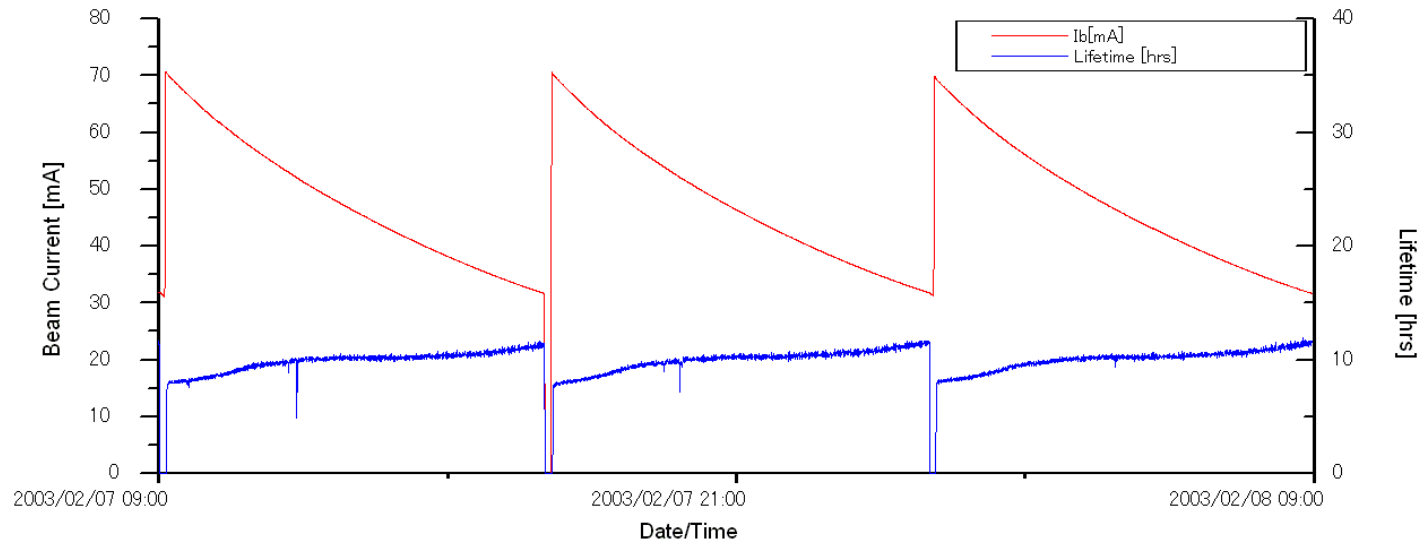# Single Bunch Purification at PF and PF-AR
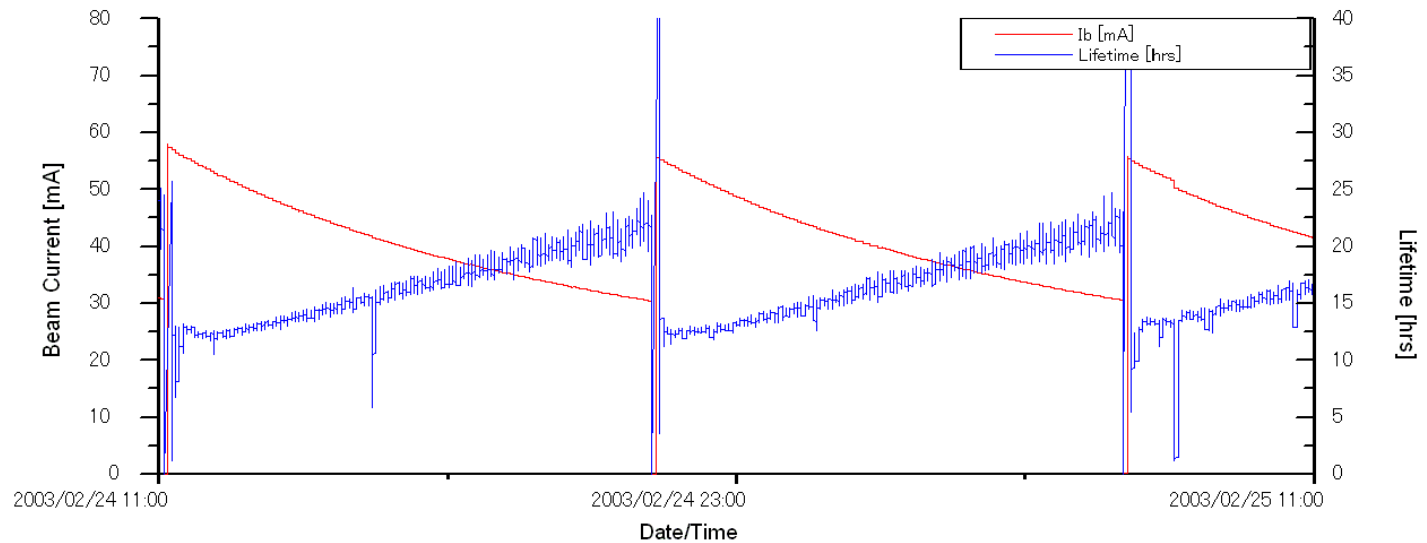
Takashi OBINA

Photon Factory, KEK

# Typical 1day operation of PF and PF-AR

PF-Ring

PF-AR

Purification at PF-Ring

- Single bunch operation
  - Initial stored current : 75mA
  - Injection : 3 times/day
- Required impurity: better than 10^{-6}
- Initial impurity without purification
  - depends on Linac condition
  - 10^{-3} to 10^{-4}
- Even if the initial impurity is satisfactory, impurity is getting worse and worse during the users operation without purification.

