On single-turn slow extraction from individual bunches using bent crystals and pulsed dipole correctors

–

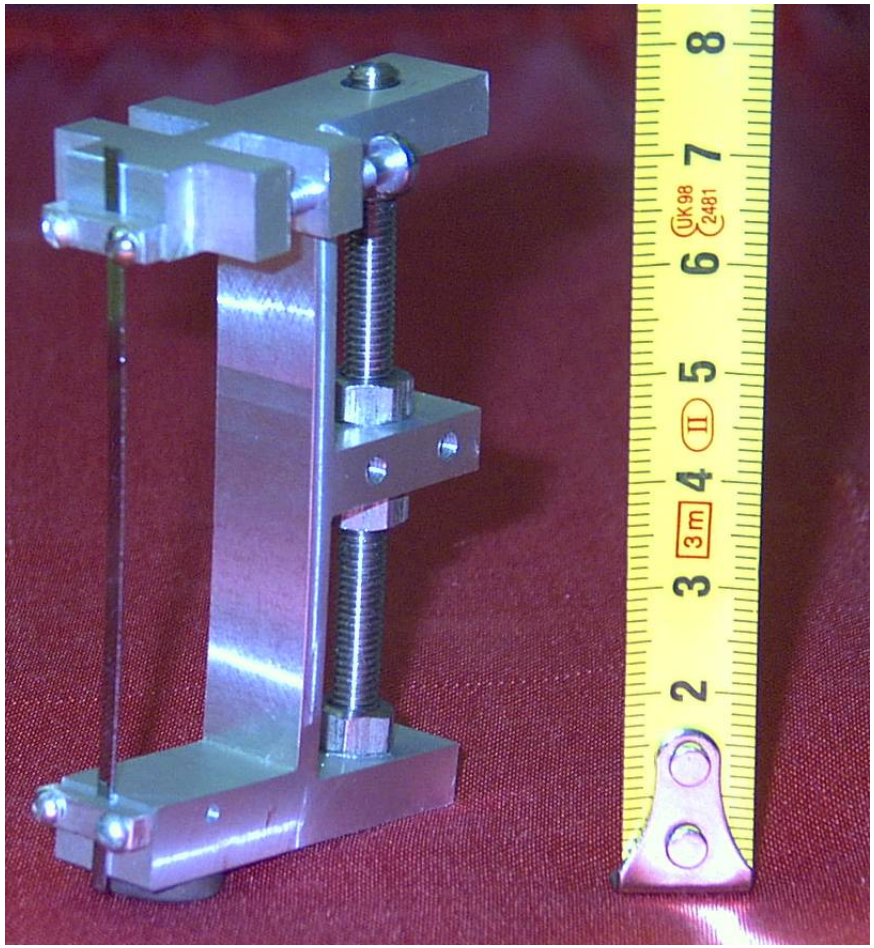
& a possible experiment in the Recycler

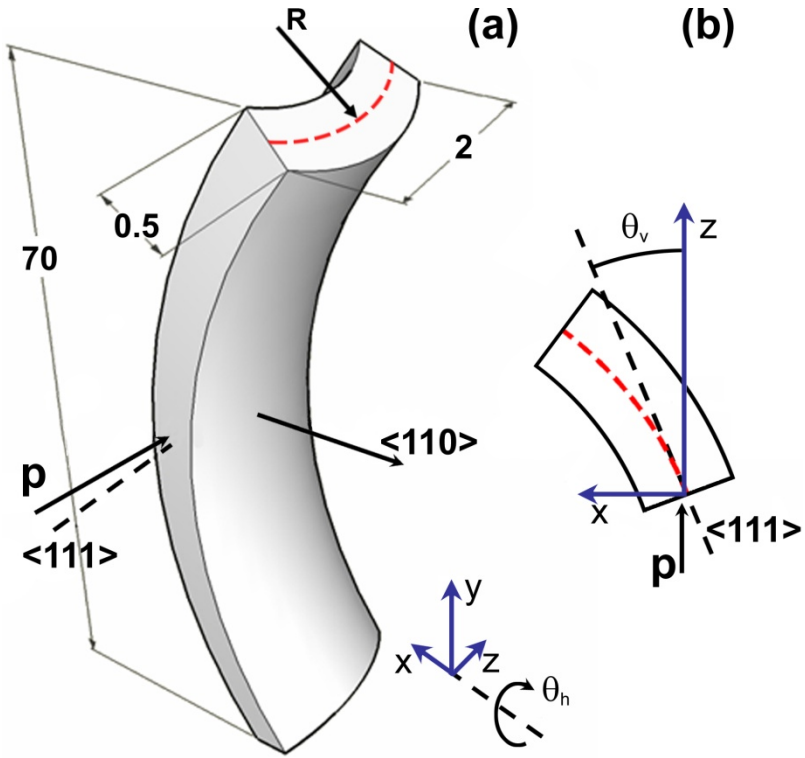
V.Shiltsev

From 9/29/2011 to

05/31/2012

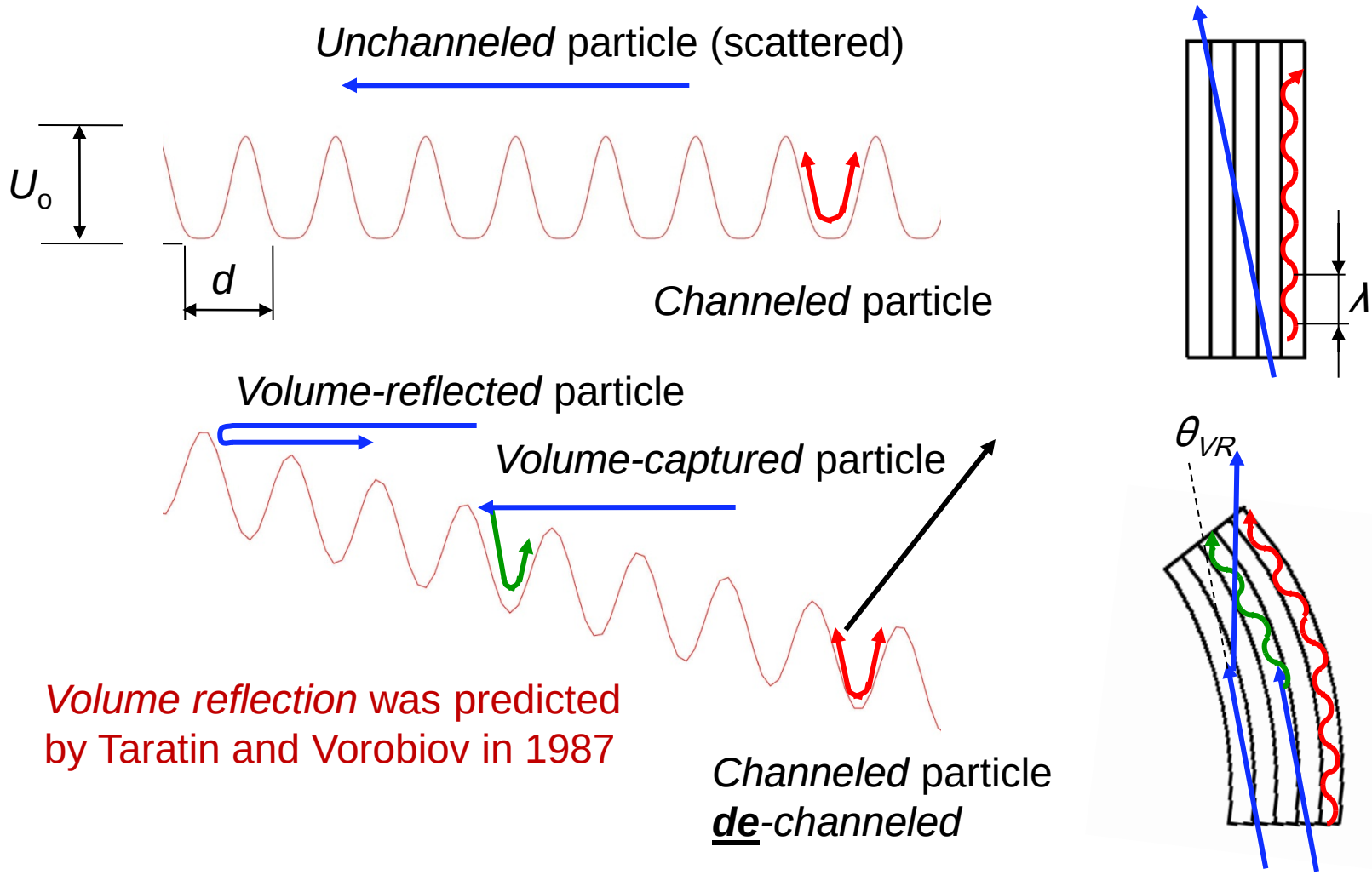
What is *bent crystal*?





