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Design of electrostatic septum for slow extraction from J-PARC main ring

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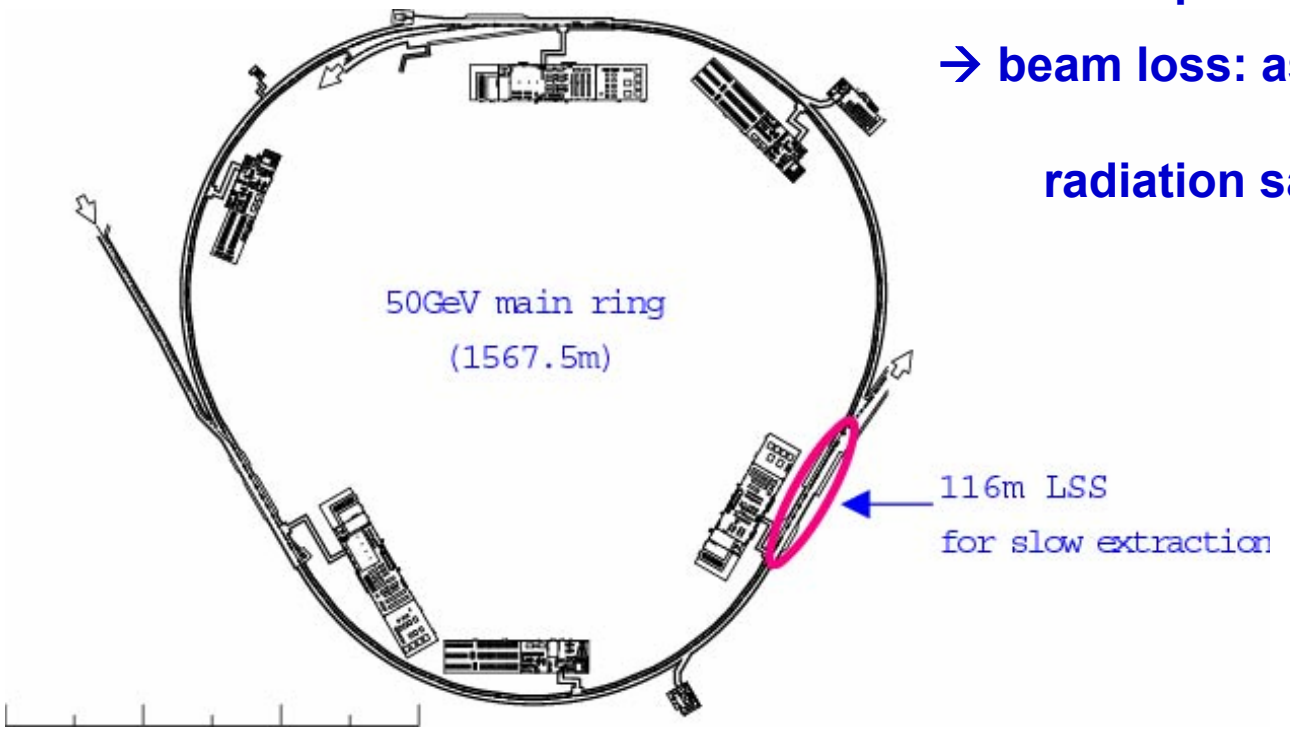
1. Introduction
2. Status of ESS R&D
   - High voltage test
   - Alignment measurement
3. Radiation and Residual Activity
4. Temperature rise by heat deposit
5. Two other types of ESS