Purification using the tune shift

- conventional method

- vertical tune dependence
  - main bunch >> unwanted bunches
  - typically 10kHz (frev=1.6MHz, fby=450kHz) at PF

- Advantage
  - Simple, Easy
  - cheap

**Vertical Tune Shift
in the Single-Bunch Operation**

980414(present measurement)
951106
960624 (3 GeV)
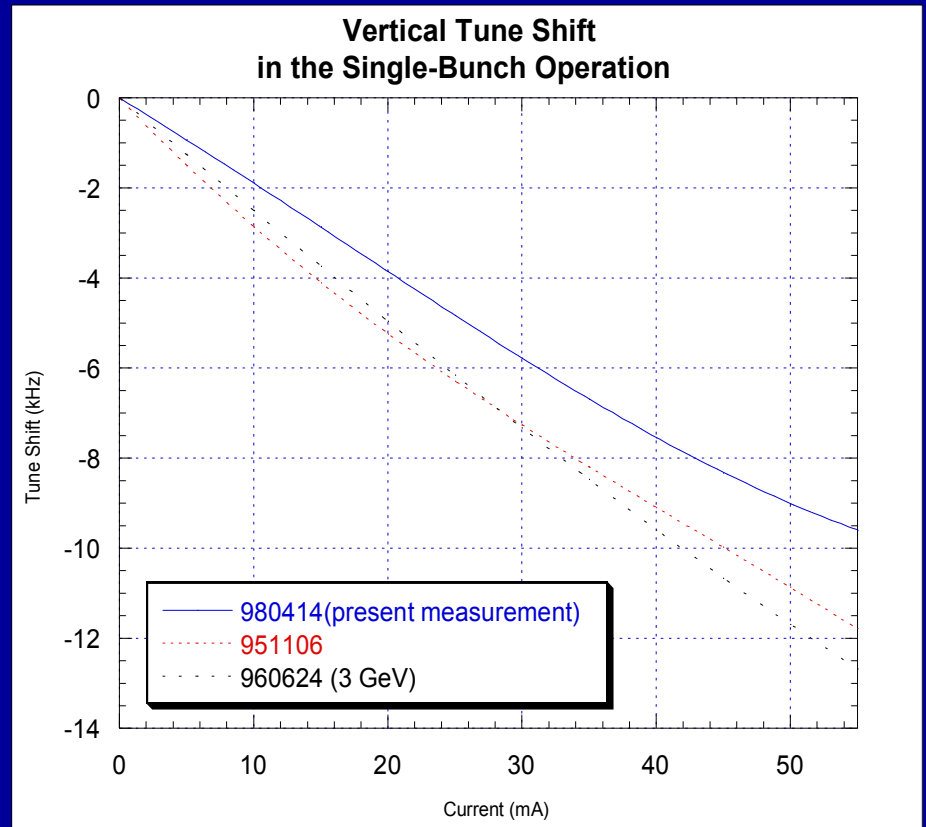
Nonlinear effect
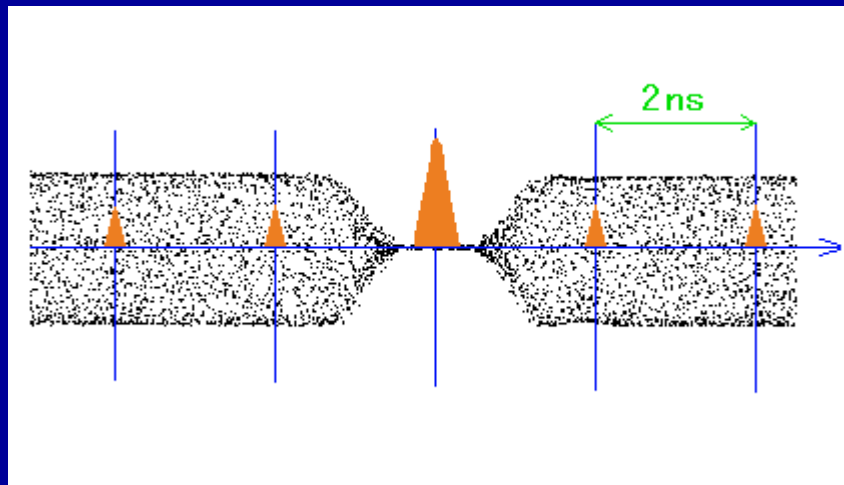
