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Progress of an accelerator mass spectrometry system on the Tsukuba 12UD Pelletron tandem accelerator

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Outline of presentation

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- Introduction
  - 12UD Pelletron tandem at the University of Tsukuba
  - AMS and facilities
- AMS system on the 12UD Pelletron tandem
  - Description of the Tsukuba AMS system
  - Recent progress
  - Performance of ^{26}Al, ^{36}Cl and ^{129}I AMS
- Summary and future plans

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University of Tsukuba, Tandem Accelerator Complex

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University of Tsukuba, Tsukuba science city

60 km from Tokyo in the northeast

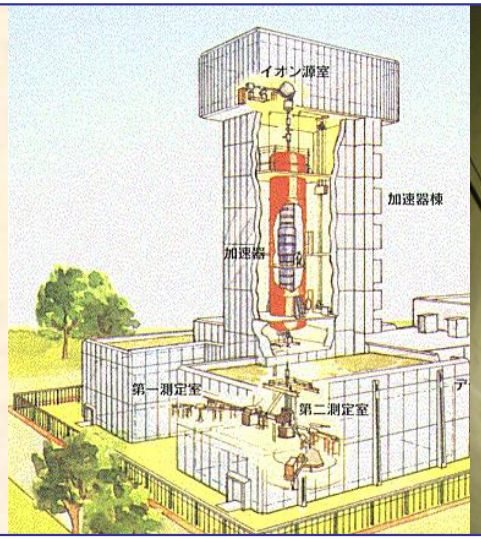
2 accelerator facilities

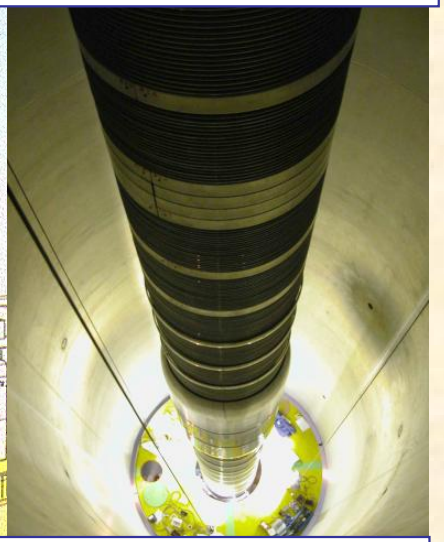
Proton Medical Research Center: PMRC

- 250 MeV Proton Synchrotron (2001)

➡ Proton Beam Radiotherapy

Tandem Accelerator Complex: UTTAC





- 12UD Pelletron Tandem Accelerator (1975)
- 1MV Tandetron Accelerator (1987)

12UD Pelletron tandem accelerator (1975)