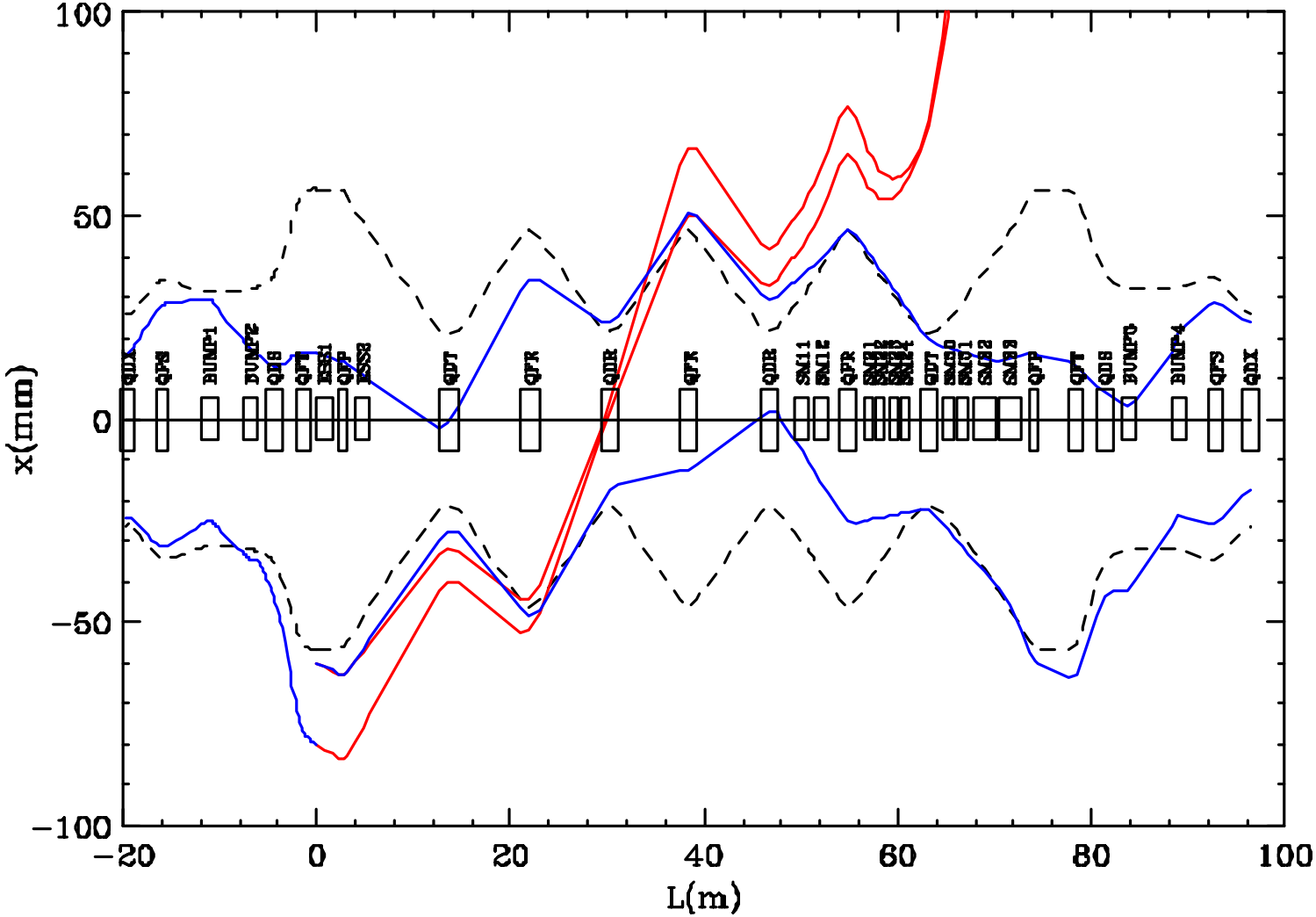
J-PARC Main Ring



- 3.3×10^{14} protons per pulse(15μA)
  full beam power : 750kW @50GeV

→ beam loss: as possible as small
<1% (7.5kW) level
radiation safety problem

psext4_007.dat
mad332.mad
env4.com

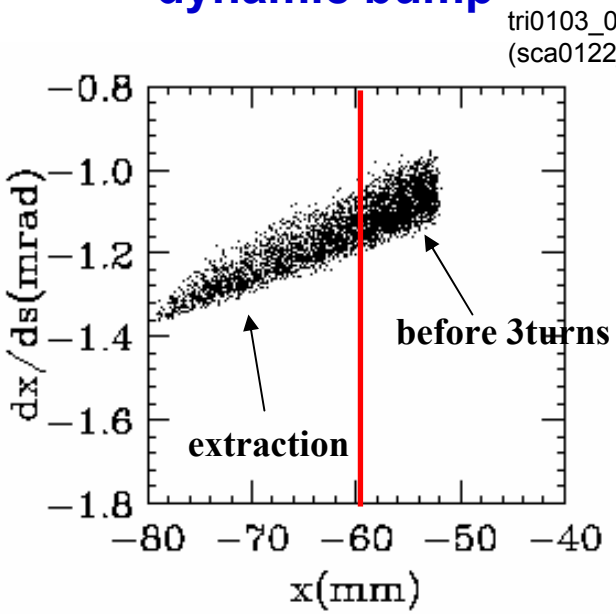


Parameters of Electrostatic septa (reference design)

	thickness (μm)	voltage(kV) /gap(mm)	L (m)	kick angle (mrad)
ESS1:W/Re(3%) wires	80+20	170/25	1.5	-0.2
ESS2:W/Re(3%) wires	80+20	170/25	1.5	-0.2

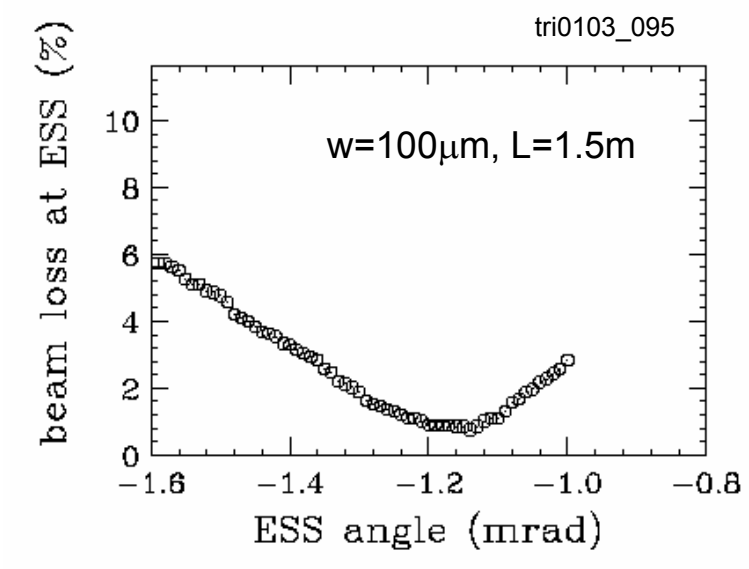
50GeV primary beam hit rate on ESS wires

dynamic bump



Qv=20.775

beam hit rate on ESS wires



Circulating Beam Parameters

ε_x=6.1π mm•mrad
ε_y=6.1π mm•mrad
Δp/p=±0.25%

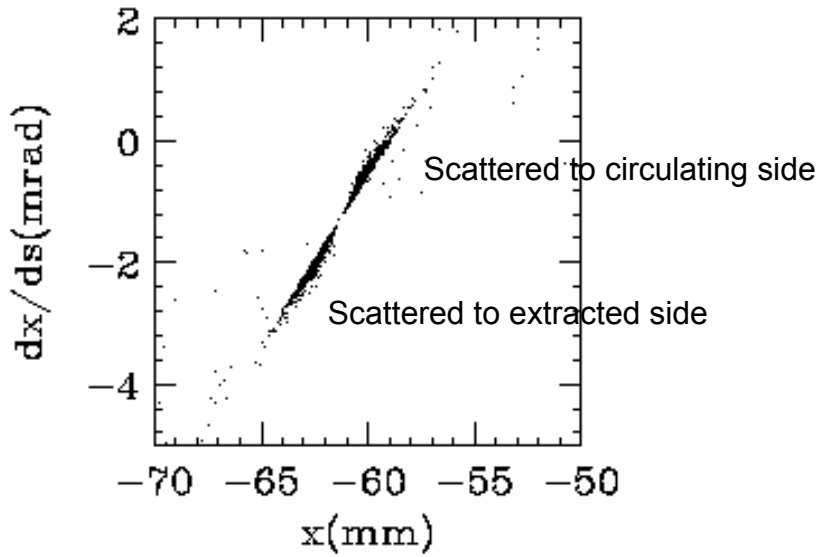
min. hit rate 0.8% @100μm
min. hit rate 0.5% @50μm