- In 1998, low emittance operation was started
  - 160 nm rad -> 30nm rad
- Nonlinearity of restoring force requires powerful KO
  - single frequency cannot kick out the beam
  - we must sweep KO frequency
- Tune spread is larger than tune shift
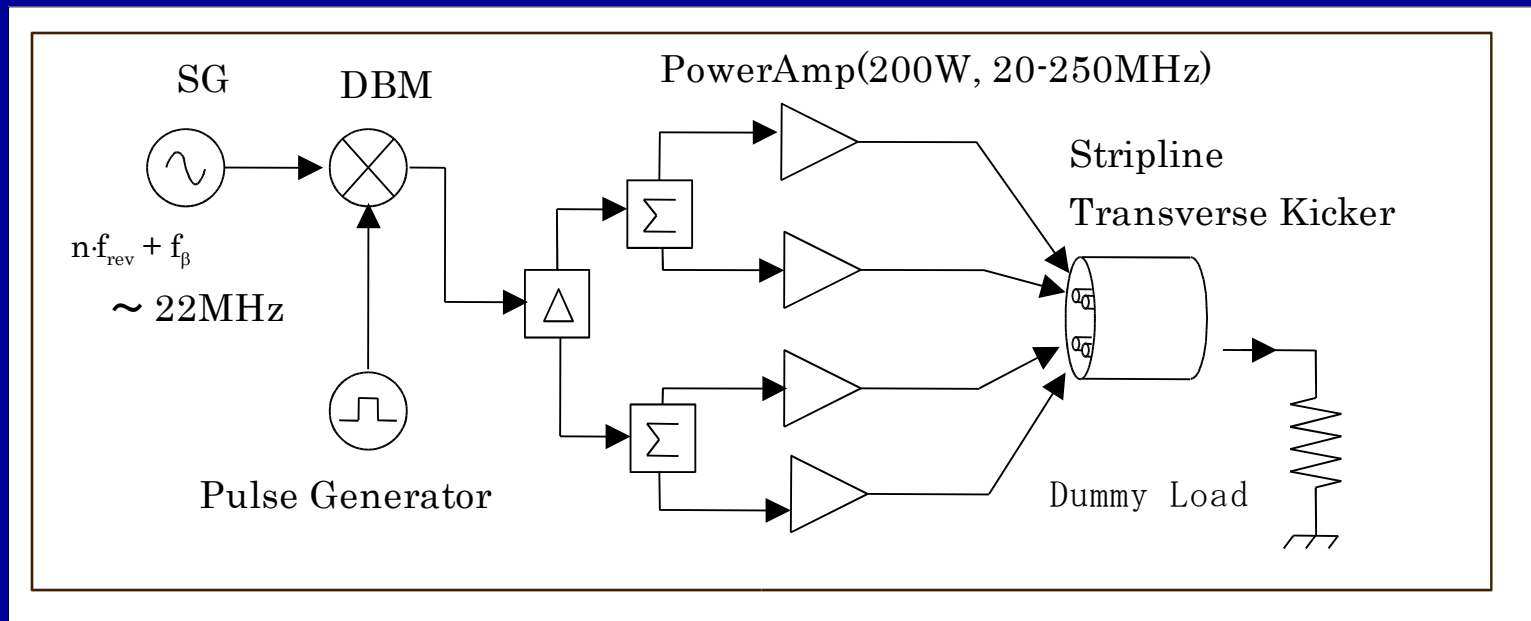
- conventional method is not satisfactory
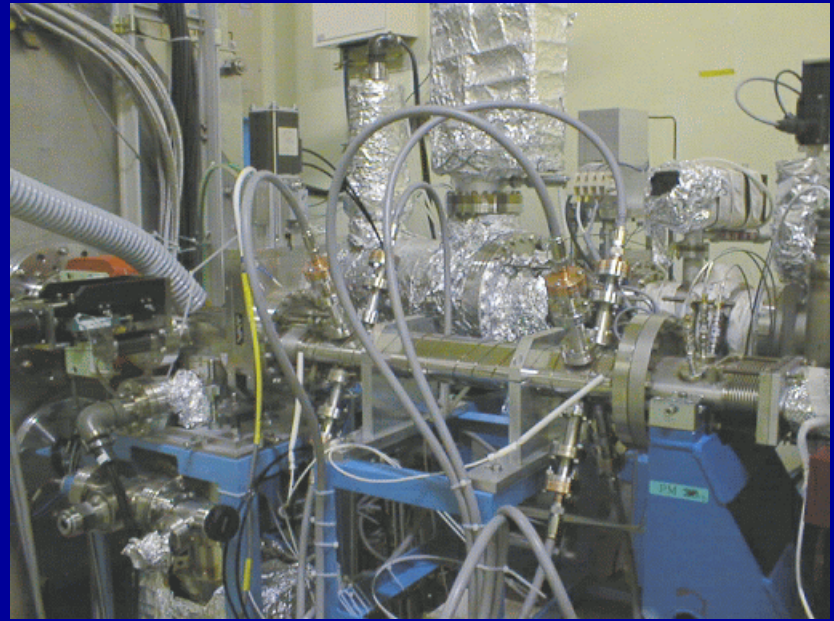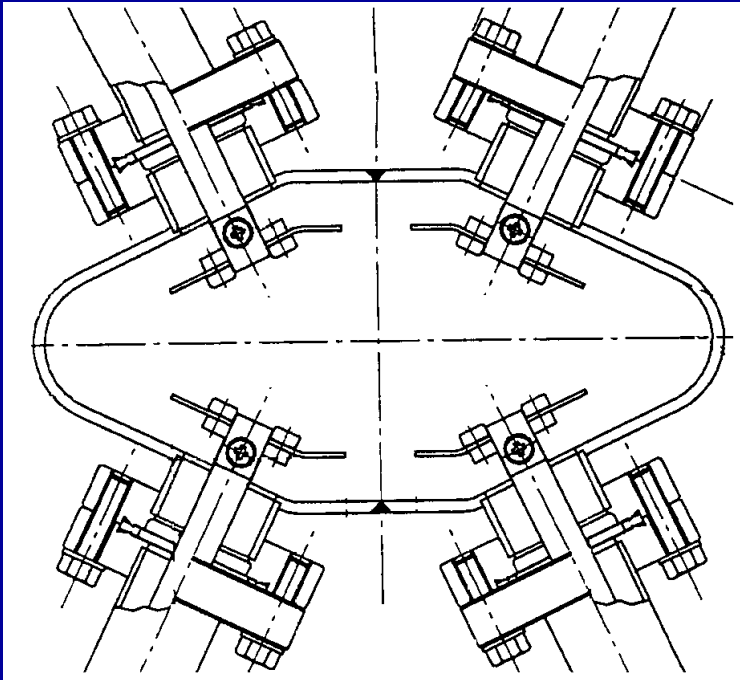
Gated RF-KO

