



Beta Beams,
EUROnu WP4



Nufact'11 workshop,
1-6 Aug 2011,
Geneva, CH



Beta Beams in the CERN complex: PS studies

E. Benedetto

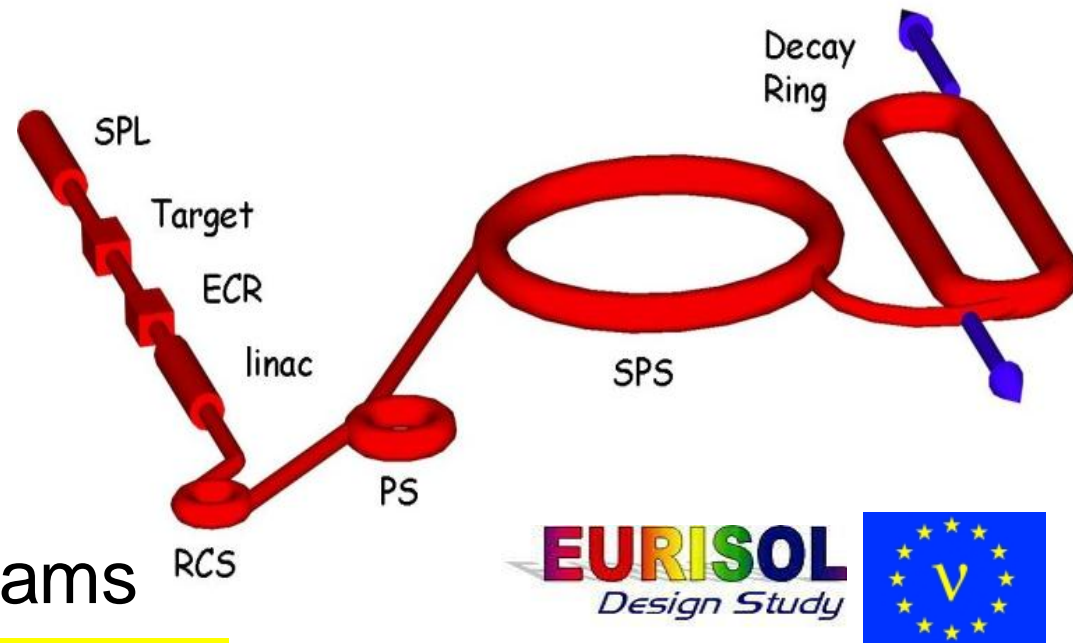
NTU-A and CERN/BE-ABP-ICE

Acknowledgements: S.Gilardoni, E.Metral, E.Wildner, and many other colleagues from CERN/BE: ABP, OP and RF for providing advices, help and ...the beam!

Beta Beams @ CERN

- **Aim:** production of pure electron (anti-)neutrino beams from the β -decay of radioactive ions for nu oscillation experiments
- Parents ions:
 - ${}^6\text{He}$ and ${}^{18}\text{Ne}$
 - ${}^8\text{Li}$ and ${}^8\text{B}$
- Challenges in:
 - Production
 - Acceleration
 - Storage/decayof **high intensity** beams

P. Zuchelli, Phys. Let. B, 532 (2002) 166-172.



EURISOL
Design Study



See C. Hansen's presentation, Fri 5th

Beta Beams @ CERN

- A “cheap” option with good physics reach
- Strong activities to make it a solid option
- Based on existing technology and on CERN existing infrastructures (as much as possible)
 - ISOLDE infrastructure & experience 😊
 - Existing PS & SPS
 - Machine experience 😊
 - Saving on costs 😊
 - BUT not optimized for Beta Beams 😞
 - equipment (kickers, septum, RF,...), “long” acceleration ramp, large impedance (SPS), shielding,...?

Beta Beams in CERN-PS



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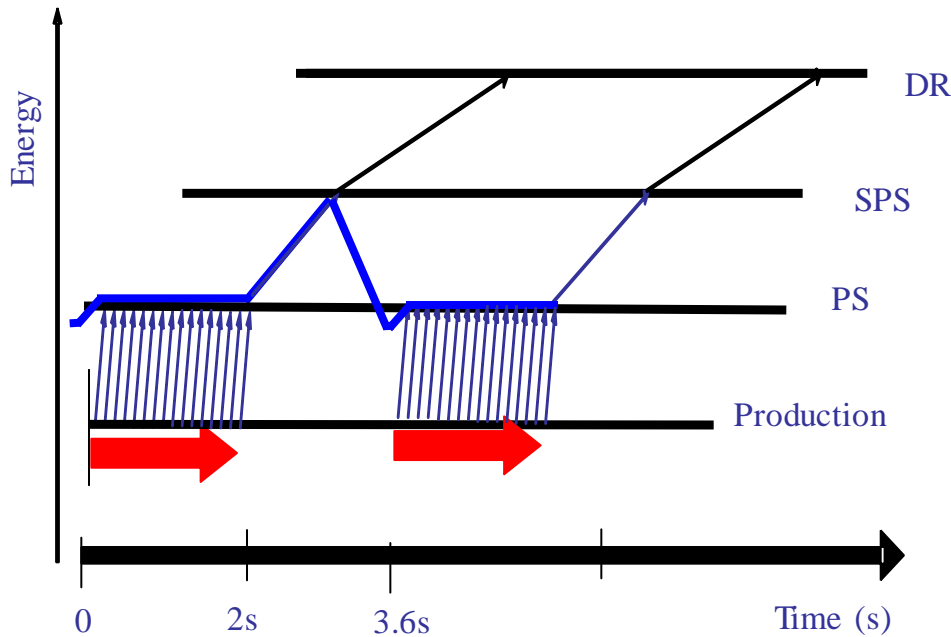
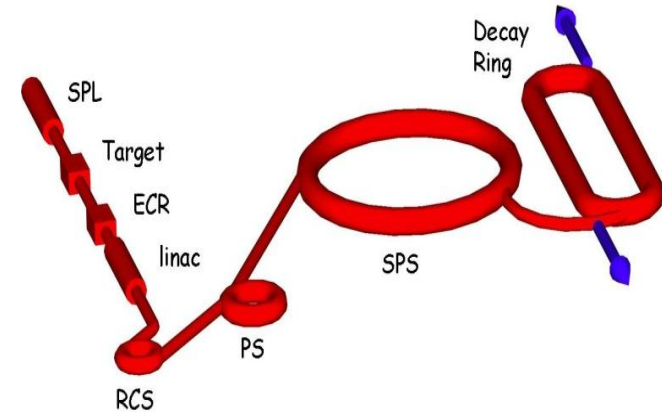
Beta Beams in CERN-PS

- Need to demonstrate feasibility asap!
- Studies in the PS (& revise work done in the past):
 - Injection scheme and energy
 - Space-charge limit
 - Radiation, vacuum
 - Not (yet) addressed: beam-wall interaction (impedance) and transition crossing
- Good timing NOW! as in // with PS-LIU(*):
 - Fruitful exchange of information
 - Common Machine Development Studies