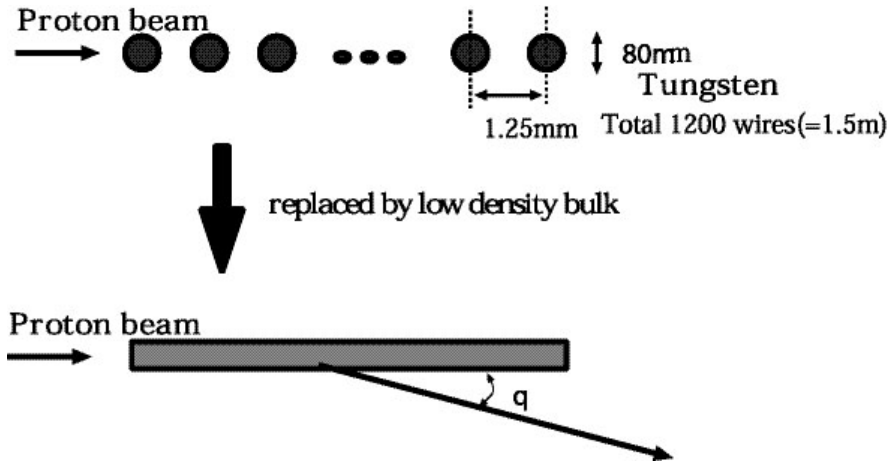
Protons scattered on the ESS wires (MARS)

40cm downstream from ESS1 exit

(Reference ESS design)

sadin_foilsct_case1.dat
r12_case1.com





Low Density Bulk Model

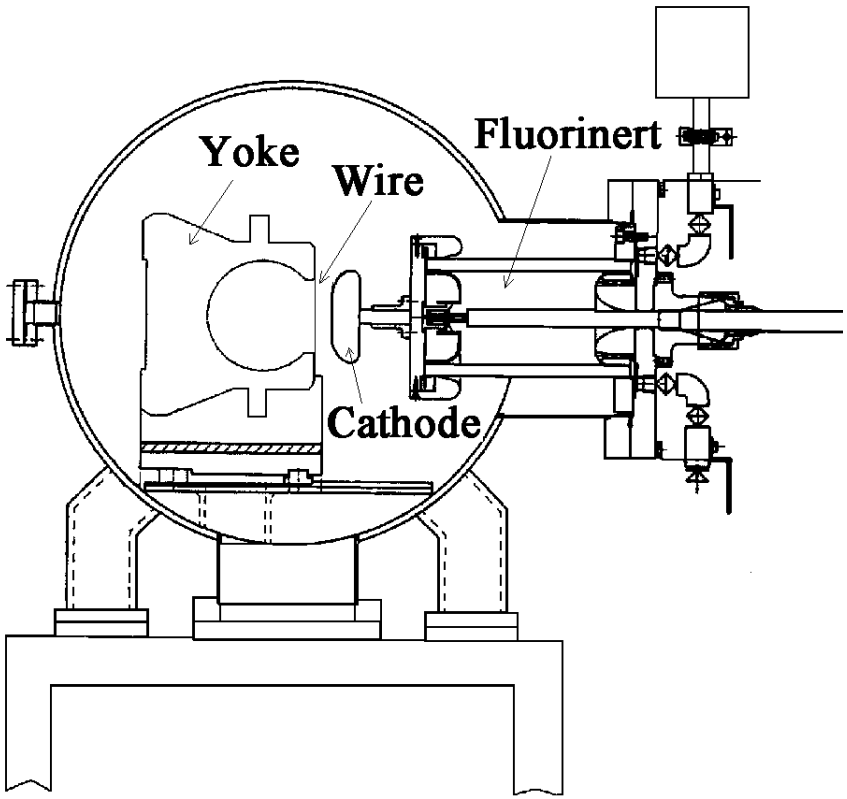
Hit rate 0.01 (1%), full beam 750kW

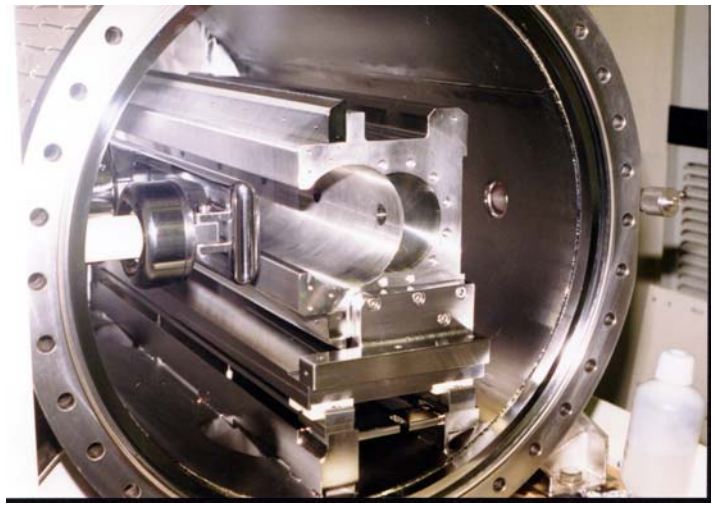
"real loss rate" = [N(hit)-N(scatt.)]/N(hit)