- Gated RF knock-out (RF-KO)

- Wide system bandwidth is required
  - fast pulse, wideband amplifier, etc
  - precise timing

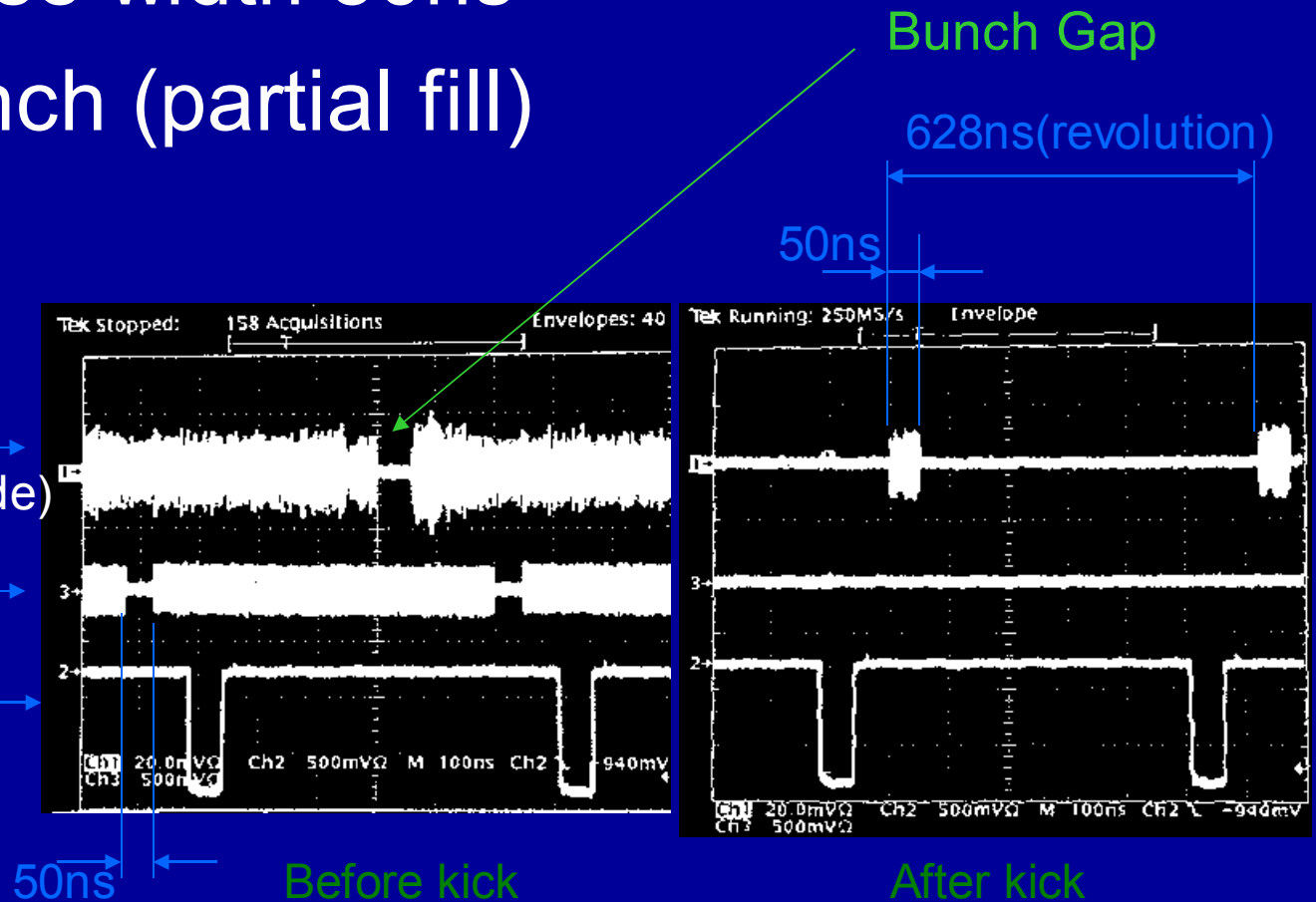# Block diagram of the system

Stripline Kicker

- length = 45cm

Beam Test

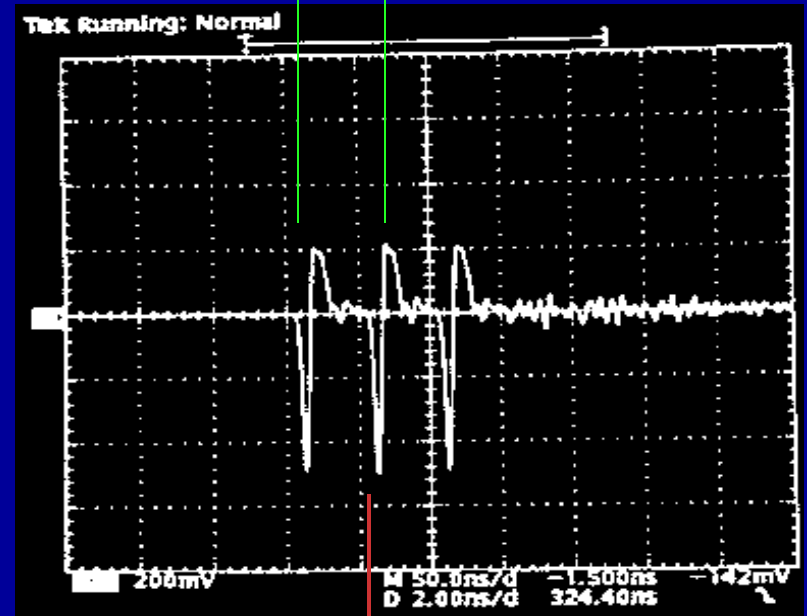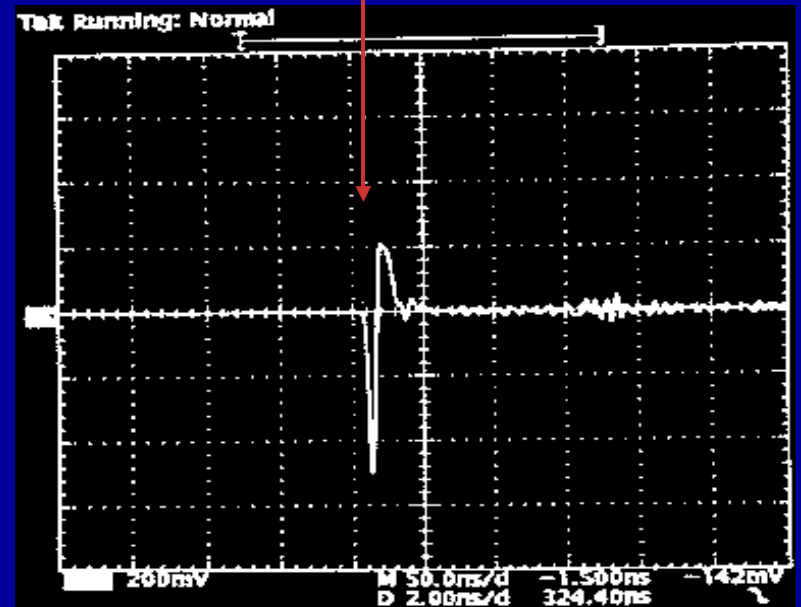- Gate pulse width 50ns
- Multi bunch (partial fill)

Beam Test

- 3 sucsessive bunches

Before kick

After kick

Result: photon counting

Before Purification :