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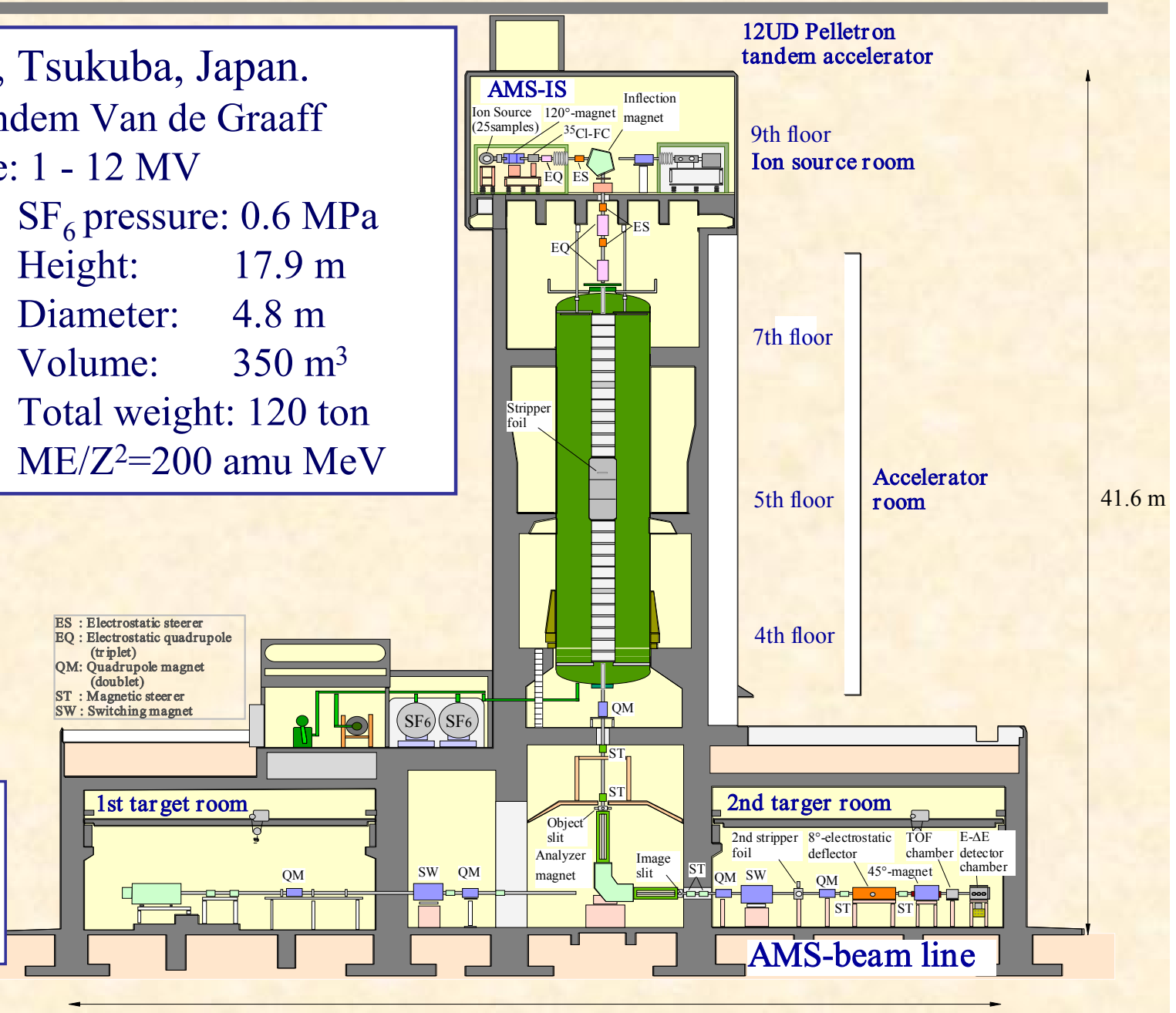
University of Tsukuba, Tsukuba, Japan.

- MODEL : Vertical Tandem Van de Graaff
- Terminal voltage range: 1 - 12 MV
- Insulation Gas : SF_6 pressure: 0.6 MPa
- Accelerator Tank : Height: 17.9 m
  Diameter: 4.8 m
  Volume: 350 m^3
  Total weight: 120 ton
- Analyzing Magnet : ME/Z^2=200 amu MeV



In the early stage

Nuclear physics

Now

- AMS
- IBA
- Material science

12UD Pelletron tandem accelerator (1975)