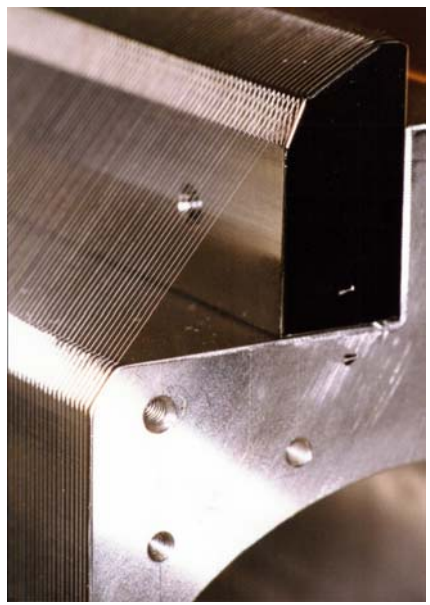
real loss 750kW x0.01 x 0.077=0.58kW

R&D electrostatic septum

80μm W/Re(3%) wires, 1.25mm space, h=80mm





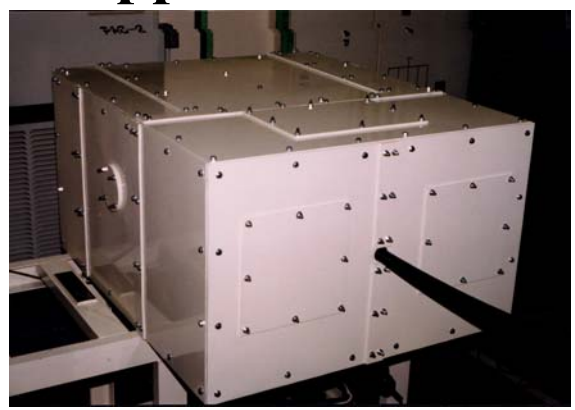


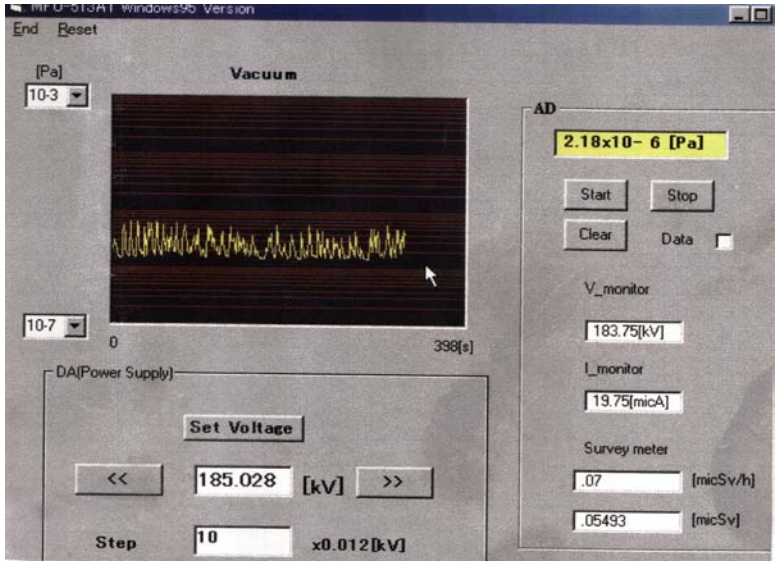
High Voltage Test of R&D electrostatic septum

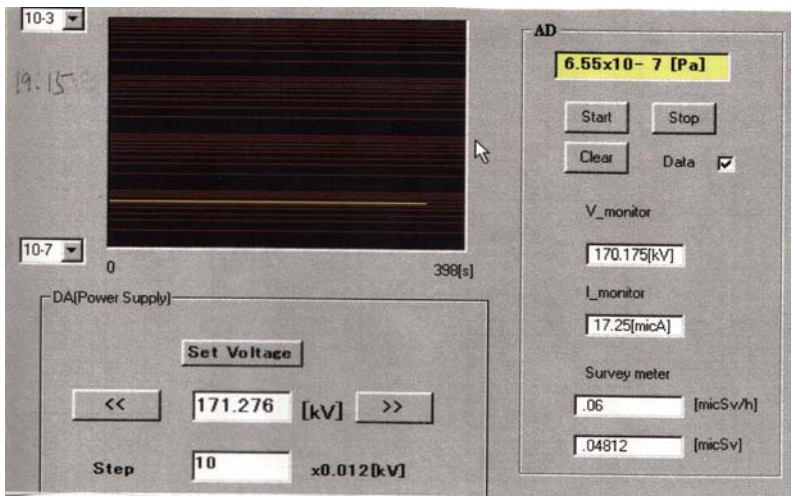
GOAL: 170kV/25mm gap, 6.8MV/m

- **SUS cathode:**
- **small discharge @170kV --> conditioning at higher voltage**
- **ceramic feedthrough was broken @237kV**
- **Ceramic A-479(99%)->KP-999(99.9%) alumina content**
- **Still small discharge @170kV --> conditioning at higher voltage**
- **A wire was cut by damage due to high dark current(~200μA)**
- **conditioning at 235kV without wires --> very stable**
- **Ti electrode(10nm oxidized film on surface----suppress e emission)**
- **wires were replaced to new ones**

-->170kV/25mm operation is stable!!







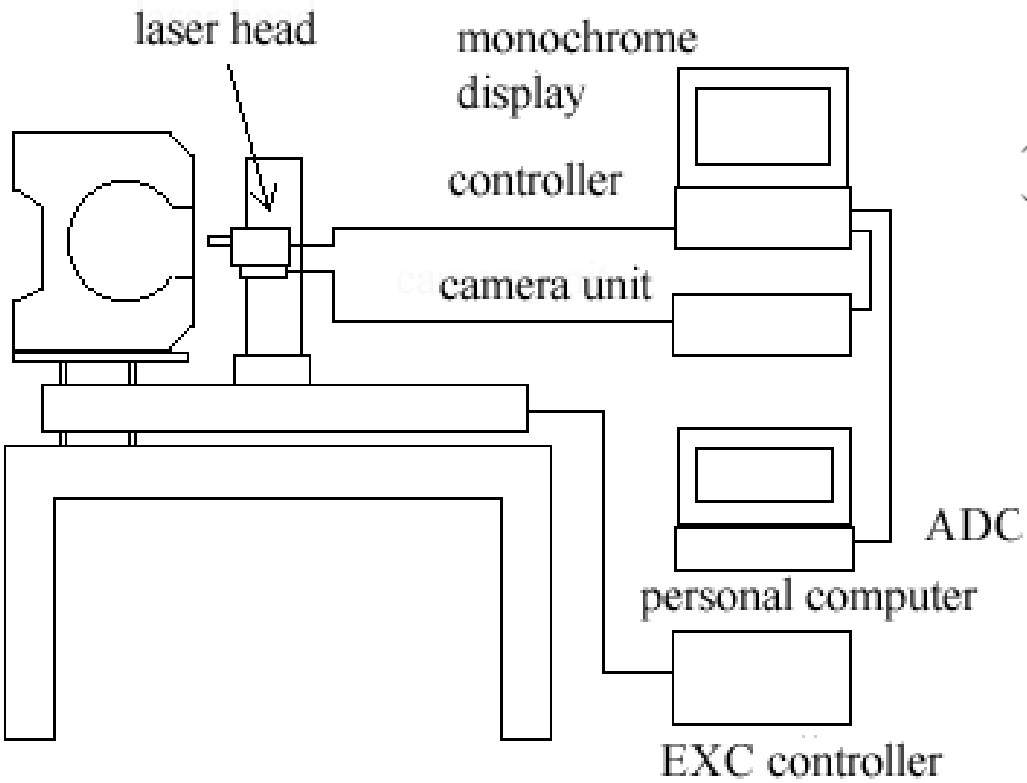
careful conditioning
not to makes any serious damage