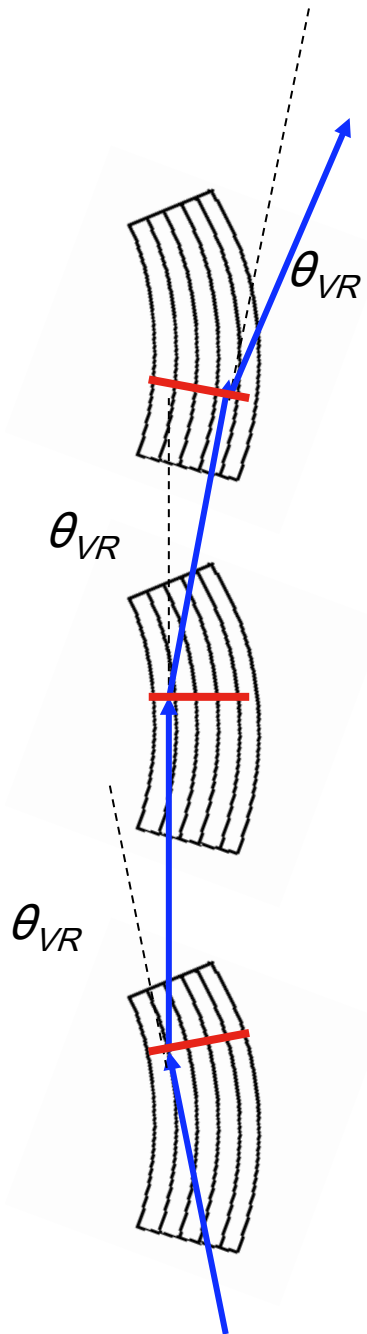
Crystal bending is accomplished through *anticlastic* deformation

Five Processes in Crystals



Volume reflection was predicted by Taratin and Vorobiov in 1987

Single or multiple Volume Reflection regime



$$One\ crystal \quad \theta_{VR} = 90\,\mu rad \ \ for\ 8GeV\ proton$$

$$\theta_{bend} = 300\,\mu rad$$

$$8\ crystals \quad \theta_{VR} = 90 \times 8 = 720\,\mu rad$$

8 Crystal “Strips” (IHEP, Protvino)

Notes:

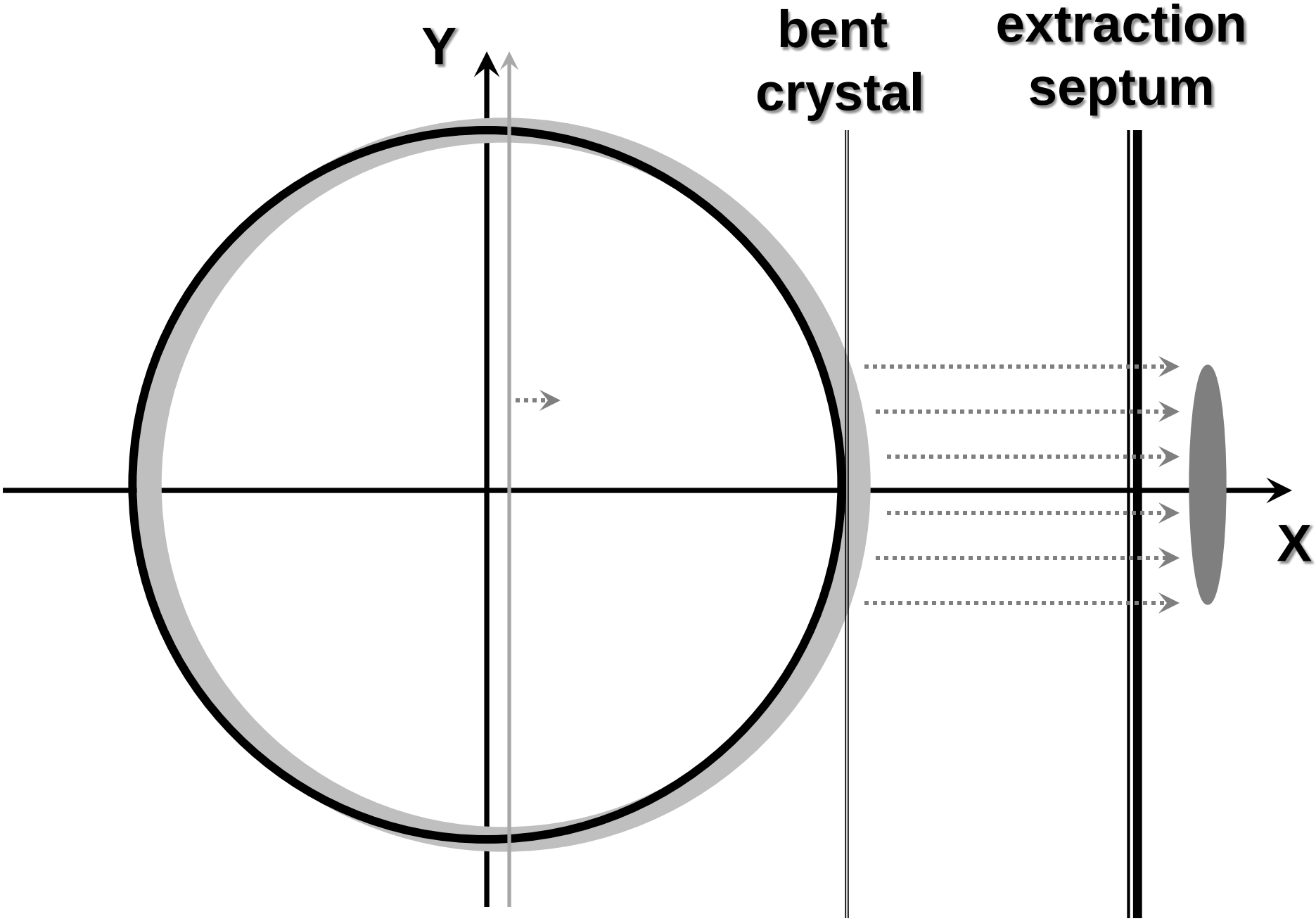
1. The concept of bent crystals has been studied in great depth during the Tevatron T980 experiments
2. Technology is proven, two goniometers available from Tevatron, various types tested
3. Enormous radiation hardness of Si crystals, better than SS
4. Efficiency for collimation demonstrated in the Tevatron and SPS, see T980 papers in :
    1. N.Mokhov, et al, PAC’2009
    2. V.Shiltsev, et al, IPAC’2010
    3. V.Zvoda, et al , PAC’2011
    4. V.Previtale, et al, IPAC’12