(*)LIU: LHC Injectors Upgrade Project (R.Garoby) → Deliver reliably beam for HL-LHC

Injection scheme

- 3.5 GeV (kinetic, p-equivalent)
- 20 bunches (h21) from RCS (10 Hz)
- 1.9s flat bottom + 0.8s accel.=3 BP
- Extraction @ 26 GeV (p-equivalent)



Note:

- High injection energy
- Long flat bottom
- Long acceleration
- (γ -transition crossing)

Long acceleration: decay losses

- Radioactive ions with lifetime at rest ~ 1 s
 - The longer they stay @ low en., the more they decay
 - Only 50% of ^6He gets to the DR (80% for ^{18}Ne)
- Report: M. Kirk, P. Delahaye, M. Magistris, S. Trovati, CERN-SC-2009-051-RP-TN
 - Air activation in environment \rightarrow well in the limits
 - Induced radioactivity in the magnets:
 - PS tunnel would remain accessible as a limited stay controlled area after a few days, depending on the position along the ring and on the operation mode!!!
- Report does not take into account beam losses in “hot” regions (septum,...) and operation losses (injection, transition,...) \rightarrow Fluka studies ongoing now

Injection energy

- 3.5 GeV chosen for Space-Charge considerations:
 - Max. Laselett $|\Delta Q| = 0.22$ (*)
 - Maybe too pessimistic!

(*) Parameter and Intensity Values, Version 3, July'07, EURISOL DS Task note 12-25-2009-0014.

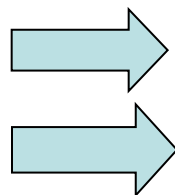
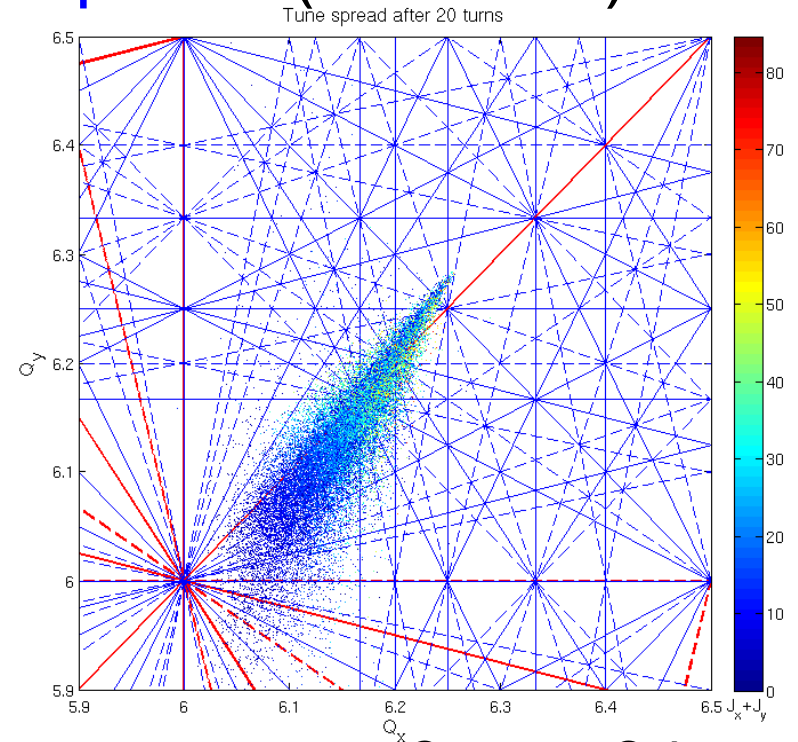
- **Challenging** to inject at 3.5 GeV, rep.rate 10Hz:
 - **Technology** of the septum
 - **Space**: PS “long straight sections” not so long!
 - Already challenging at 2 GeV for proposed **LIU-RCS**!
 - **Thanks to S.Gilardoni, B.Goddard for discussion!**



Can we reduce the PS BBeams injection energy ideally to 2GeV ?

Space Charge

- Space-charge induces **tune spread** (**'neck-tie'**)
- Particles can cross betatron resonance lines and
 - either lost
 - either emittance blow-up
- For BBeams max. (safe!) $\Delta Q = -0.22$ @ 3.5 GeV but e.g. Tof in PS has $|\Delta Q| \sim 0.30$

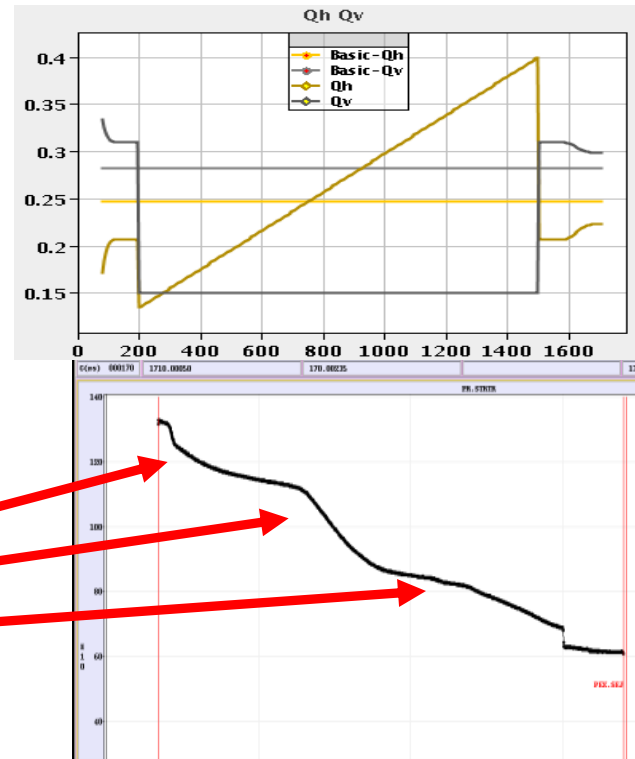


Identify SC limit (max tolerable ΔQ)