Impurity=4.0×10^{-4}
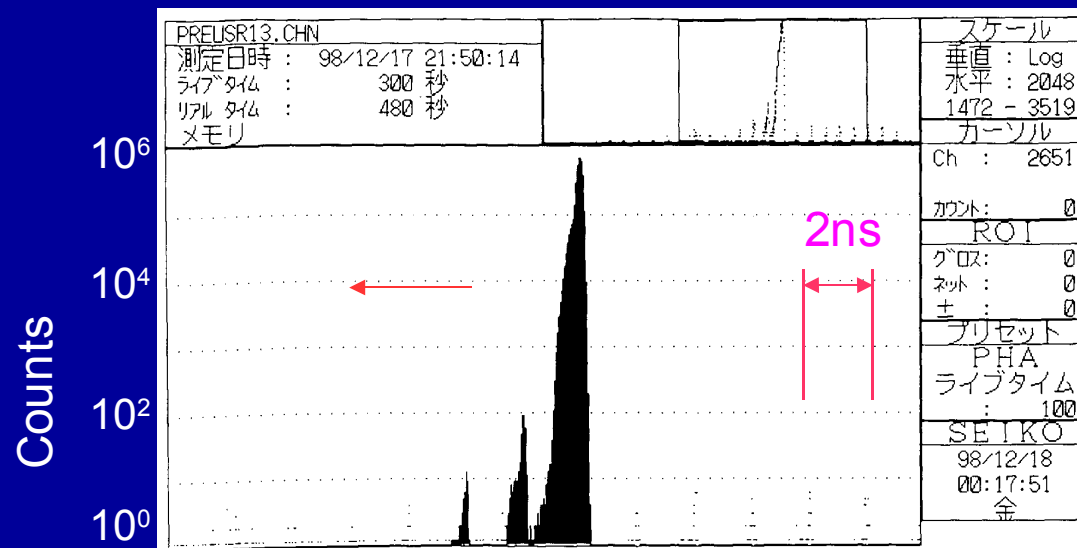
After Purification :

Impurity=3.9×10^{-6}
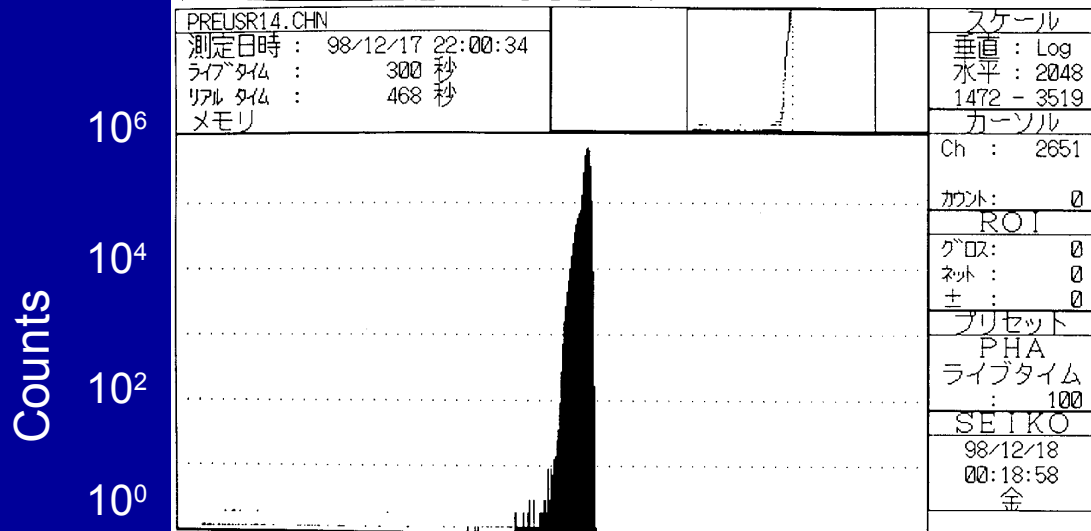
Typical purity measurement

purity measurement during users operation (S. Kishimoto)

E=8.05 keV
Dec.19,1998
15:20- (1000 s)
I_R=45.7-44.6 mA

Main peak
(2.067×10^8 counts)

2.5×10^{-7}
(52 counts)

$< 0.6 \times 10^{-7}$
(13 counts)

