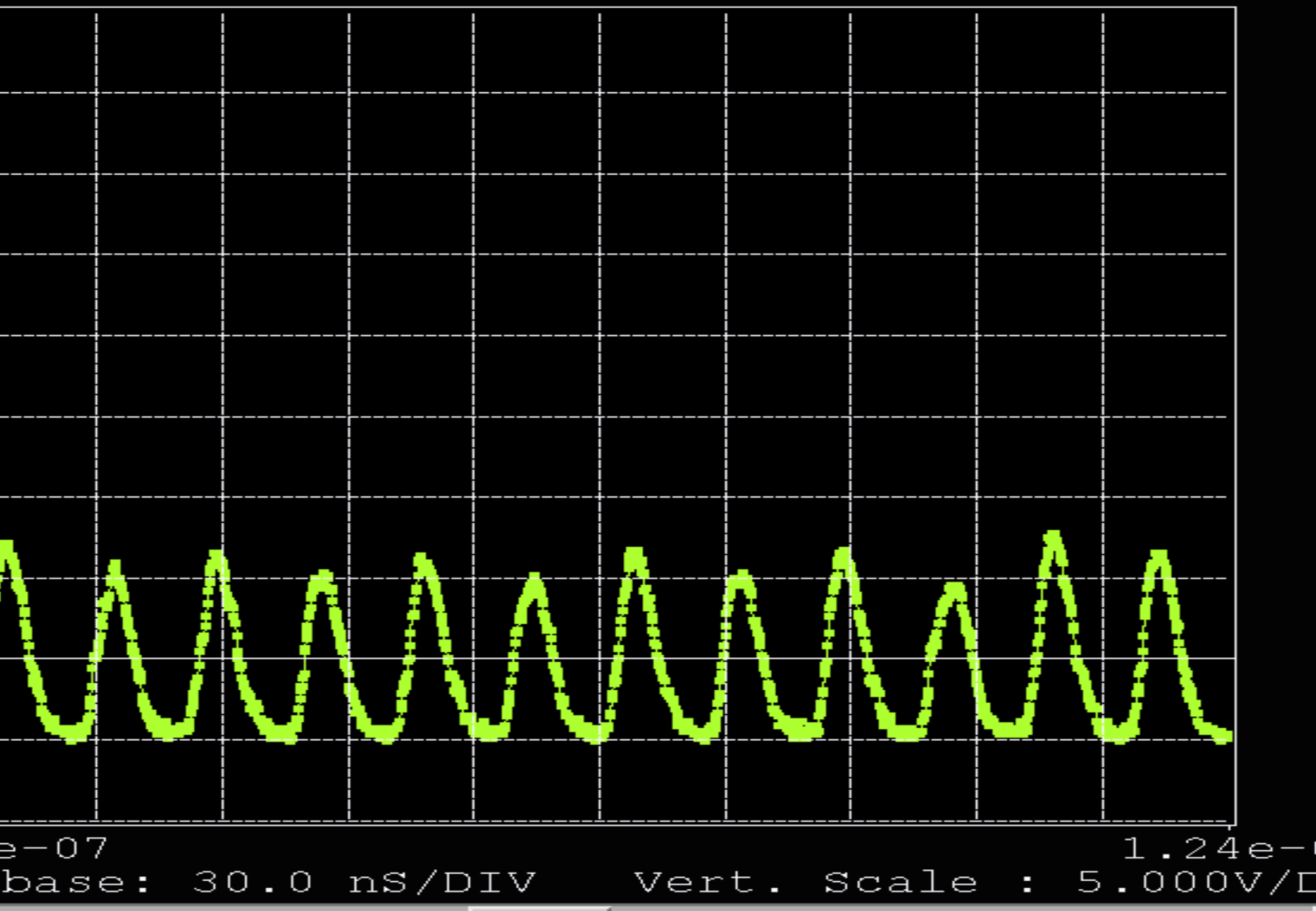


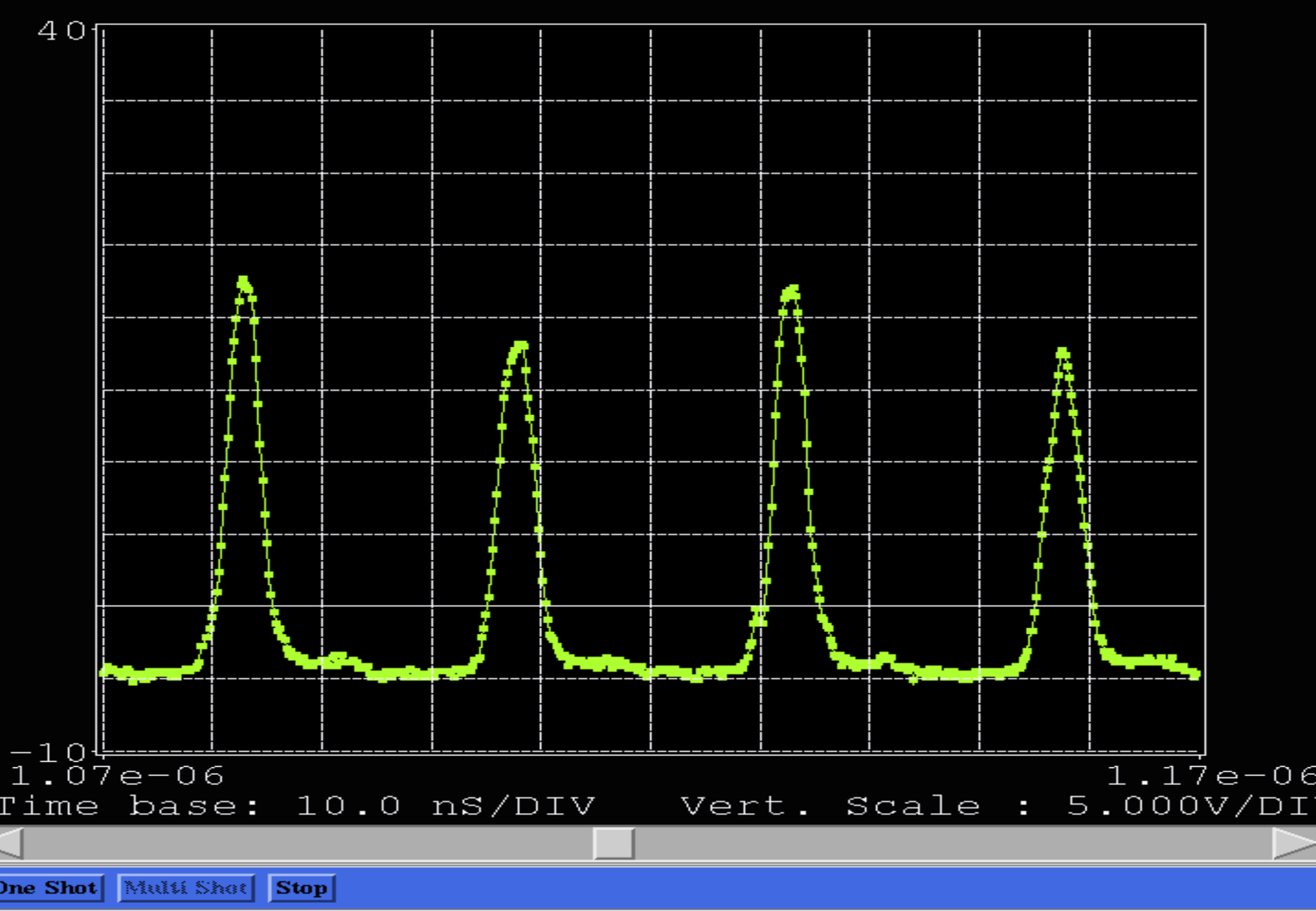
5e-07
base: 30.0 nS/DIV Vert. Scale : 5.000V/