Automatic high voltage conditioning by PC

0.12kV/5min

Alignment Errors of Wires

Laser focus displacement meter



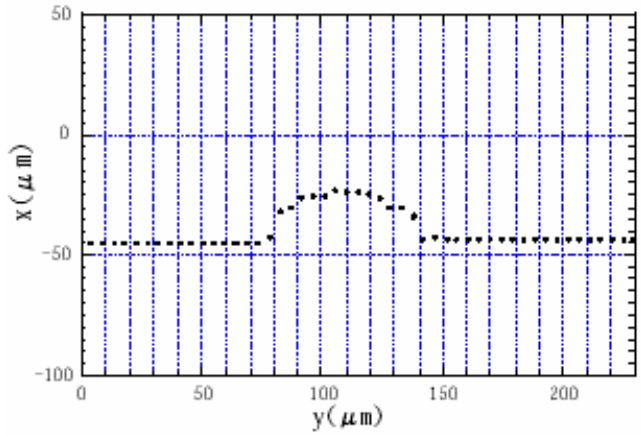
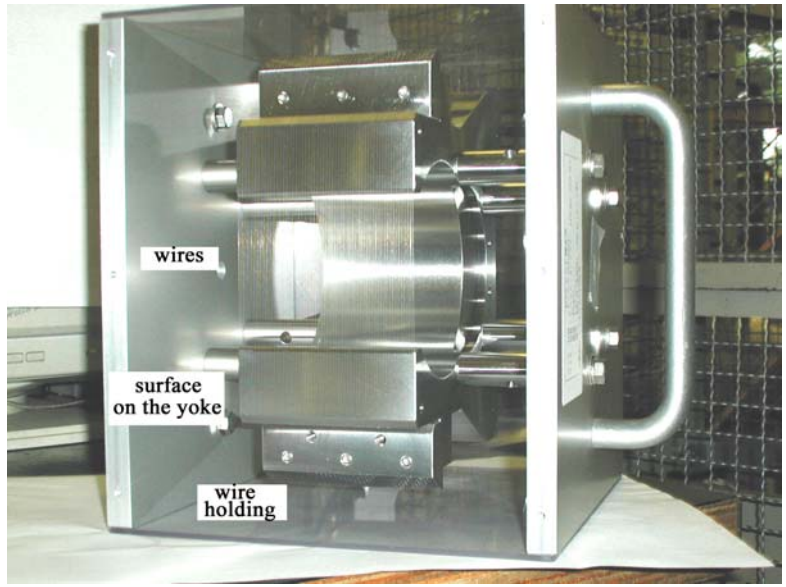


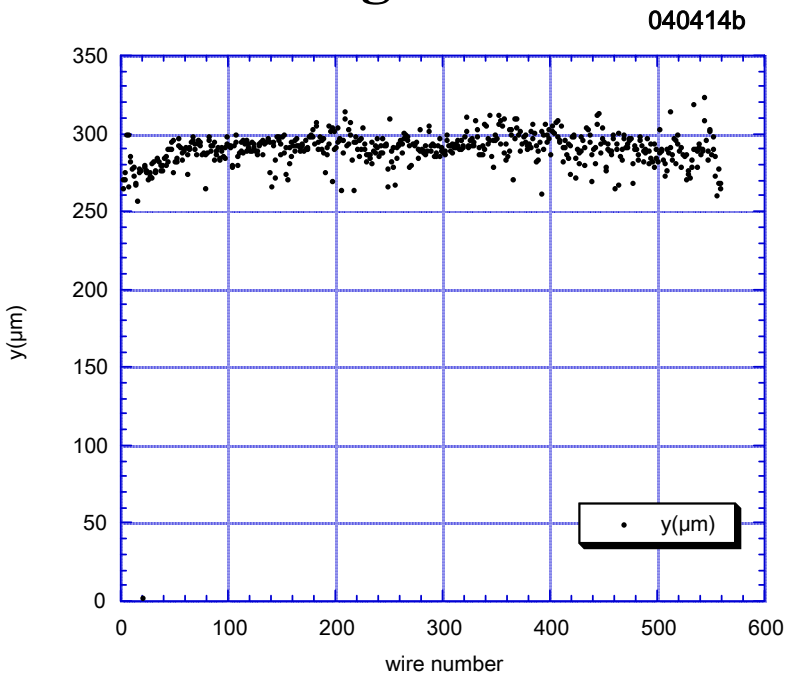
Fig. 5: Profile of a wire.