Determine the optimum working point

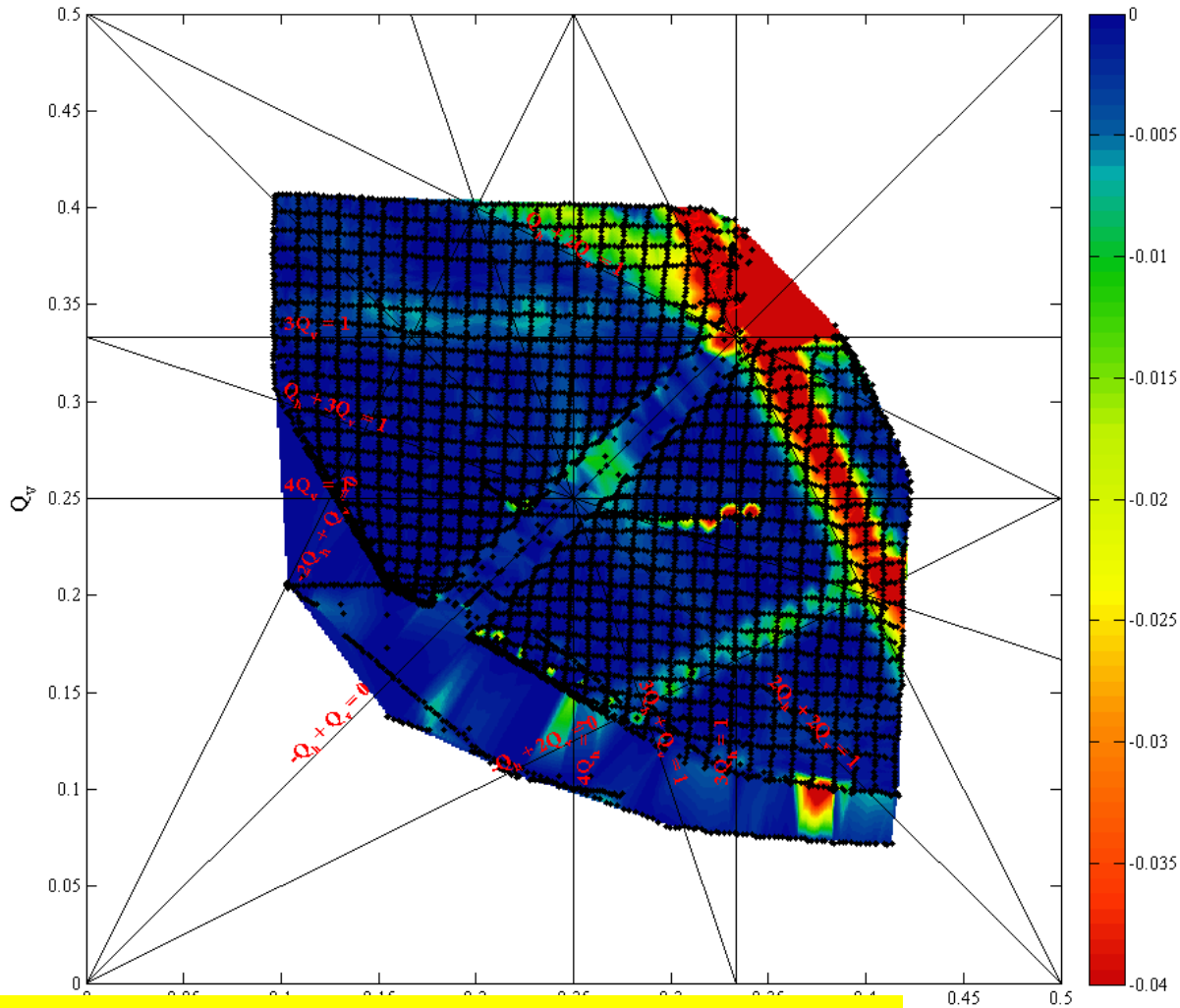
Tune scan (and WP optimization)

- Identify dangerous resonance lines in tune diagram
- Loss measurements: → Started by A. Huschauer, autumn 2010
 - Low intensity beam (not SC-dominated) → 130×10^{10}
 - Large emittance (to fill the chamber & provoke immediate losses)
 - Long flat bottom @ 2 GeV
 - Tune program:
 - Scan between (0.1 - 0.4)
 - Vertical tune constant
 - Sweep of the horizontal tune
 - Slope in the intensity signal indicates importance of the crossed resonance line



Ref. G. Franchetti, GSI internal note 2004

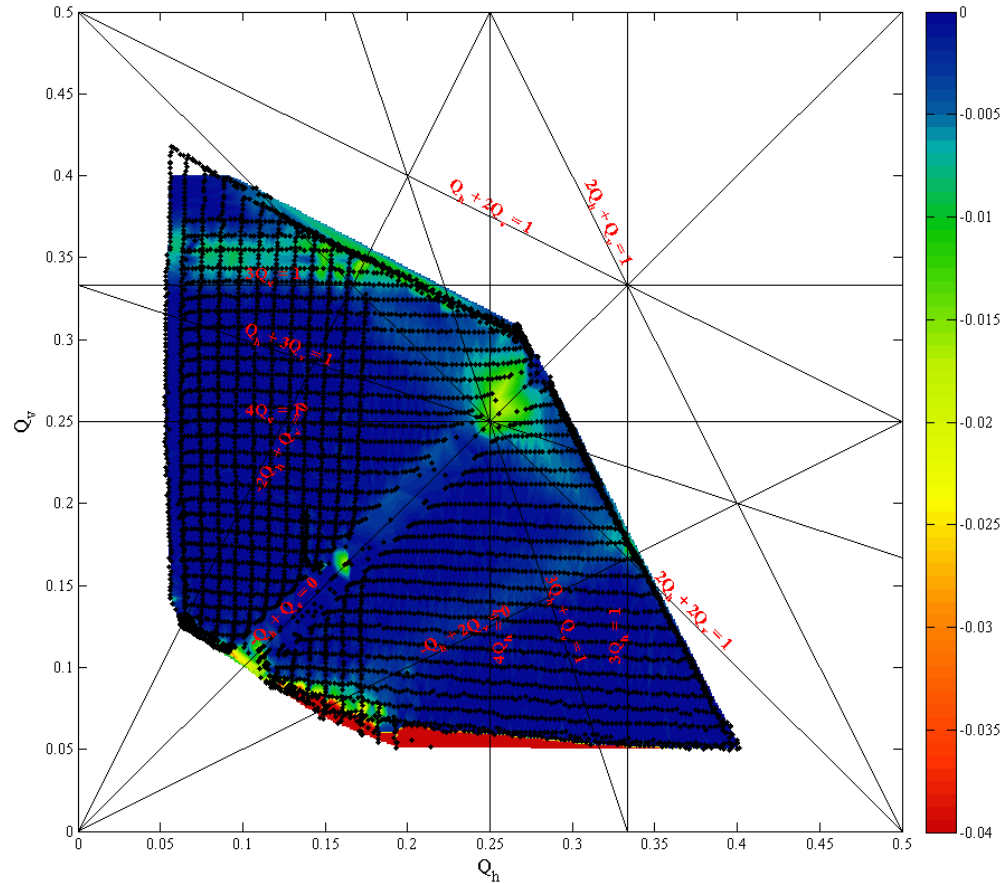
Tune scan @ 2GeV



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→ Same lines as in scans @ 1.4 GeV, by A. Huschauer

Tune scan @ 2GeV



PFW control
to access
lower corner.

Chromaticity
as previous
measuremen
ts (natural xi)

- Integer stop band @ $Q_h=0.03, Q_v=0.05$

→ Successfully reproduced in PTC-ORBIT simulations by J. Brenas

High intensity studies: Started

- Considered 2 different type of beams:
 - Small emittance, “LHC-type” beam
 - Expected (depending on the WP choice)
 - Beam emittance blow-up (integer crossing)
 - or Losses with bunch shape deformation
 - High intensity, large emittance, “Tof-like” (more similar to BetaBeams)
 - Beam blow-up will translate into losses
 - Aim is to identify different mechanisms...and find a cure!