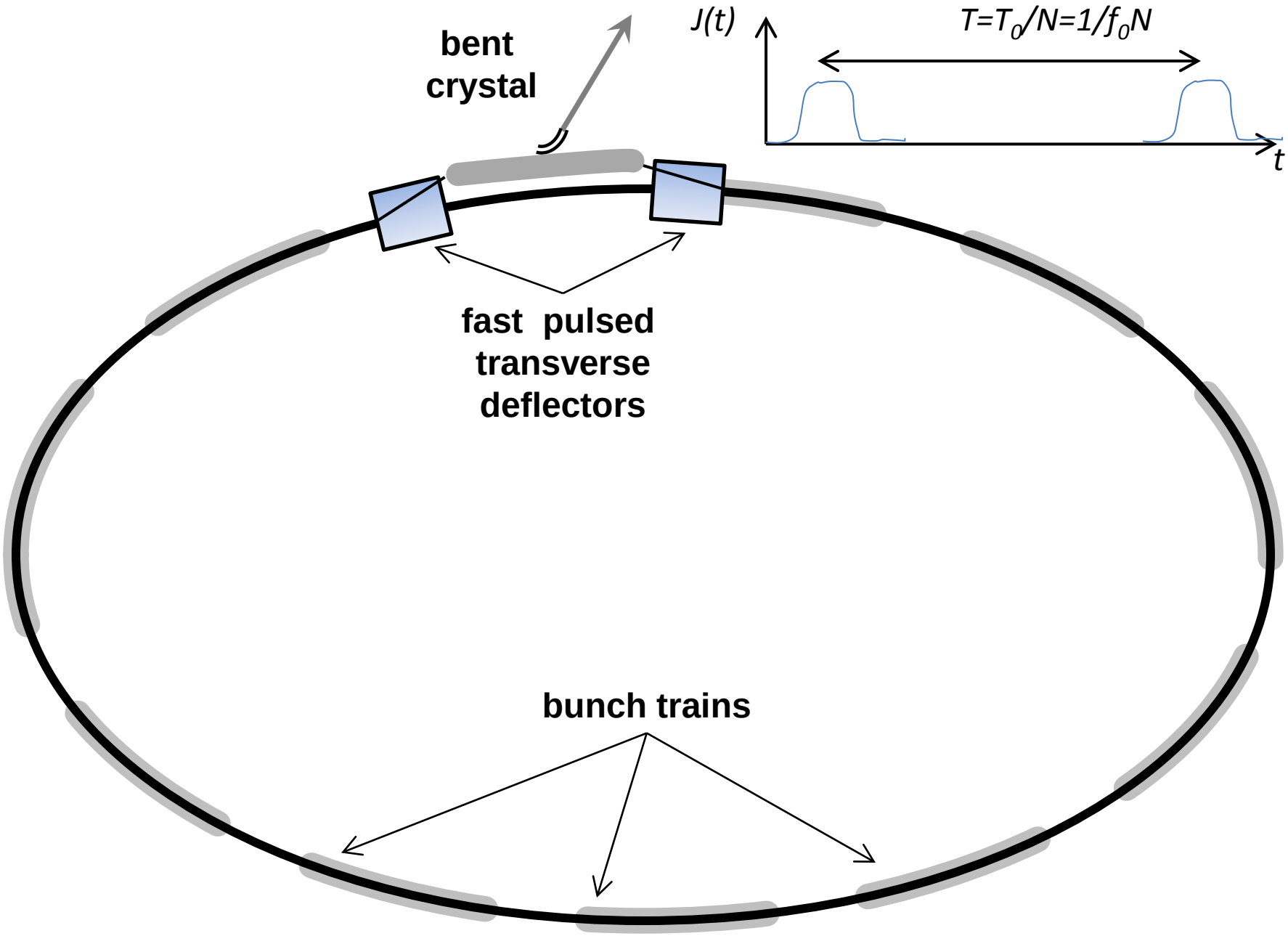
What's needed for the scheme of slow extraction with use of the bent crystals:

(8 GeV proton beam example)

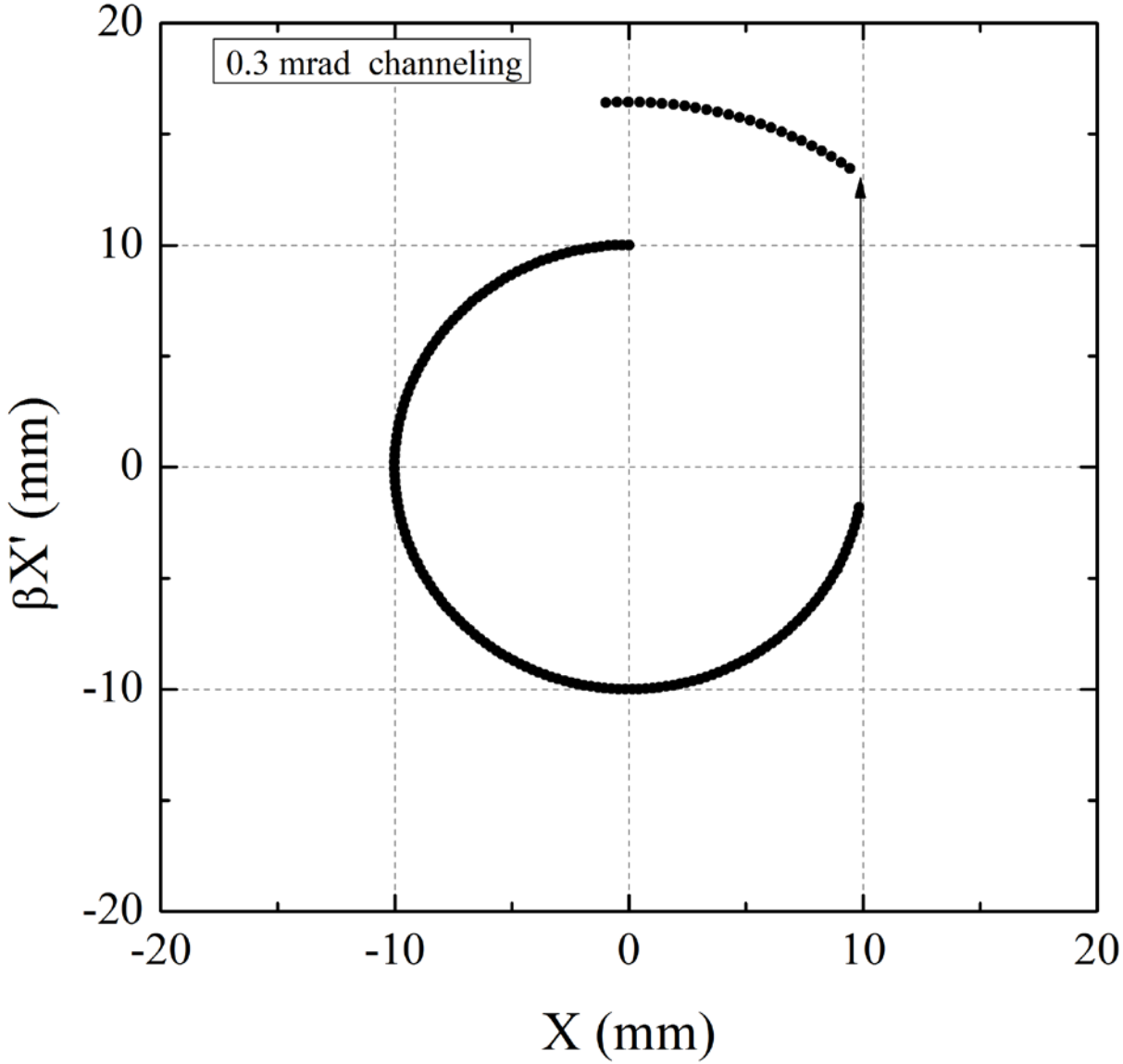
1. Crystals (some 0.3 mm long) and mechanical system for their alignement (goniometer - ~1 m long each)
2. Pulsed dipole hor corrector , to act on only 10 bunches at once (200 ns flot top, 4 m long each, with two some 1.5-2 kV pulsers) (mb the second one to form a tow bump)
3. Septum – might or might NOT be required