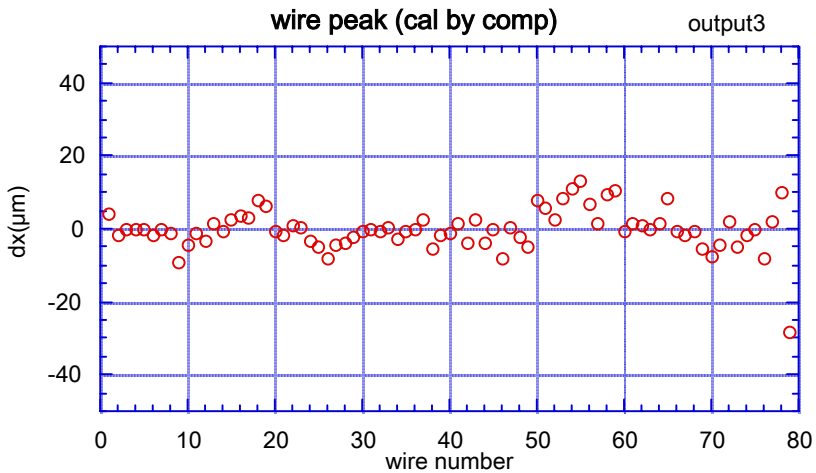
Short Test Piece



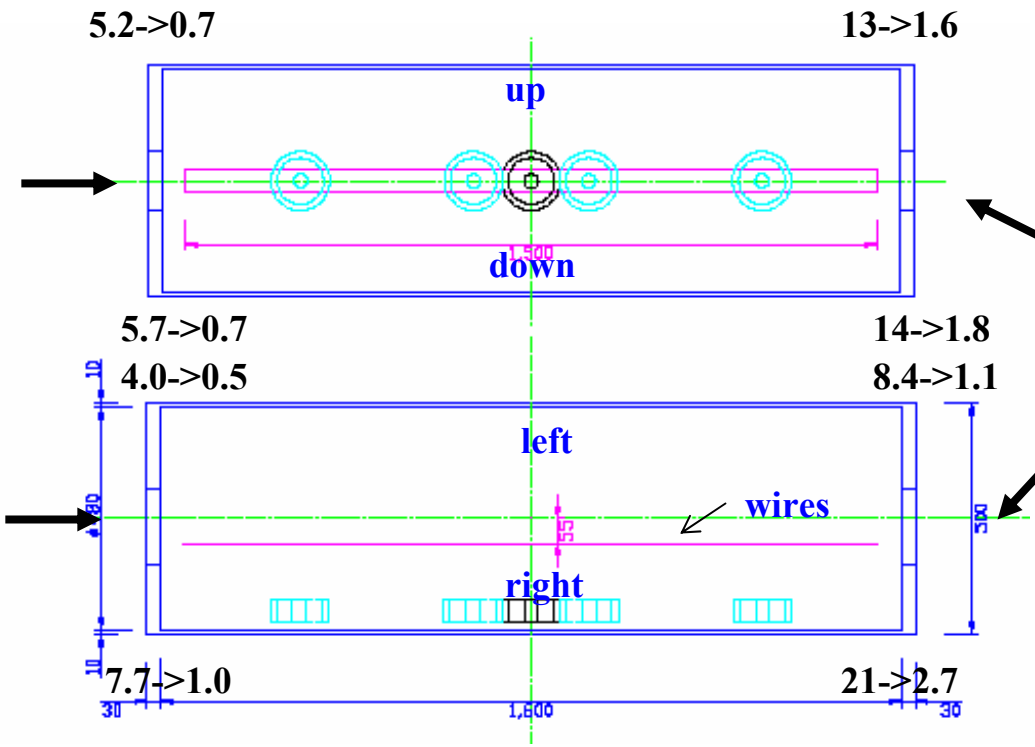
Prototype

Damage of wires
Guide groove





Residual Activity of Ti ESS chamber

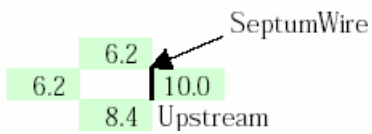


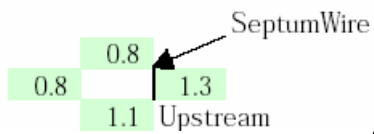
30days irradiation
Unit mSv/h
1 -> 30 day cooling

ESS chamber side
ESS chamber end
ESS downstream

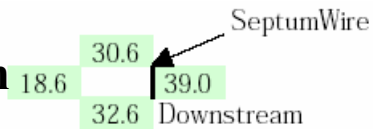
Ti Flange 59.9->7.5
Ti Duct 94.8->11.9

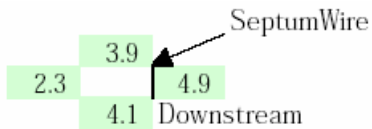
upstream





downstream





1day cooling

30days cooling

Absorbed dose of QFP coil insulation (polymid)

1 year operation (5000h)
wires hit rate: 1% of 750kW

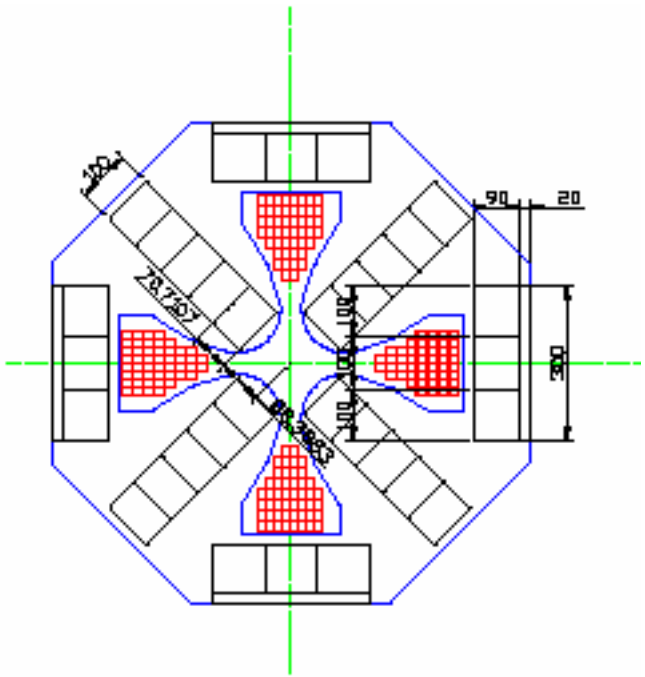
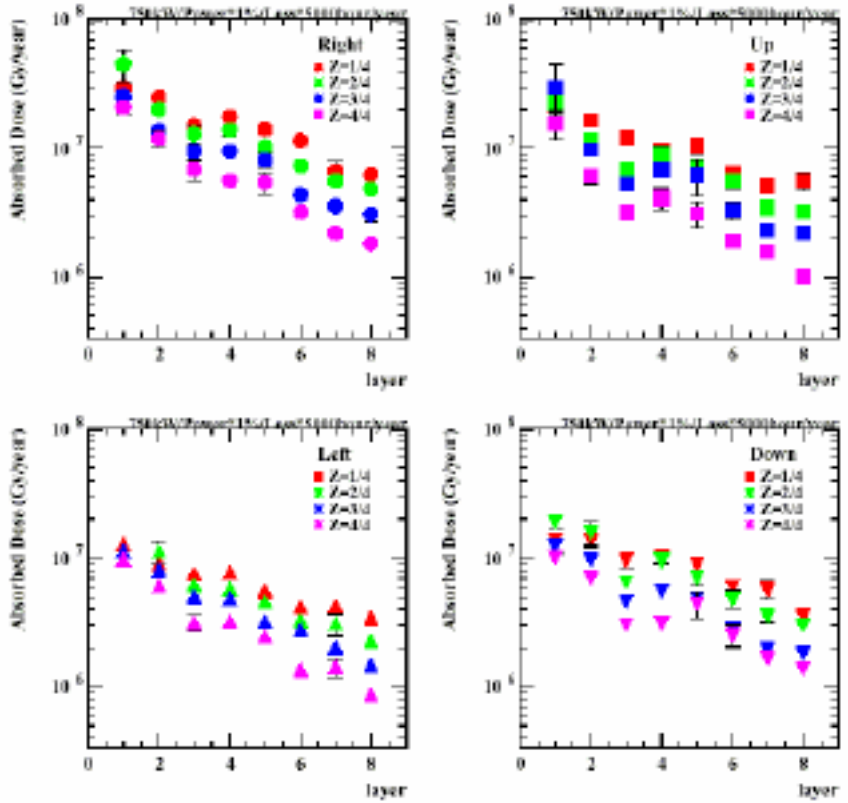