SC & Emittance growth

→ S.Gilardoni, R.Steerenberg et al.,

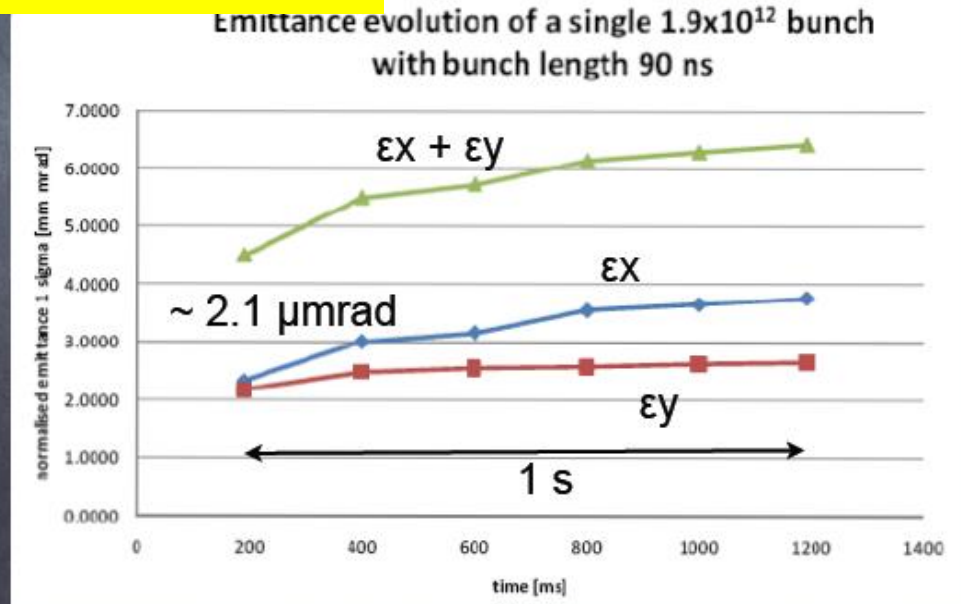
Test end 2010:

$190 \cdot 10^{10}$ ppb (at PS ejection)

90 ns

Increase total emittance ($\epsilon_x + \epsilon_y$) ~40%

$$\begin{cases} \Delta Q_x^{\text{LHC25MD}} @ \text{PS_FT} = -0.34 \\ \Delta Q_y^{\text{LHC25MD}} @ \text{PS_FT} = -0.56 \end{cases}$$



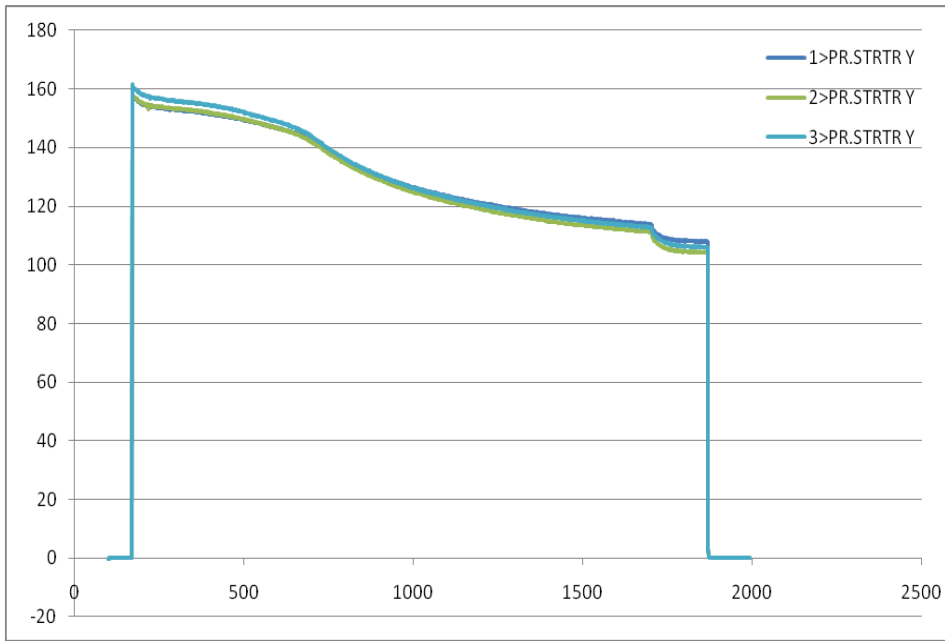
Chamonix 2011 · S. Gilardoni for PS-LIU ³

- See also *R.Cappi et al., PAC'93*
- Repeating them @ 2 GeV

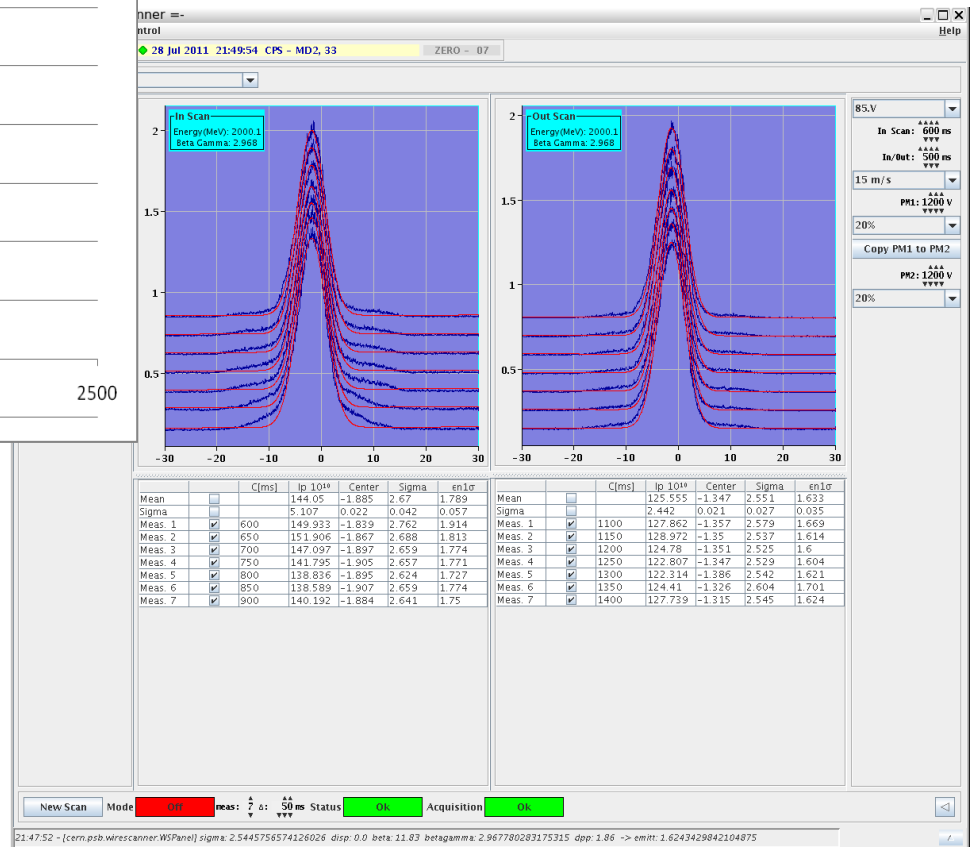


Identify max allowed SC blow-up

SC & Losses (Preliminary!!!)