How it works →

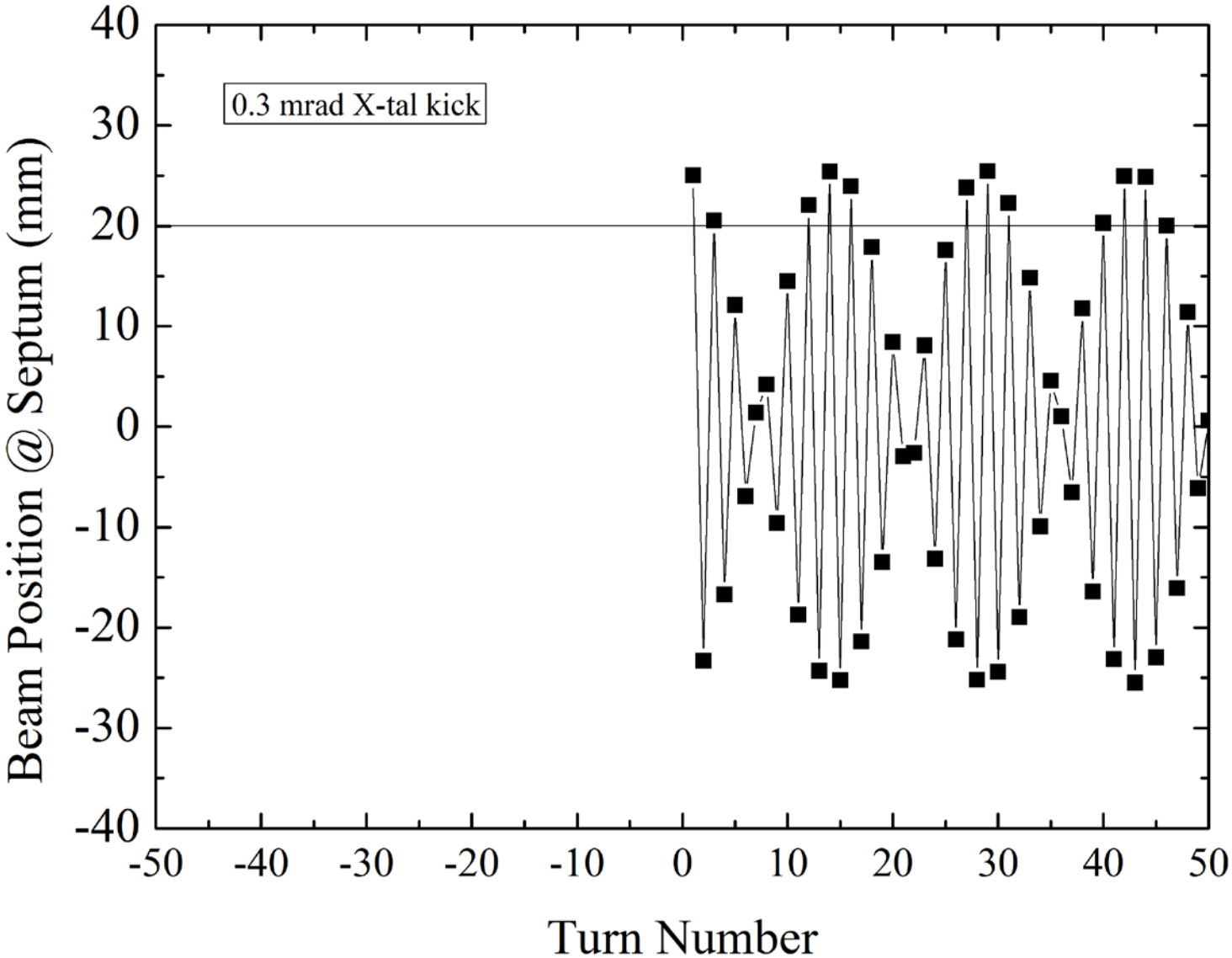

Y
bent
crystal
extraction
septum
X


bent
crystal
J(t)
T=T0/N=1/f0N
t
fast pulsed
transverse