図 1



Polimid ~400MGy
---> Life >10 years

Residual Activity of Quadrupole (QFP)

30days irradiation
Unit mSv/h
1 -> 30 day cooling

QFP upstream

QFP side view

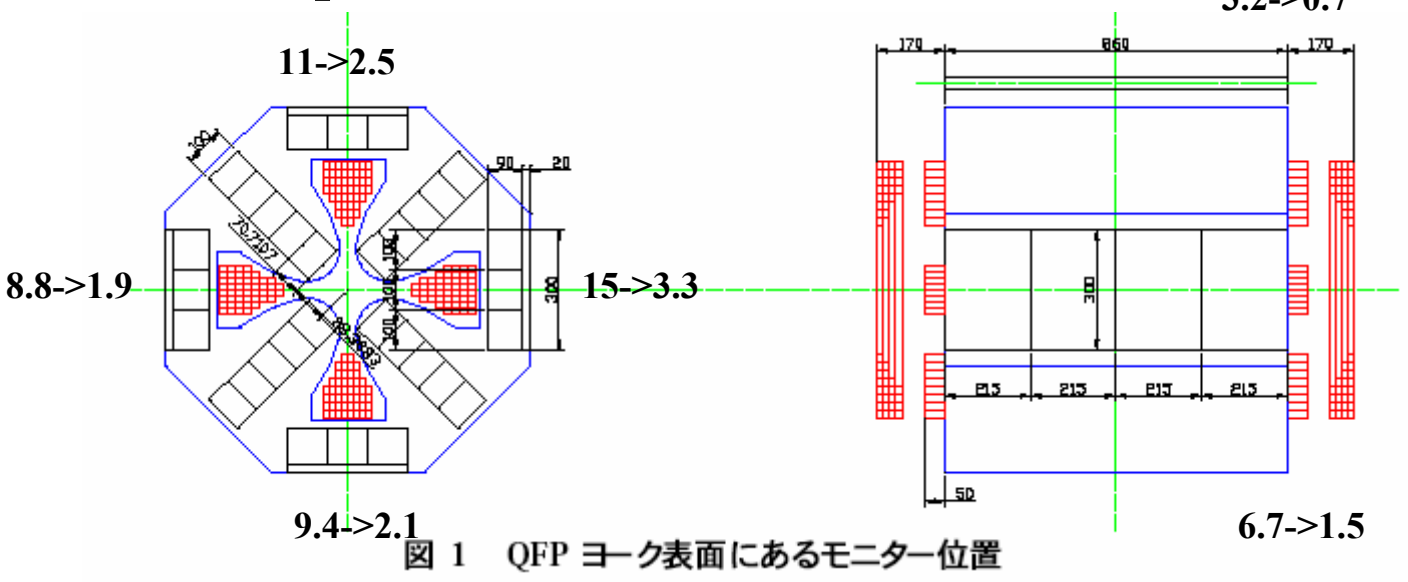
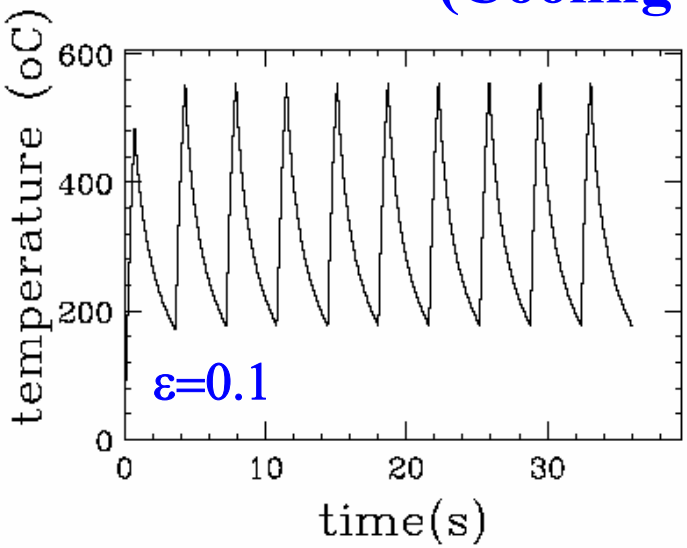
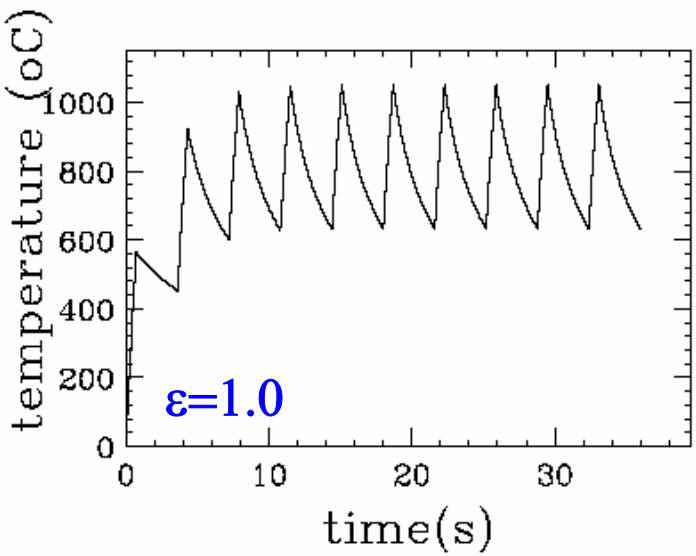


図 1　QFP ヨーク表面にあるモニター位置

Temperature rise by energy deposition in Tungsten wires

Cooled by thermal radiation
(Cooling by conduction can be neglected)





$E=\varepsilon\sigma T^4$

σ: Stefan Constant

ε: emissivity

Initial temperature: 30°C
repetition period: 3.6s
Flat top time: 0.7s
proton number : 3.3×10^{14}ppp x 0.01
proton dE/dx: 5.72×10^{-12} J/cm