Counts

Time (ns)
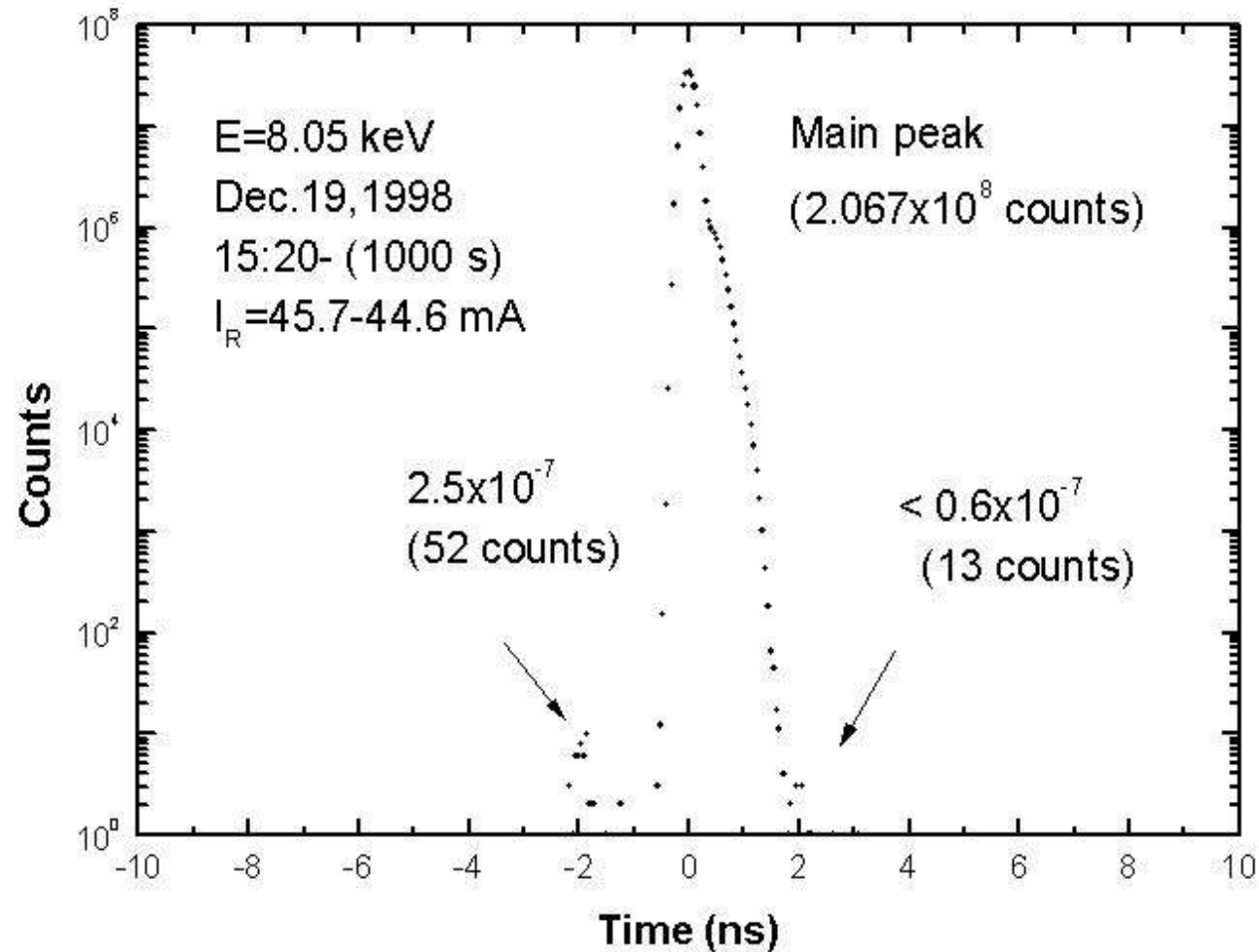
Impurity growth in PF-AR

- Purify at Injection Energy of 3GeV
  - No purification after the energy ramp up (6.5GeV)
- Even in the high energy machine, impurity growth is obvious!!
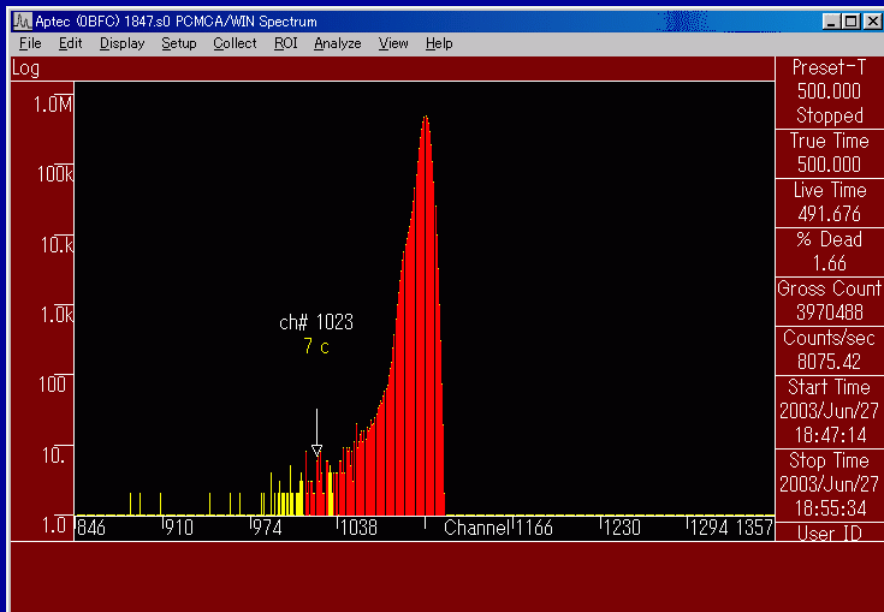
Just after injection
2003/06/28 18:50
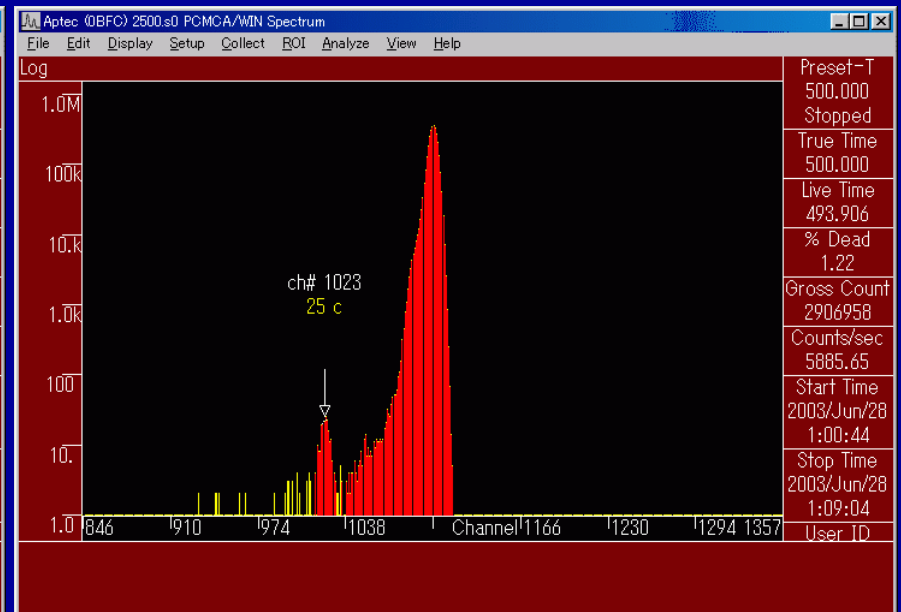
6 hours later
2003/06/28 25:00

Impurity growth of the 1ˢᵗ bunch

- 10:00 -> 17:00
- 2ns = 80ch (25ps/ch)

Impurity

- baseline offset: 2.5×10^{-5}
    - actual impurity is better than 1×10^{-6} at the start time
    - noise source: tail of the main bunch
- Growth rate: 1.5×10^{-7} / min

calculation of impurity growth

- ## parameter :