deflectors
bunch trains

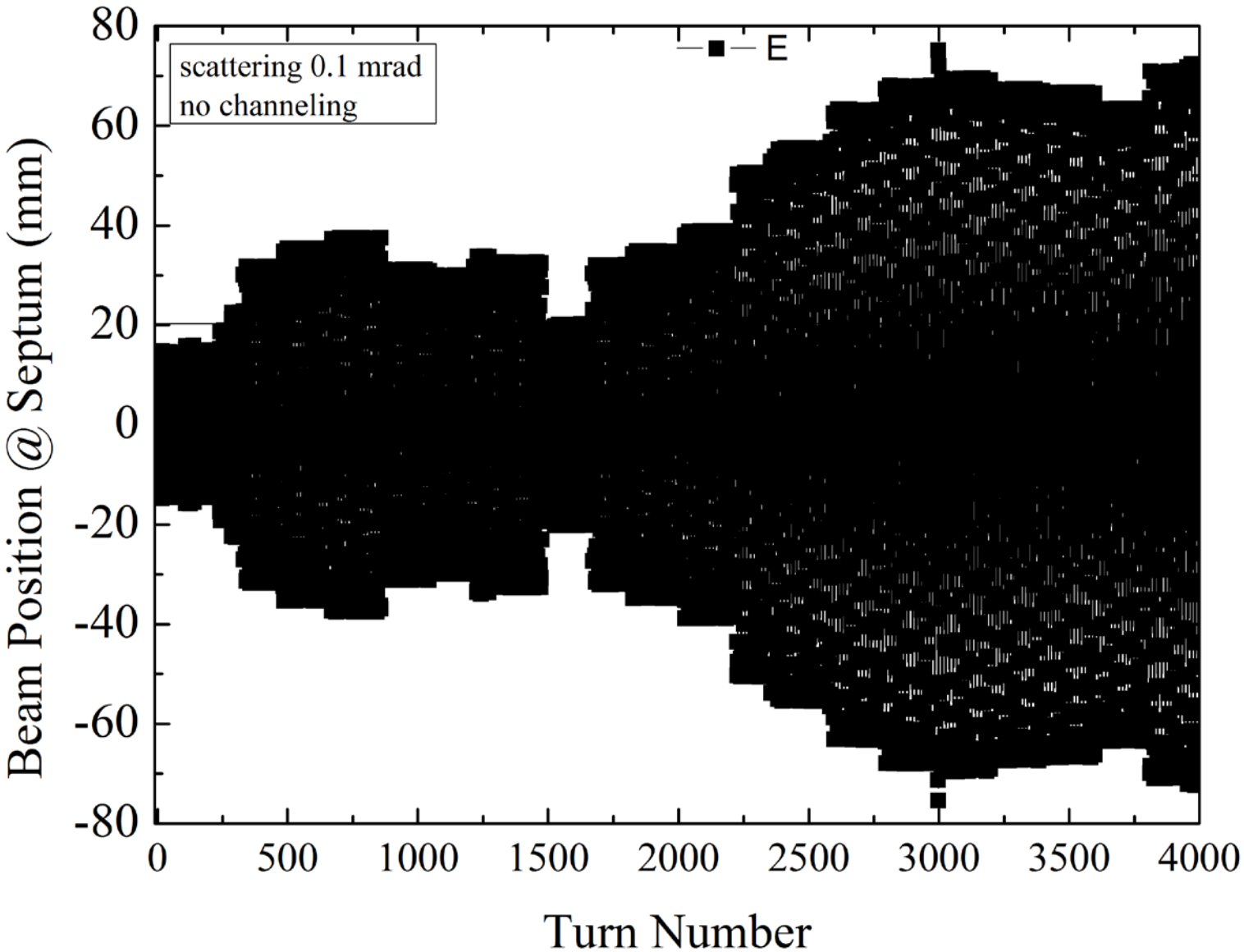
Simulations (IPAC'12)



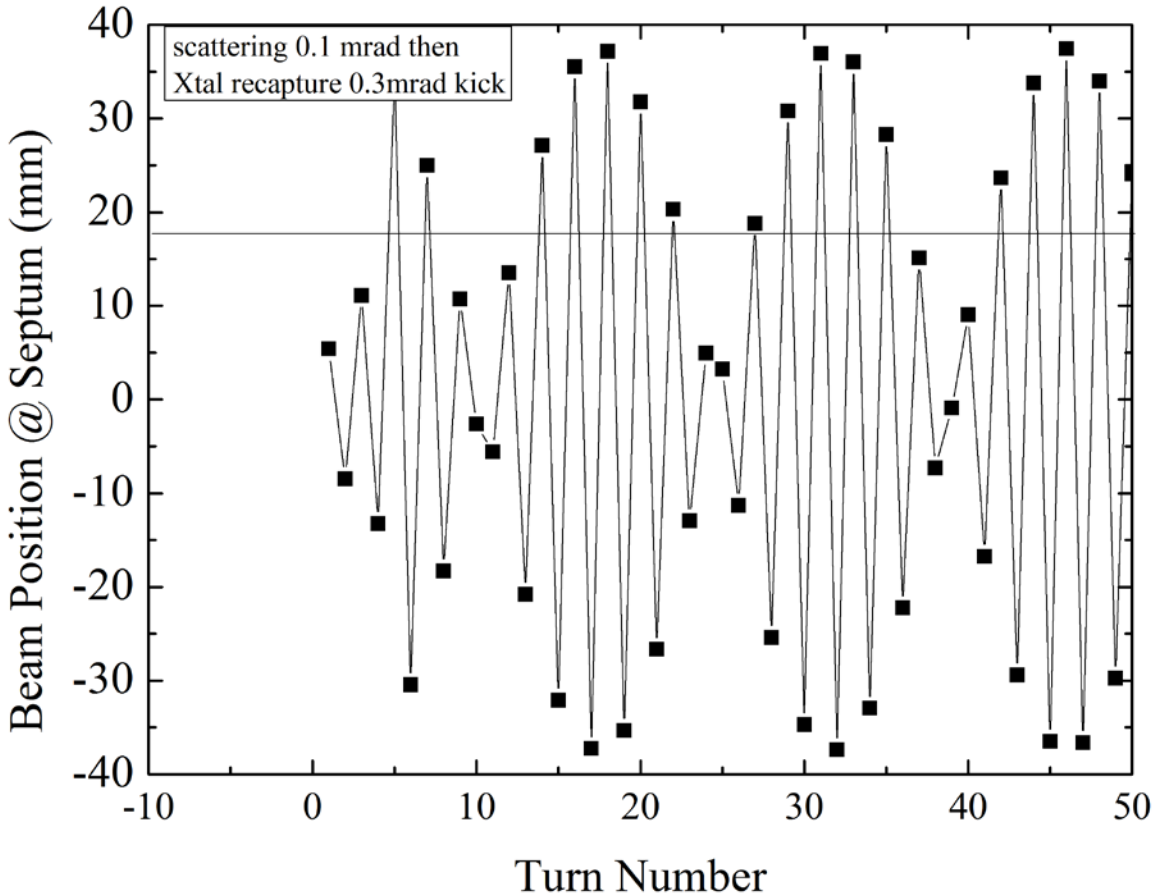
Channeling 0.3 mrad (only)