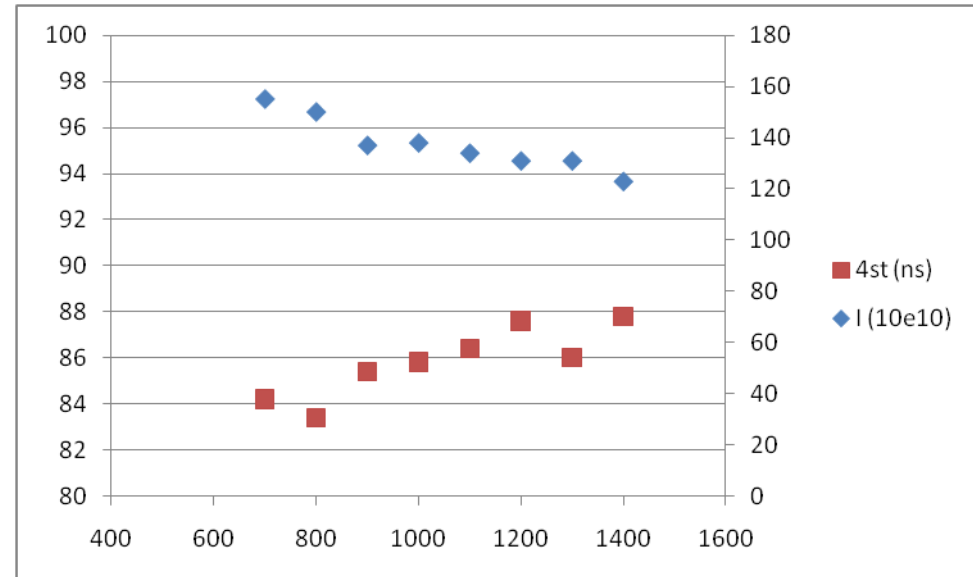
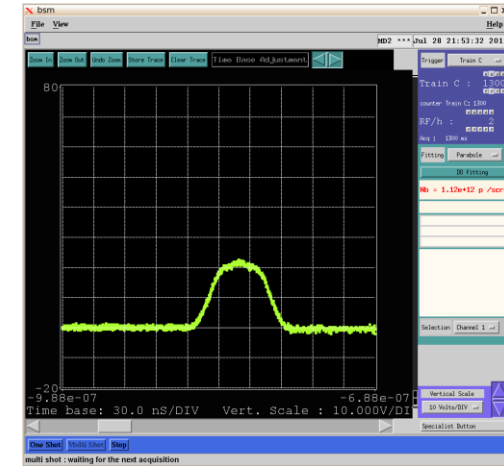
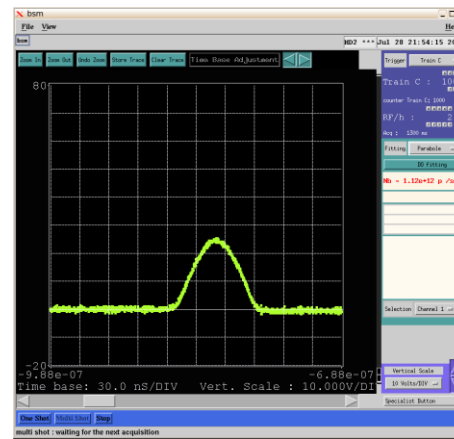
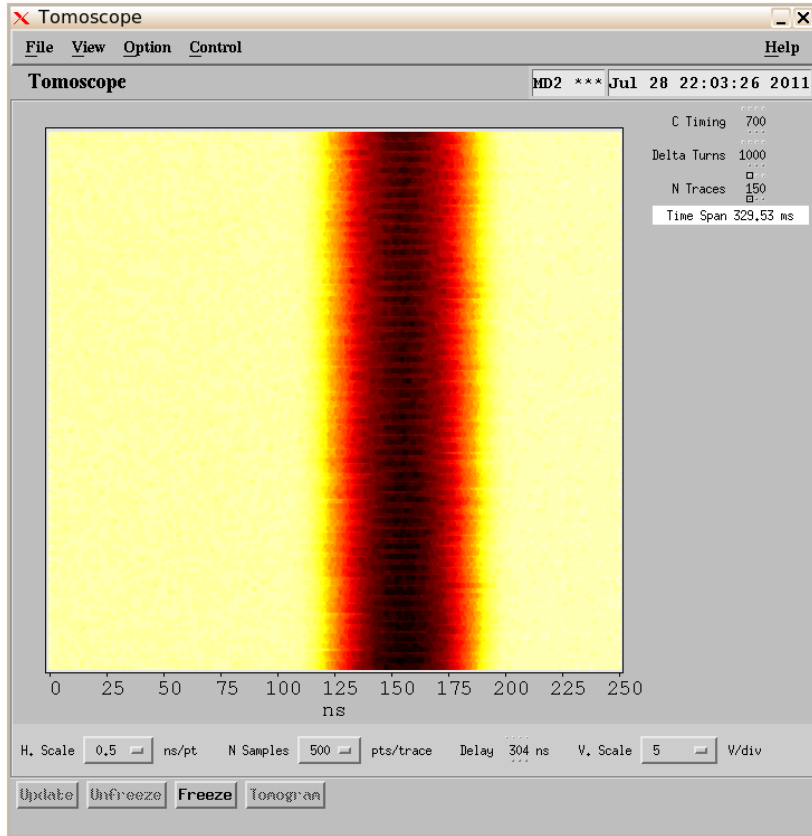


Qh=6.17, Qv=6.30
Xi ~ -1



- Tails in the transverse distribution (vertical)

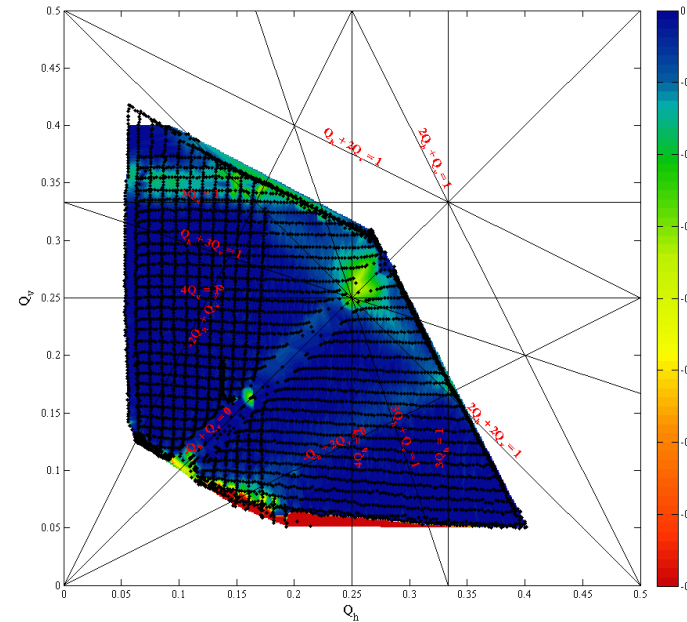
SC & Losses (Preliminary!!!)