Next Step

- **dE/dx by MARS**
- **Measurement of ε by heat load in the vacuum**

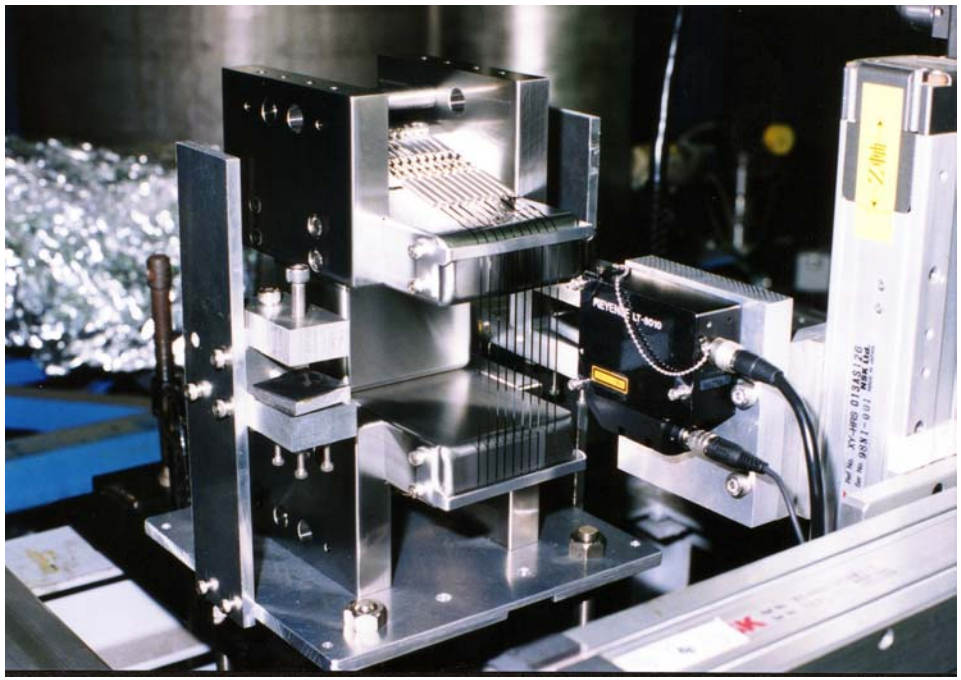
Ribbon foils (AGS type)

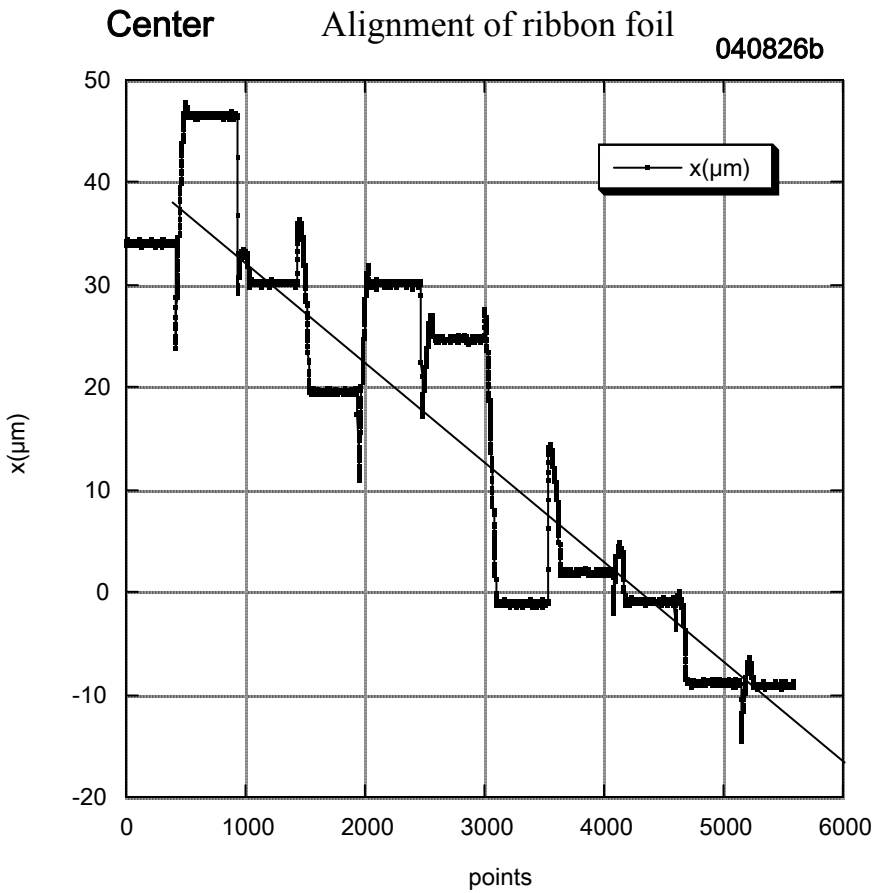
ESS1: W, 30μm+20μm, 1mm, 4mm spacing, L=1.5m, 0.2mrad
ESS2 :W, 30μm+20μm, 1mm, 4mm spacing, L=1.5m, 0.2mrad

Thinner: reduce hit rate
Mechanically stronger: reliable
Smaller deviation due to electric filed

Alignment Errors of Ribbon Foils

Tension 2kg





Scatterer+ribbon ESS

Scatterer: 30μm+20μm, 1mm, 40mm spacing, L=0.5m, 0mrad
ESS1: W, 30μm+20μm, 1mm, 4mm spacing, L=1.0m, 0.133mrad
ESS2: W, 30μm+20μm, 1mm, 4mm spacing, L=2.0m, 0.267mrad

Scatterer: low average mass density, no electric field
Beam hits scatterer
Multiple scattering is dominant process
--> radiation is reduced
Beam hit rate on downstream ESS foils is small

Needs more space to get same kick angle

Beam Loss Performance of three types

- hit rate at wires or ribbons
- Scattering process by MARS (low density bulk model)
- Track scattered protons
  - check apertures of other all septa and ducts
  - circulated protons
  - survived protons at exit of the ring

	real loss in the whole ring	extraction efficiency
80+20μm wires	1.88kW	99.75%
30+20μm ribbons	1.05kW	99.86%
scatterer+ribbons	0.71kW	99.91%

Low density bulk model is realistic ?

- **Production of Slow Extraction Devices will start from spring 2006.**

- **We have one more year to fix ESS scheme!**

- **Scattering simulations**
- **R&D ESS (alignment and high voltage test)**

- **establish maintenance scenario under high residual activity**
  - **high voltage cable**
  - **vacuum flange**
  - **ESS chamber install/uninstall by Air palette**
  - **fluorinert exchange/circulation**