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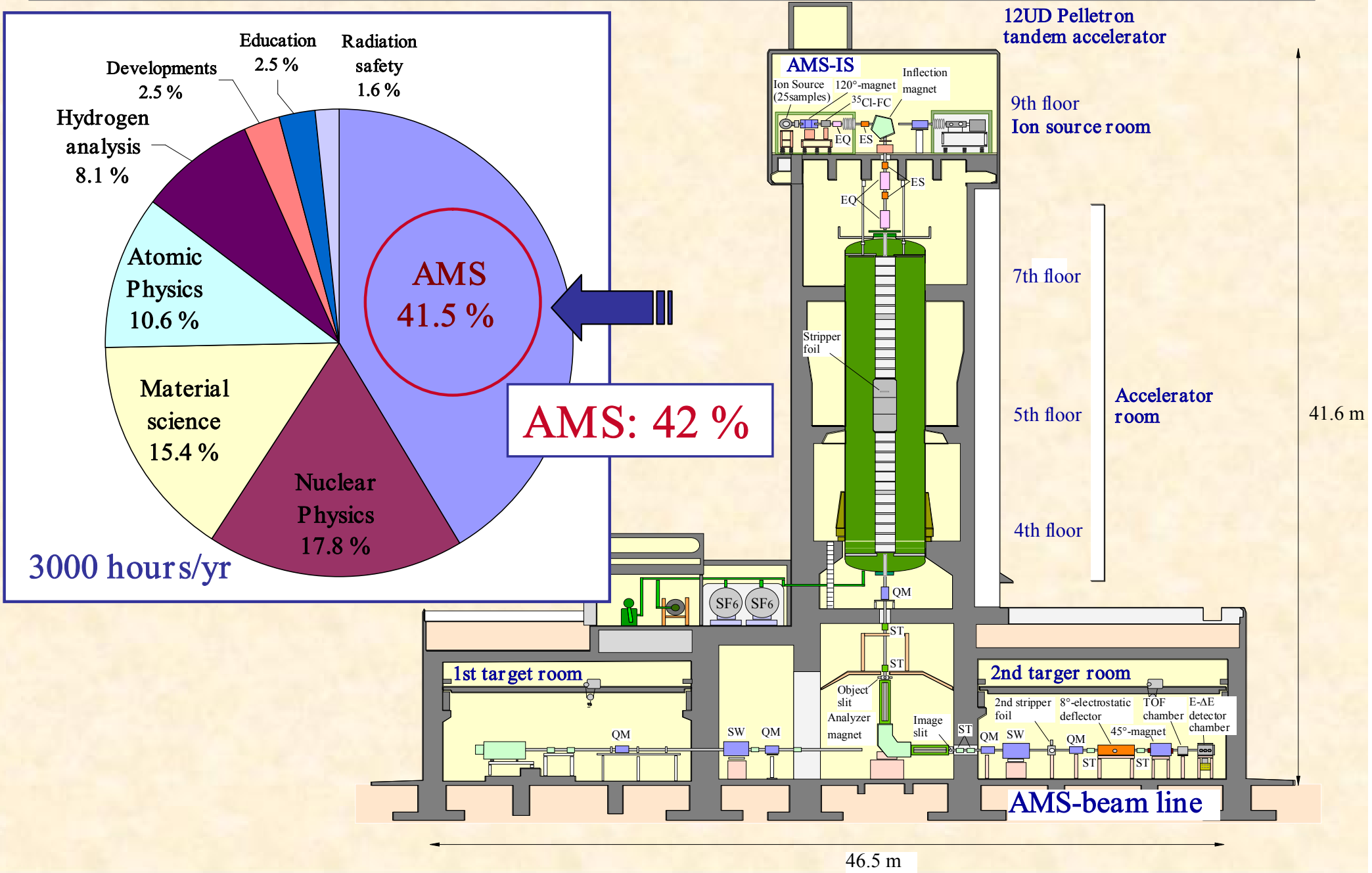