- Longitudinal bunch shape deterioration

SC & Losses (Preliminary!!!)

- Questions: (Qh=6.17, Qv=6.30)
 - Which line are we touching?
 - Can we compensate for it?
 - Find “good” PFW configurations
 - Effect of Chromaticity?



- So far, with small emittance beam:
- Is this the same mechanism for high intensities, large emittance beams?
 - We will have similar tunes
 - Looking forward to get more measur. with ToF beam!

Summary

- Feasibility of using CERN-PS:
- All possible issues identified and work ongoing
- Fruitful collaboration with PS-LIU
- RadioProtection:
 - Decay products in the magnets → Report exists (FP6)
 - Operation losses (injection,...) → Fluka simulations ongoing
- Inj. energy @3.5 GeV:
 - it is a challenge (with existing equipment)
- Studies to reduce it to 2 GeV
- Space-Charge main issue

Summary

- Space-Charge studies
 - Tune scans to identify resonances → done
 - SC dominated beam studies → ongoing
 - LHC beam
 - ToF beam (more similar to BetaBeams)
 - Identify loss mechanisms and find cures
 - Identify max possible Space Charge tune spread
- Impedance and transition crossing → next

Thank you for your attention!

Back-up material



CERN Beta Beams, Synoptic

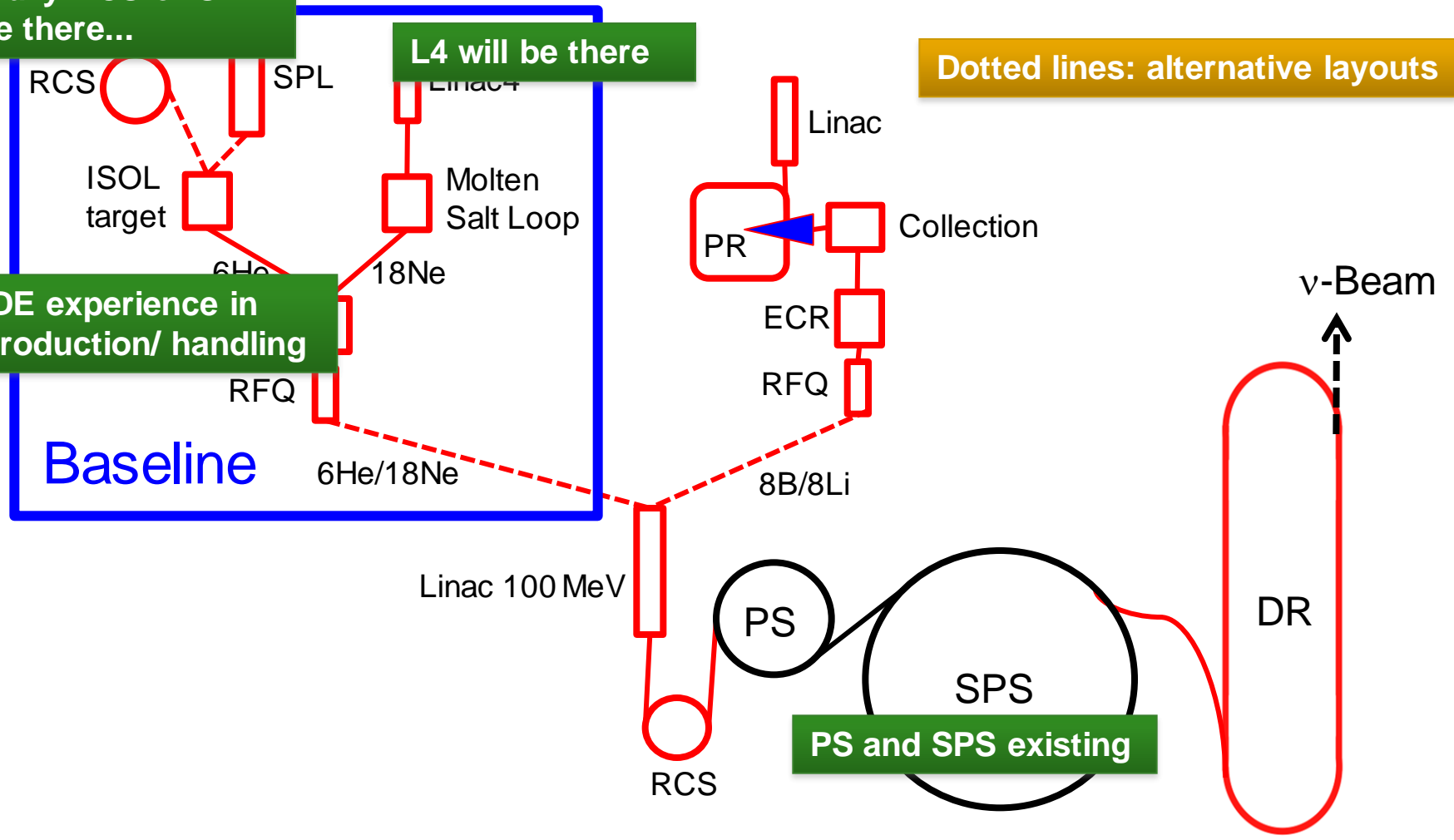
Hopefully RCS or SPL will be there...

L4 will be there

Dotted lines: alternative layouts

ISOLDE experience in ^8B production/handling

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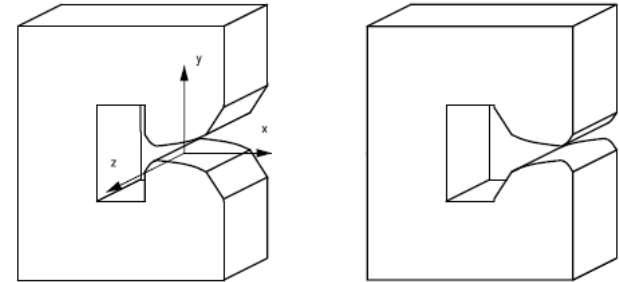


$B\rho \sim 500 \text{ Tm}$, $B = \sim 6 \text{ T}$, $C = \sim 6900 \text{ m}$, $L_{SS} = \sim 2500 \text{ m}$, $\gamma = 100$, all ions

PS magnets and WP control

- Combined function magnets:

- Dipol+Quad component

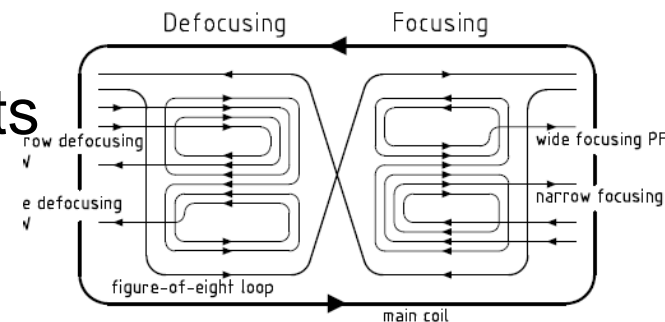


- Low-energy Quadrupoles

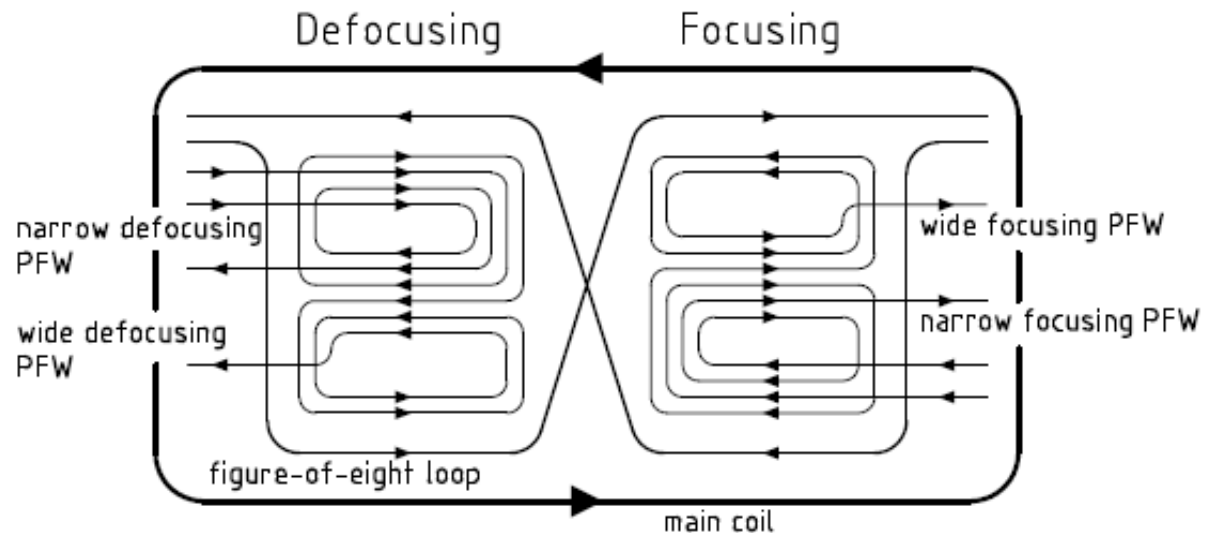
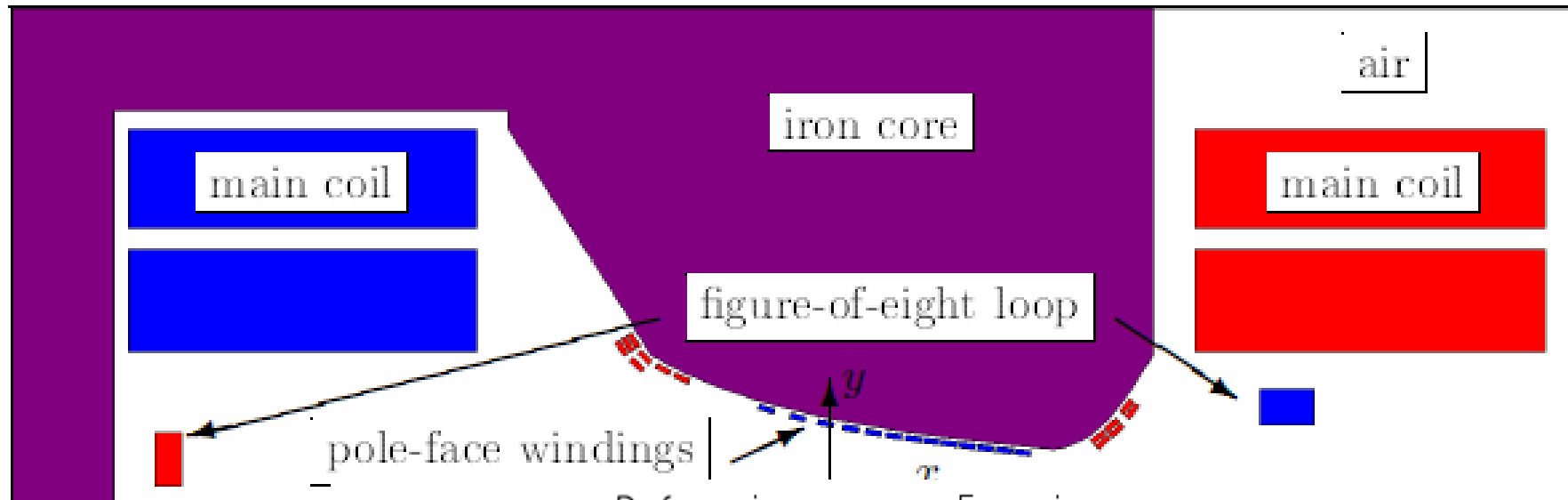
- Change the tune (Q_h, Q_v) @ injection
- Only linear component
- BUT no control of Chromaticity

- Pole Face Windings (PFW)