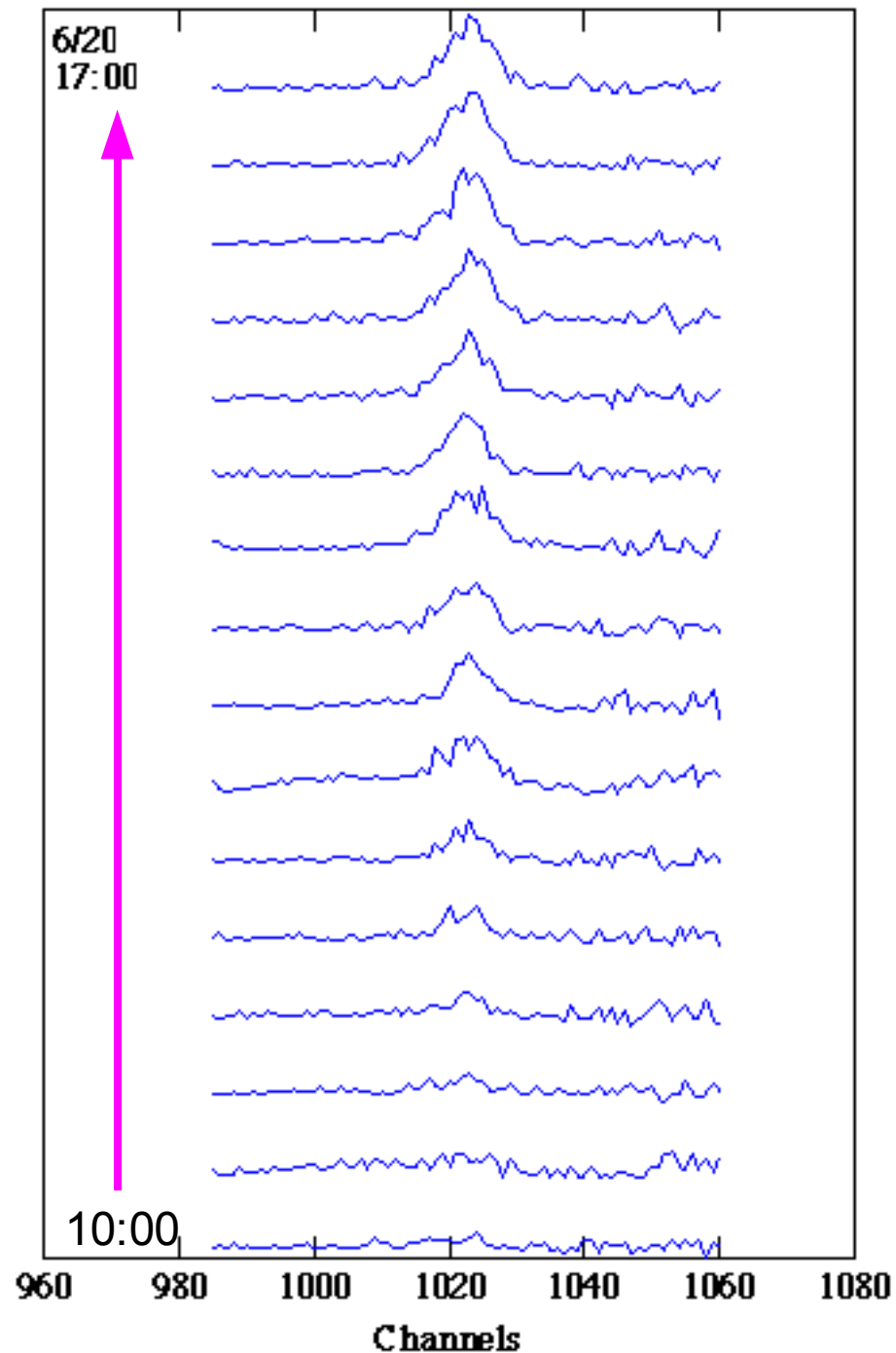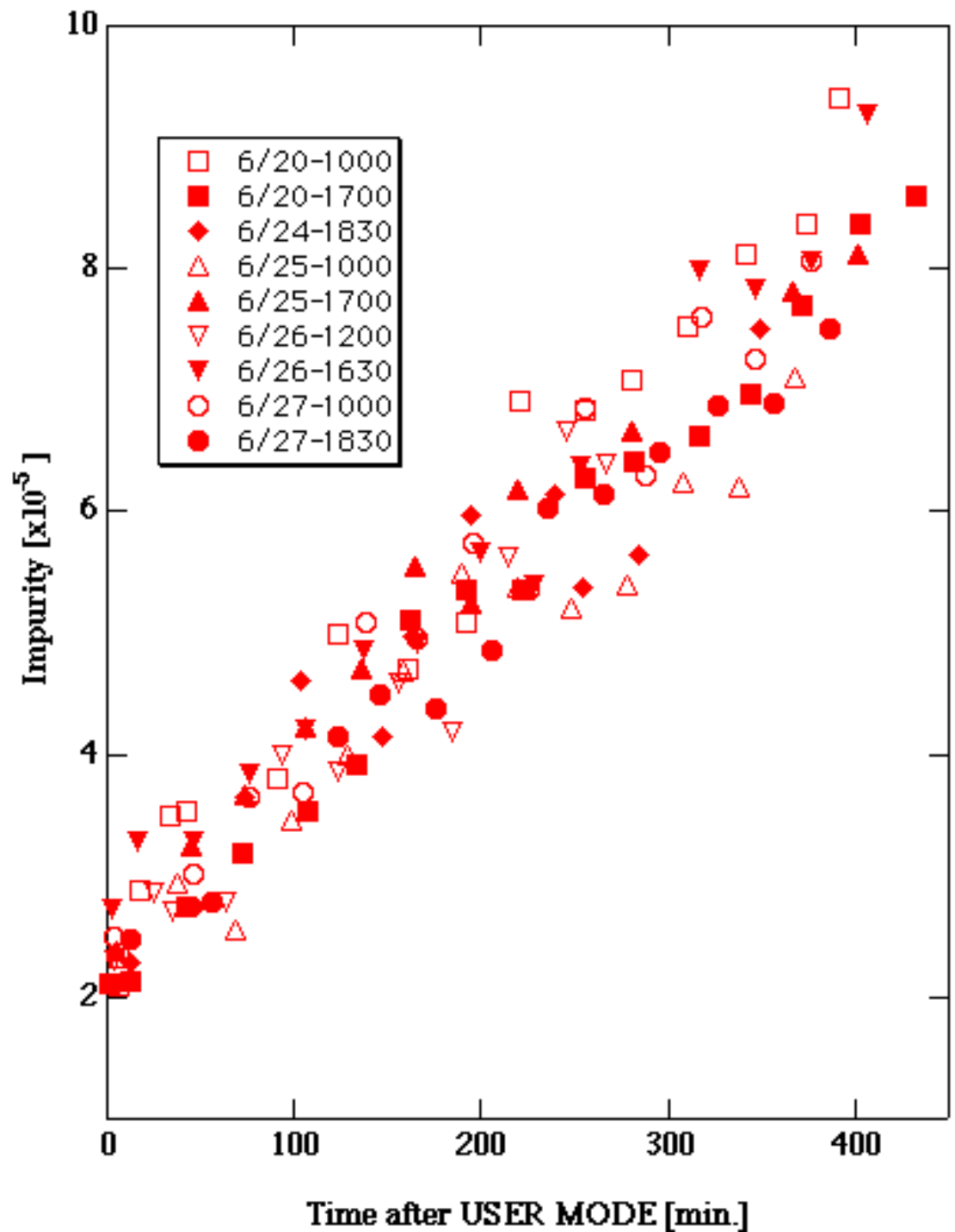|		
Beam Energy	E0 = 6.5	GeV
Harmonic number	h = 640	
Revolution freq.	f0 = 794.7	kHz
Energy loss per turn	U0 = 6.66	MeV
Effective voltage	Vc = 15.2	MV
Momentum compact.	alp = .0126329	
Damping Time		
	X = 2.49	ms
	Y = 2.47	ms
	Z = 1.22	ms
Emittance	X = 2.94E-7	
	Y = 1% coupling	
Energy spread	1.14E-3	
Bunch Length	16.7	mm
Ib	50	mA
Particles/bunch	3.9E11	