Upgrade of the 12UD Pelletron tandem

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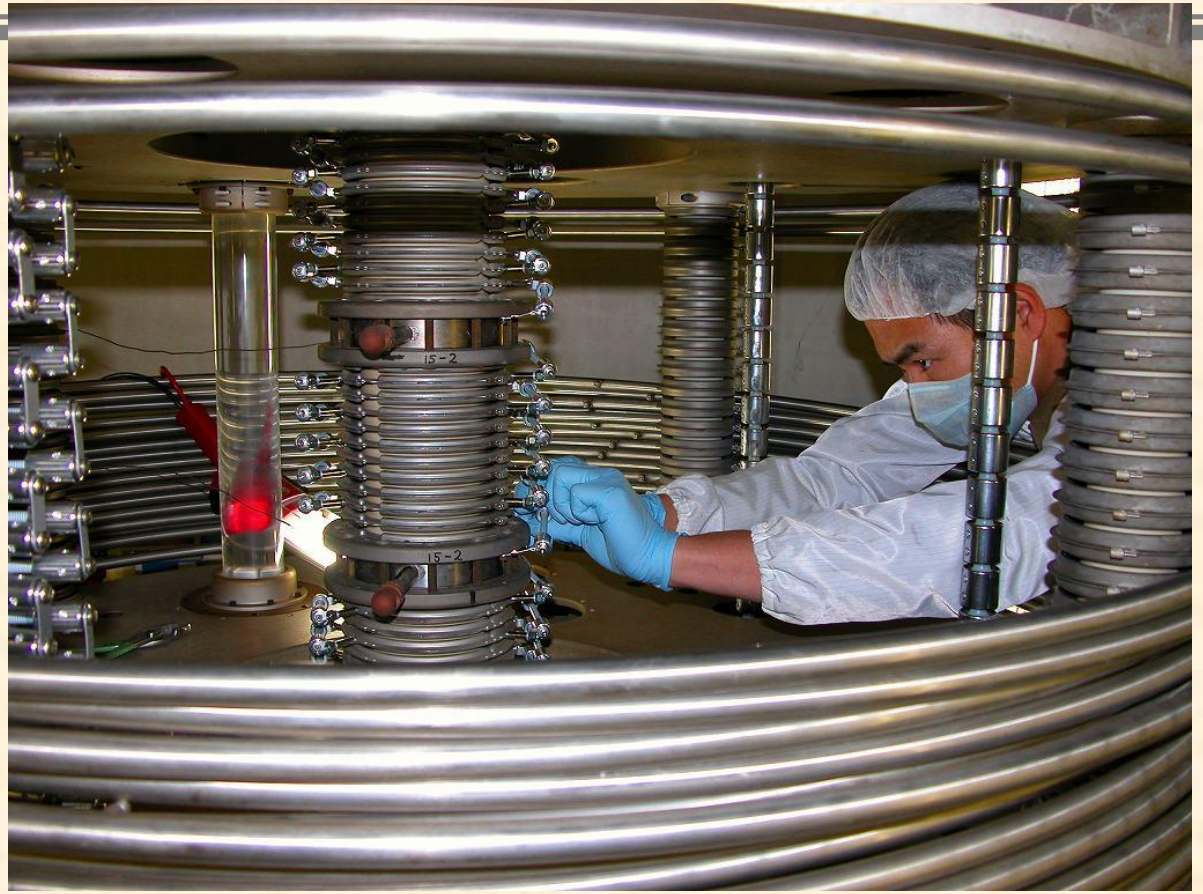

2009 Divided resistor system

We replaced the old corona needles with the divided resister system.