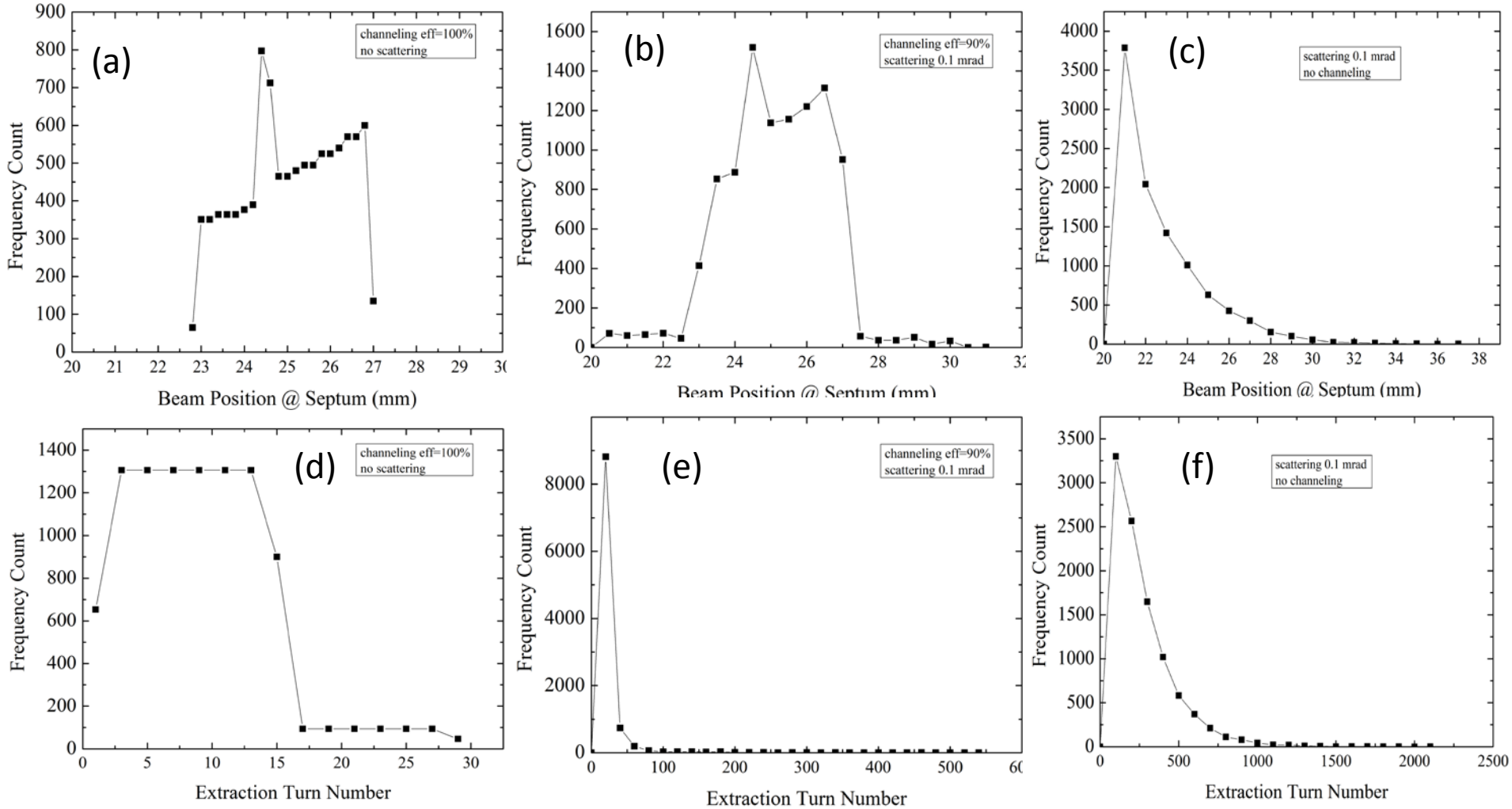


Just Scattering (no channeling)



Scattering 10% and Channeling 90%





Channeling 100%
Scattering 0%

Channeling 90%
Scattering 10%

Channeling 0%
Scattering 100%

Comparison

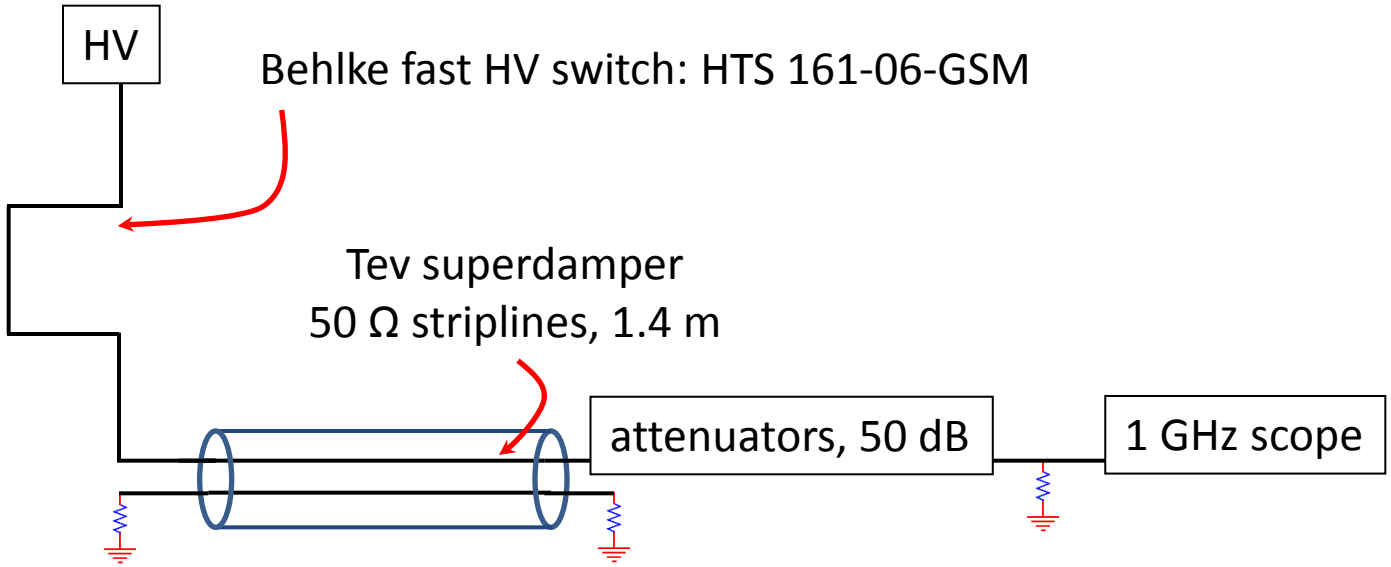
Kickers Part :

Fast Pulsed Kickers for some slow extraction schemes (doc-3944)