1.24e-

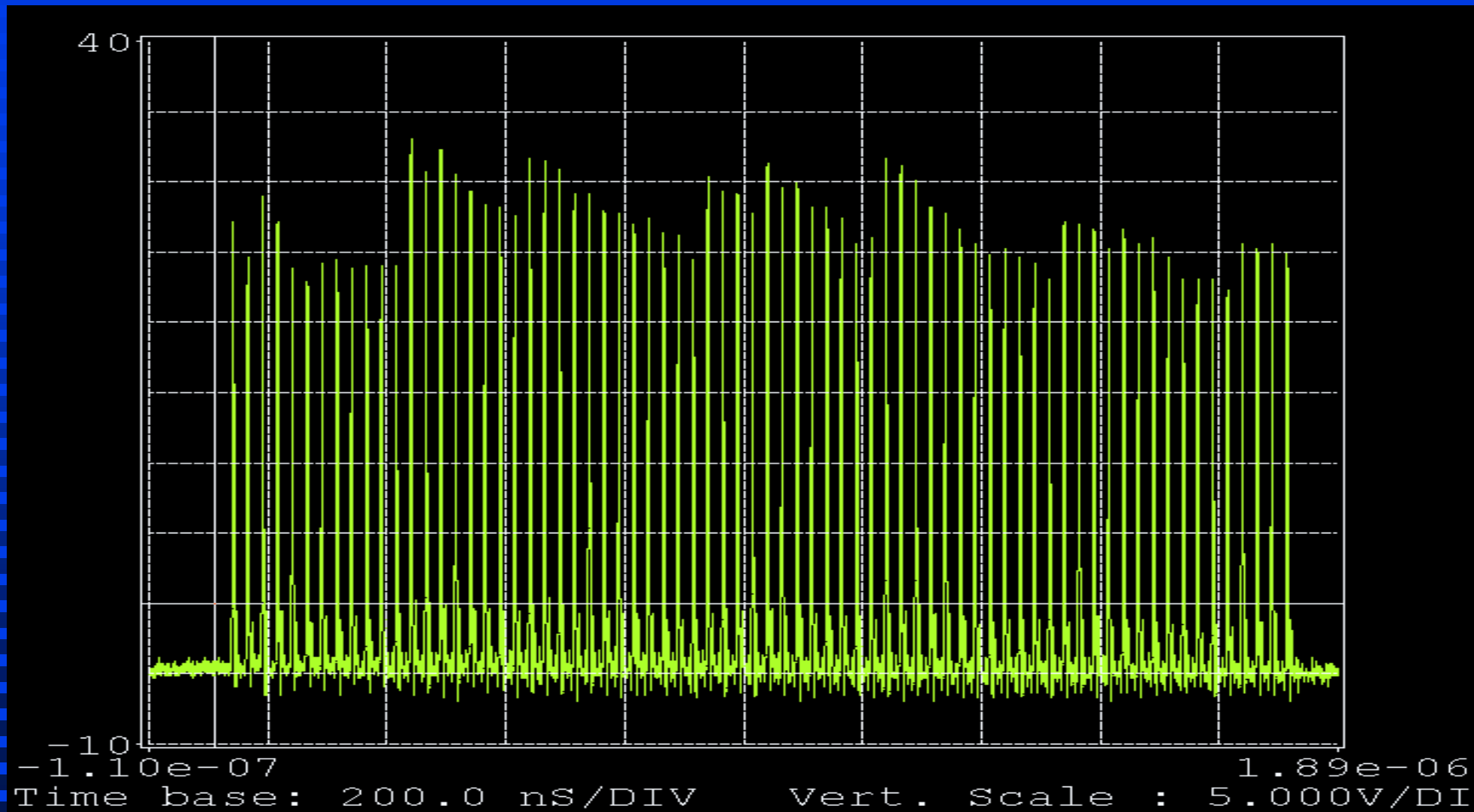


e-07 1.24e
base: 30.0 ns/DIV Vert. Scale : 5.000V





72-bunch train ready to be sent to SPS



Thanks for your attention!



Questions ? ...