Variable terminal voltage
(No shorting column) ⇨ $V_t = 1 \sim 12$ MV

Accelerator Mass Spectrometry

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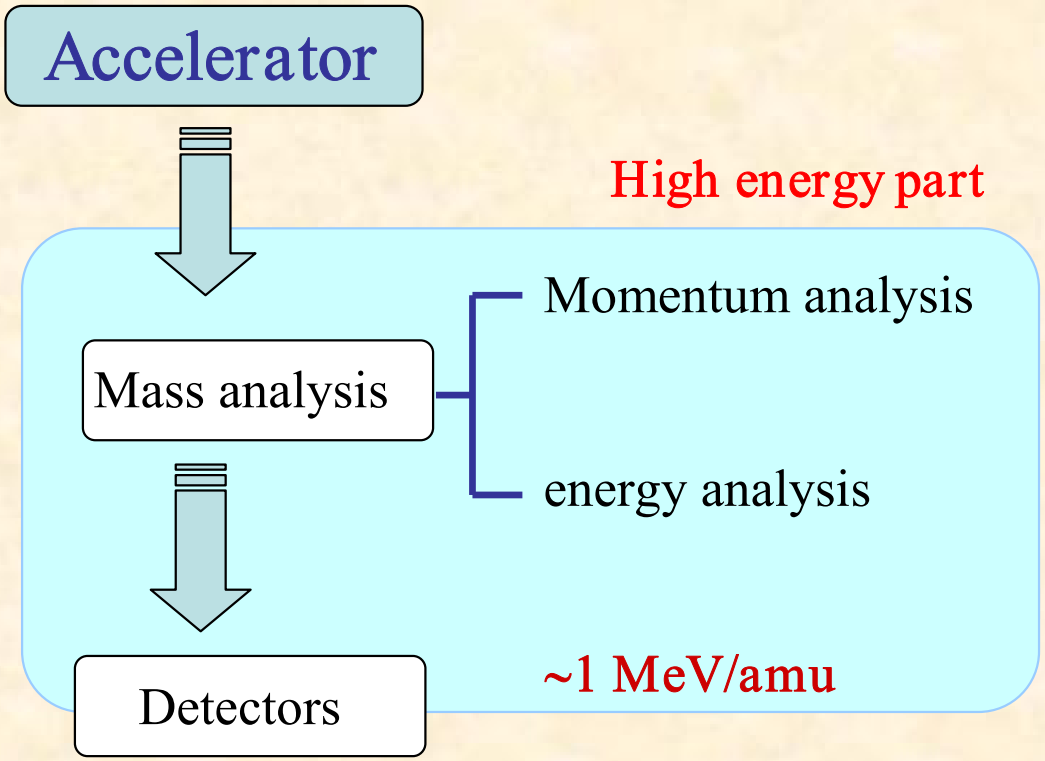
Targets of AMS

^{10}Be ($T_{1/2}$=1.36×10^6 yr)
^{14}C (5730 yr)
^{26}Al (7.1×10^5 yr)
^{36}Cl (3.0×10^5 yr)
^{129}I (1.57×10^7 yr)
...