natural →

use fixed value
for rough estimation →

Mechanism of impurity growth
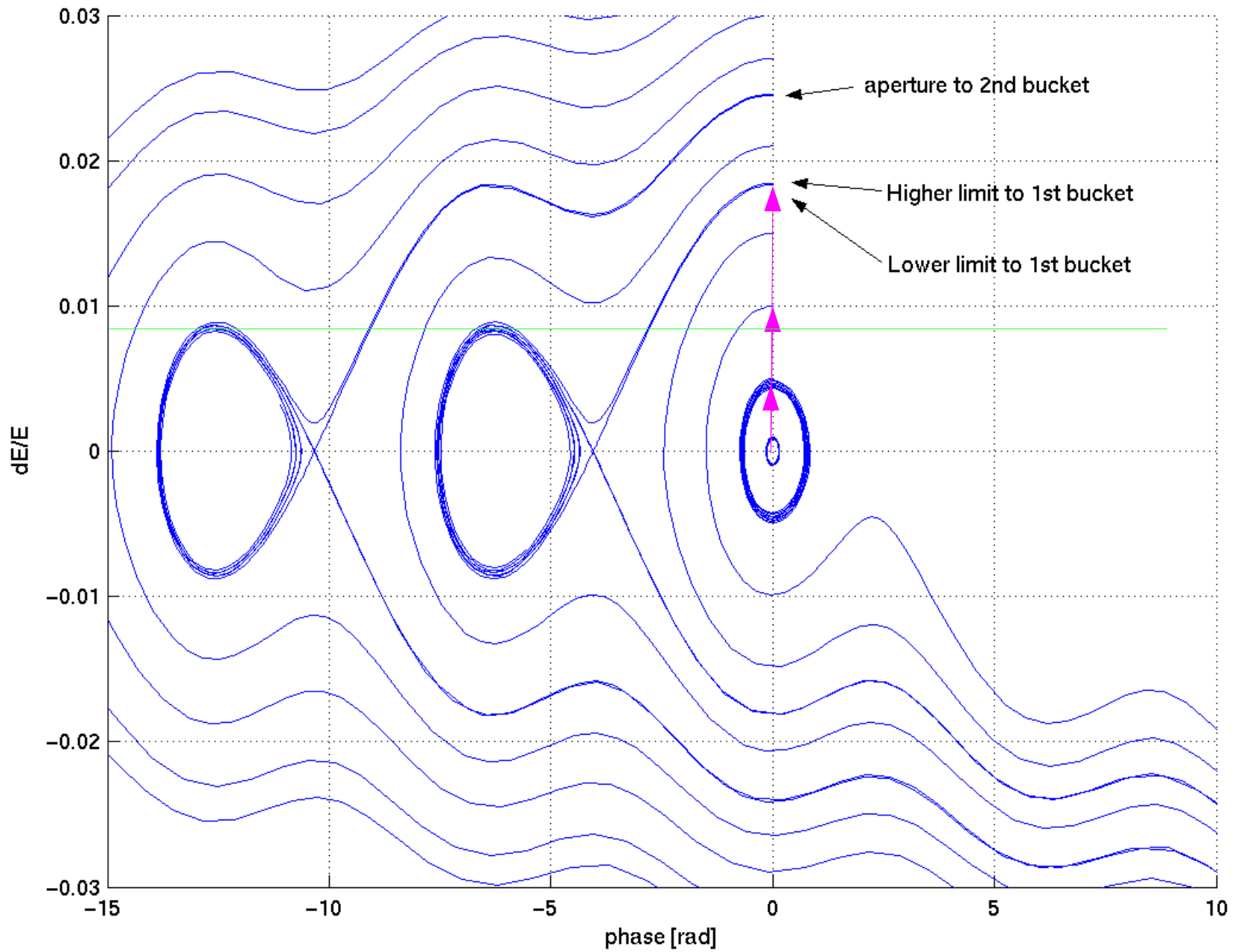
- aperture of the opening of the bucket is calculated by solving the differential equation numerically (matlab)

- Touschek Lifetime is estimated by ZAP

$$\frac{d\varepsilon}{dt} = \frac{eV_0}{TE_0}\sin(\phi_0 - \phi) - \frac{U_0}{TE_0} - \frac{2}{\tau_\varepsilon}\varepsilon$$

$$\frac{d\phi}{dt} = -h\omega_0\alpha\varepsilon$$

$$(\varepsilon = p\,/\,p_0)$$

PF-AR 6.5GeV calc.

result (calculation)

- Opening of the bucket is one order of magnitude larger than that of PF-2.5GeV ring

- estimated impurity growth: 1.88×10^{-7} [/min]

- measured impurity growth: 1.5×10^{-7} [/min]

- difference:
    - fixed bunch length
    - coupling

1st Bucket

Lower limit	1.833717647E-2
Higher limit	1.844003784E-2
delta P	<u>1.0286137E-4</u>
Tauschek rate	6.2523E-9 [/sec]

2nd Bucket

Lower limit	2.449095951E-2
Higher limit	2.457326718E-2
delta	0.8230768E-4
Touschek rate	8.70E-10 [/sec]

How to purify in 6.5 GeV???

- We must purity during 6.5GeV user run!

- Monitor
    - Open/Close Beam shutter from control room...finished
    - automated measurement.....not finished.
- Kicker
    - move stripline kicker location where the vertical betatron function is larger than the present value...finished

- Amplifier
    - More Power!!
        - However, budget for the amplifier is not approved yet.
- Usage of scraper, Local bump,
    - We can kick unwanted bunches if the lifetime of the main bunch is decreased....

- Skew Q magnet, RF voltage, Linear optics.....