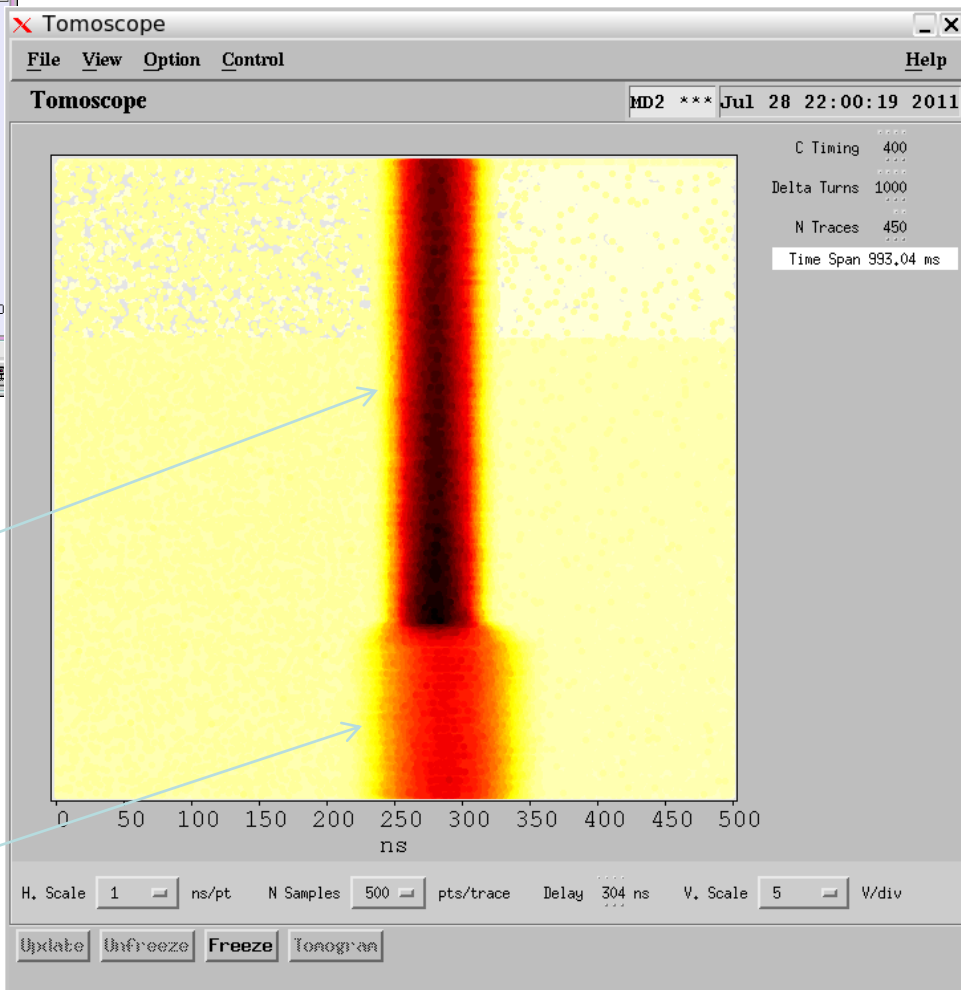
- Additional coils around main magnets
- Control tune AND chromaticity
- BUT non-linearities & resonances



Pole Face Windings



“LHC type” with dp/p blow-up

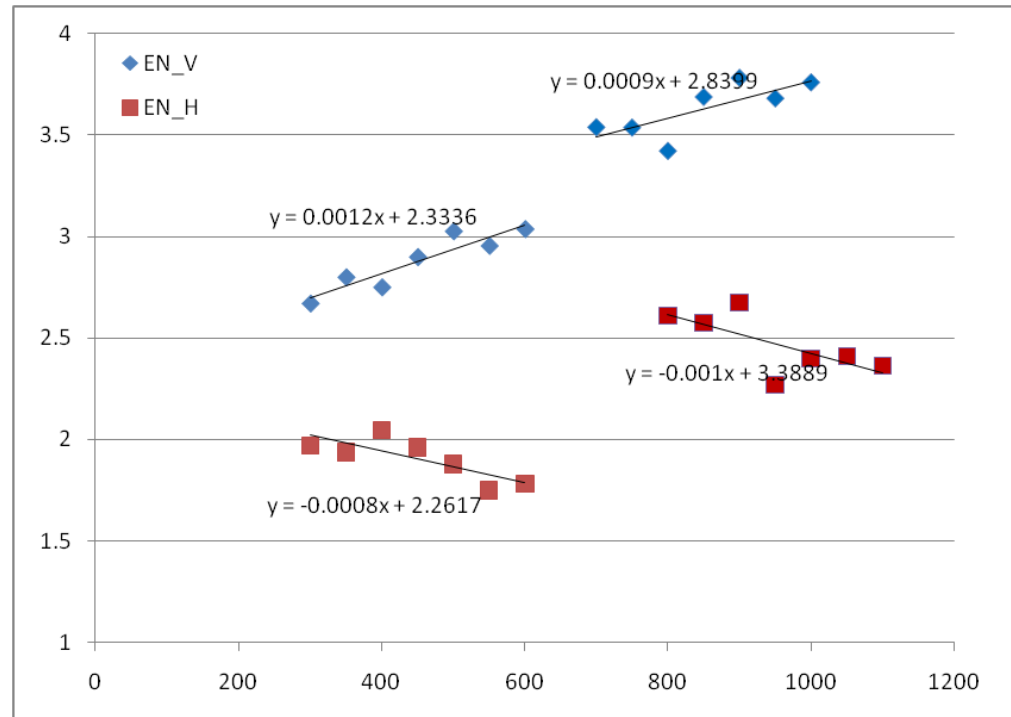
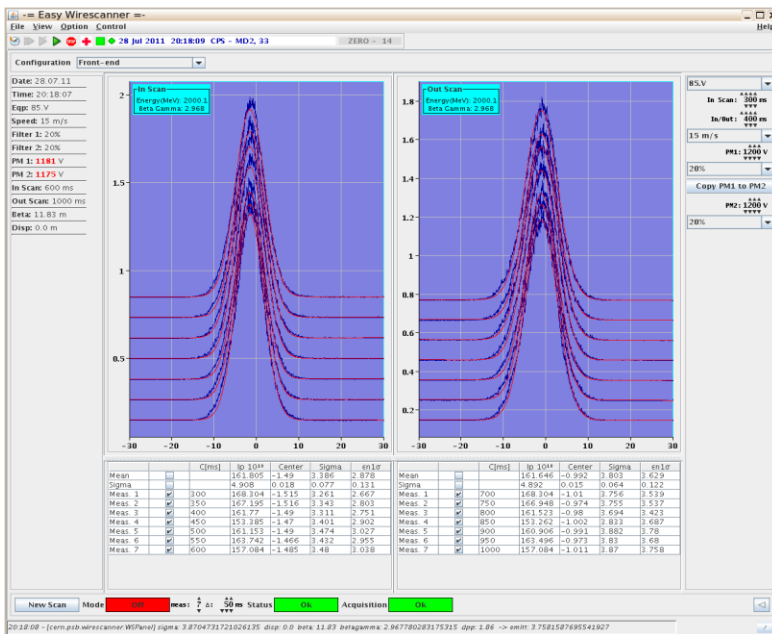
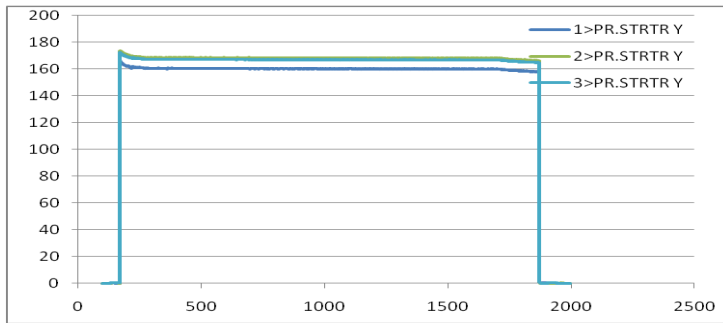


4st=80ns → DQh=0.19, DQv=0.27

4st=130ns → DQh=0.16, DQv=0.197

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Meas #1 (Qh=0.196, Qv=0.15)



Meas #2 (Qh=0.17, Qv=0.23)