→ Isobar, Isobaric Molecular suppression



Beam energy for the 12UD Pelletron

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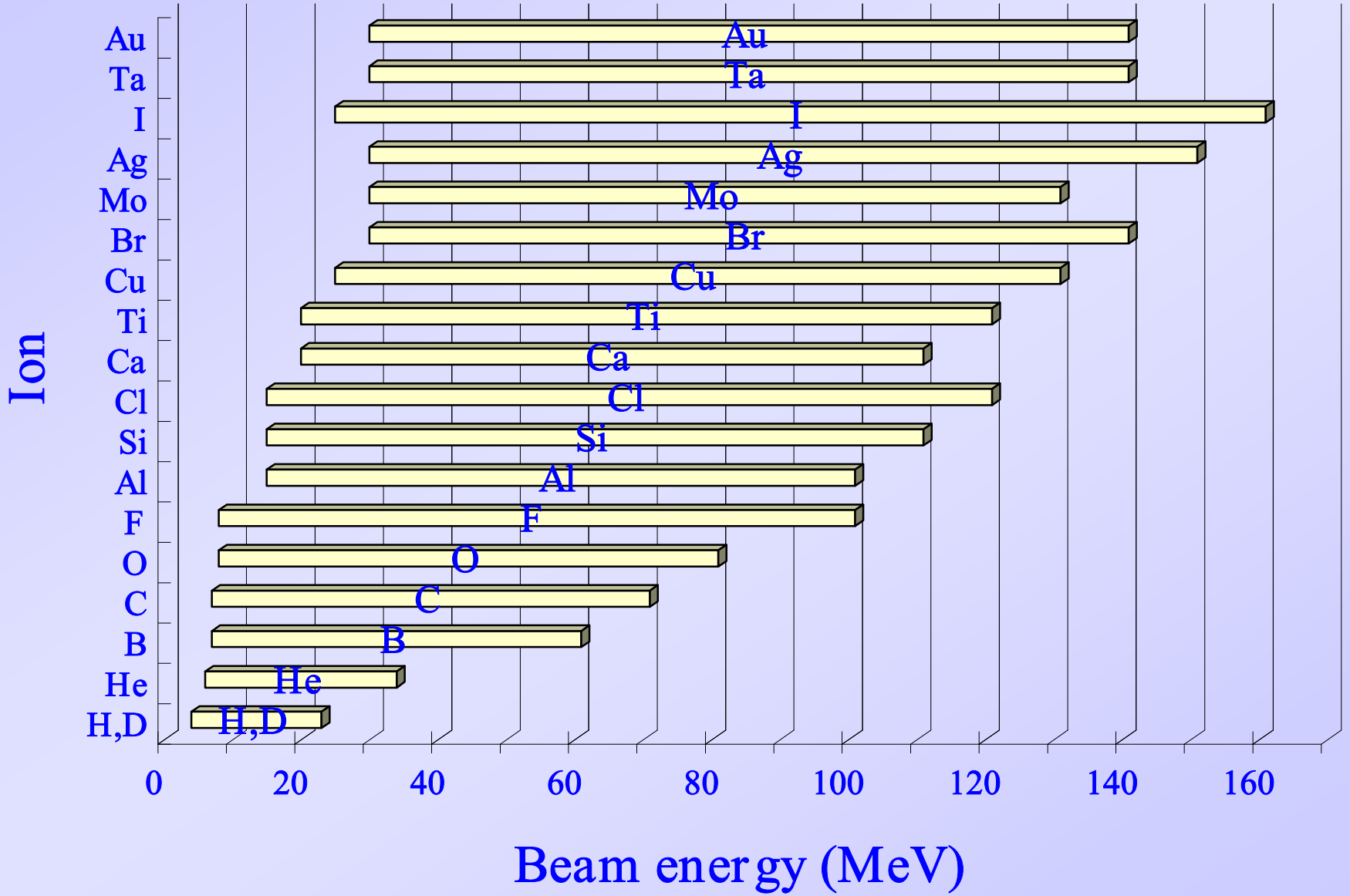
Terminal voltage: 1 - 12 MV



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- AMS on the 12UD Pelletron tandem
  - Description of the Tsukuba AMS system
  - Recent progress
  - Performance of ^{26}Al, ^{36}Cl and ^{129}I AMS

Tsukuba AMS system

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Progress of the Tsukuba AMS system

1993-1996	Trial AMS measurement for ^{14}C.
1996-1998	Development of AMS system
	^{14}C-AMS
	AMS ion source (original)
	Mass separator beam line
1999-	Development of ^{26}Al, ^{36}Cl-AMS
	Pilot beam methods (Instead of GVM control)
2002-	Development of ^{129}I-AMS
2007-	^{36}Cl AMS 9 MV→10 MV (Improved beam line)
	Background: $^{36}Cl/Cl < 1 \times 10^{-15}$
	Repetition accuracy: ± 3 %
2009-	Upgrade of the 12UD Pelletron (Resister system)
	⇨ GVM terminal control system