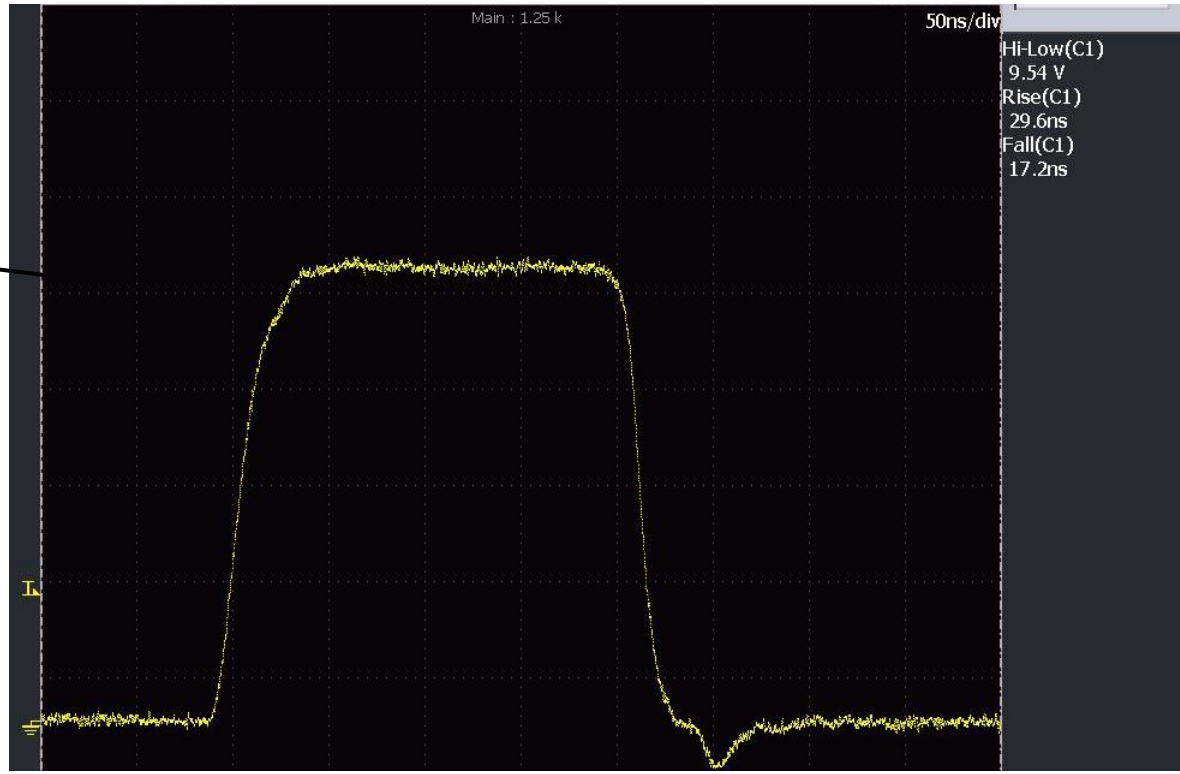
D.Wildman, R.Madrak

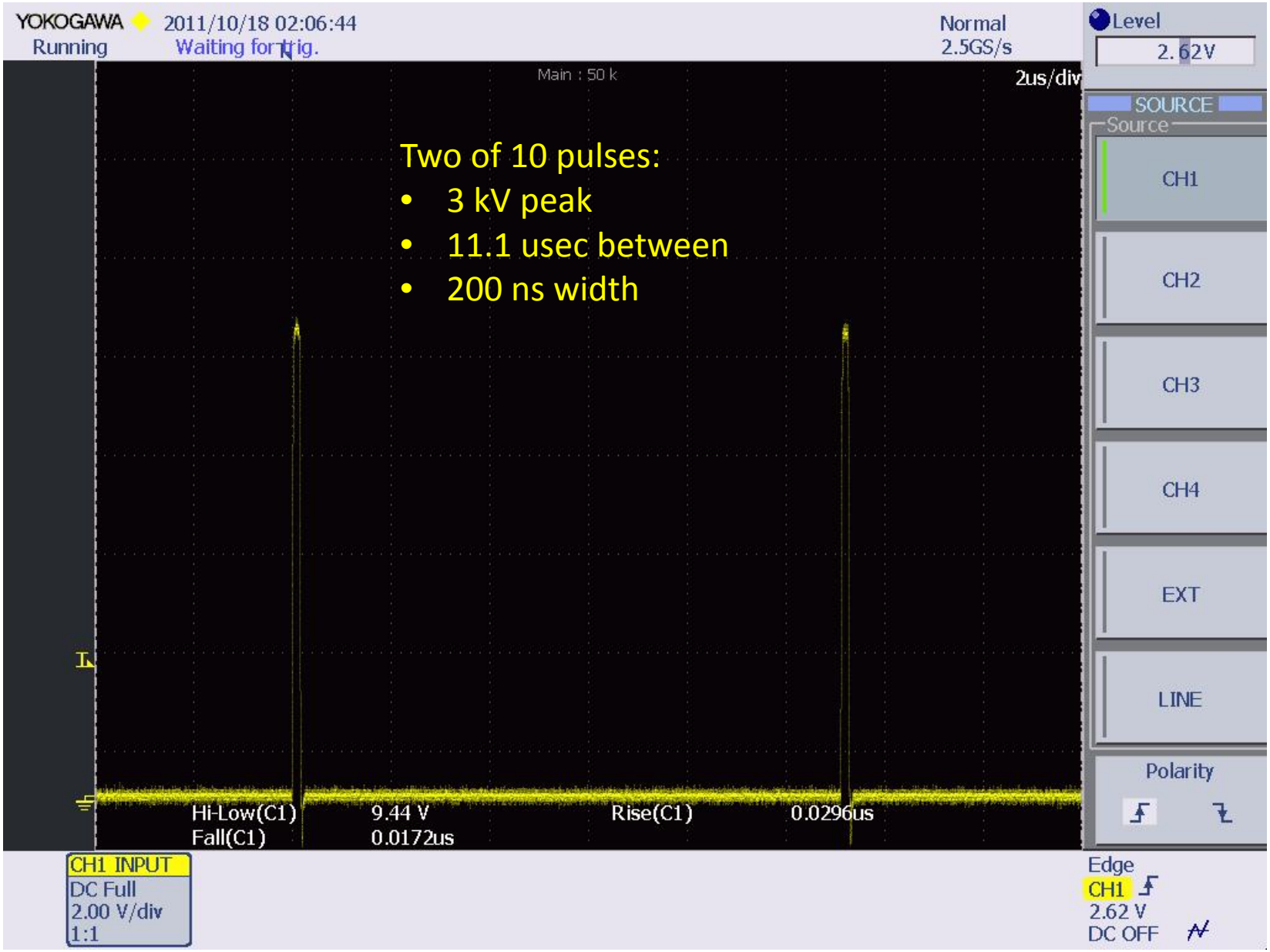
Oct 17, 2011

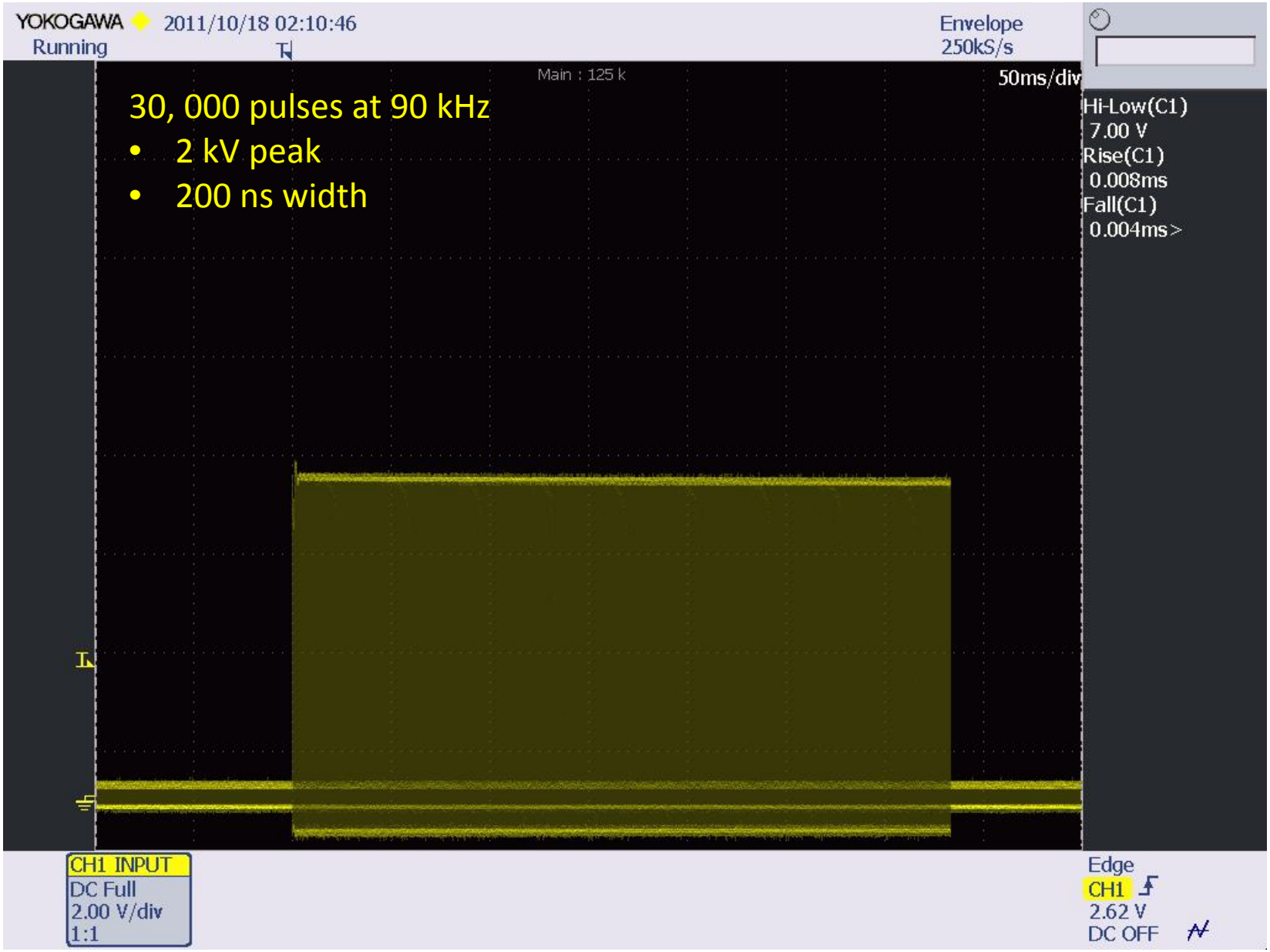
Setup:



- One pulse out at peak Current of 60 A
- Vout = 3 kV
- Pulse width = 200 ns (min pulse width for this particular switch)

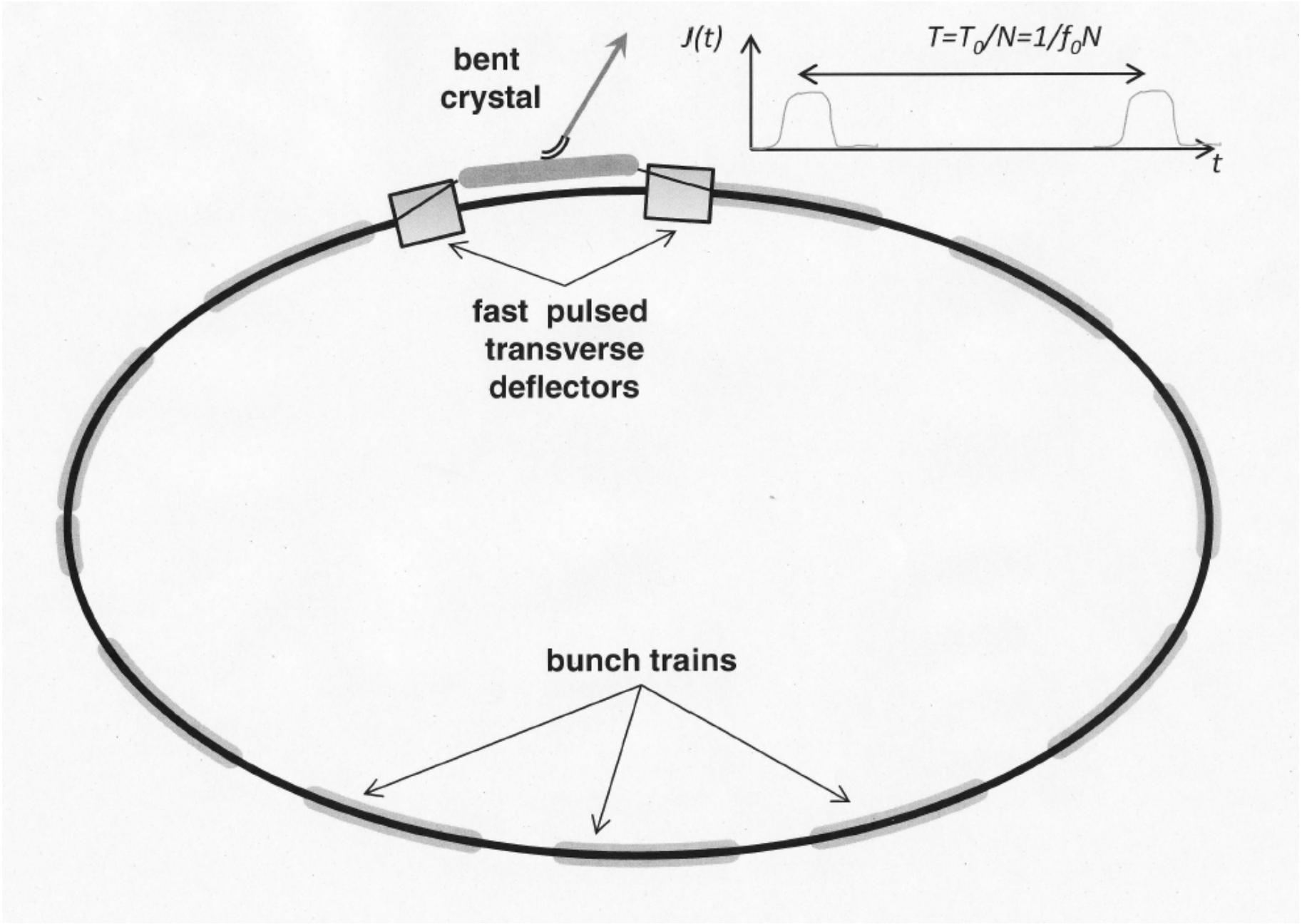



YOKOGAWA
2011/10/18 02:06:44
Running
Waiting for trig.
Normal
2.5GS/s
Level
2.62V
Main : 50 k
2us/div
SOURCE
Source
CH1
CH2
CH3
CH4
EXT
LINE
Polarity
Two of 10 pulses:
• 3 kV peak
• 11.1 usec between
• 200 ns width
Hi-Low(C1)
Fall(C1)
9.44 V
0.0172us
Rise(C1)
0.0296us
CH1 INPUT
DC Full
2.00 V/div
1:1
Edge
CH1
2.62 V
DC OFF


YOKOGAWA
2011/10/18 02:10:46
Running
Envelope
250kS/s
Main : 125 k
50ms/div
30, 000 pulses at 90 kHz
• 2 kV peak
• 200 ns width
Hi-Low(C1)
7.00 V
Rise(C1)
0.008ms
Fall(C1)
0.004ms>
CH1 INPUT
DC Full
2.00 V/div
1:1
Edge
CH1
2.62 V
DC OFF

Summary:

1. the scheme does not require sextupoles or other nonlinear elements – it's a single turn extraction
2. Seemingly needs much less aperture (mu2e from RR)
3. The fast orbit deflectors seems perfectly feasible
4. Crystals can provide 0.3 mrad kick (channeling or three strips – volume reflection)
5. Efficiency of extraction > 98%, can be achieved if single turn xtal efficiency is 90% or better
6. That requires crystals 0.3-0.5 mm or less along the beam direction
7. Experts are ready to bring such crystals → therefore, the need of the Xtal experiment in RR


bent
crystal
J(t)
T=T0/N=1/f0N
t
fast pulsed
transverse
deflectors
bunch trains