Tsukuba AMS system

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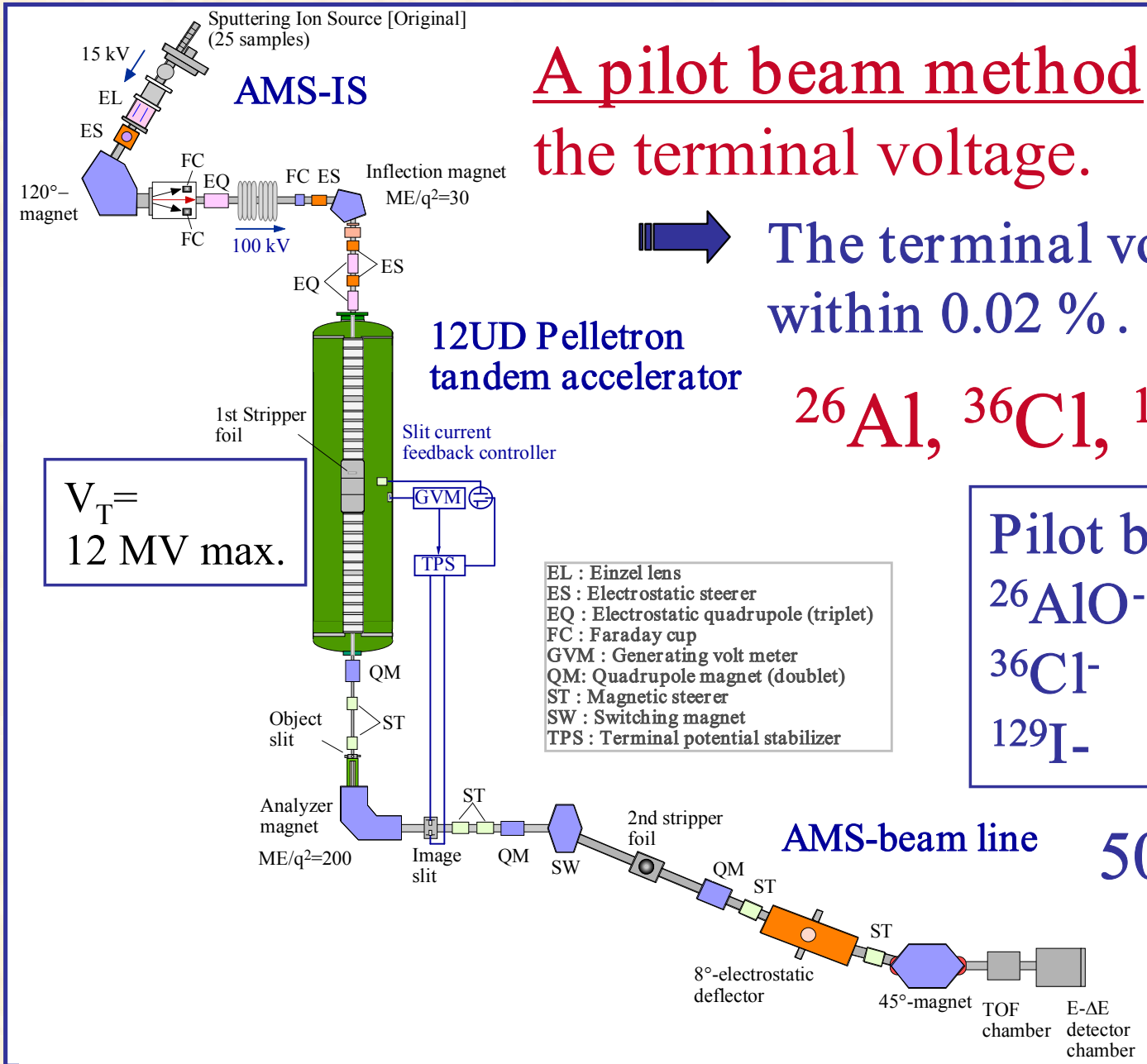

V_T=
12 MV max.

EL : Einzel lens
ES : Electrostatic steerer
EQ : Electrostatic quadrupole (triplet)
FC : Faraday cup
GVM : Generating volt meter
QM: Quadrupole magnet (doublet)
ST : Magnetic steerer
SW : Switching magnet
TPS : Terminal potential stabilizer

AMS-beam line

<u>A pilot beam method</u> is used to stabilize the terminal voltage.

➡ The terminal voltage is kept stable within 0.02 %.

^{26}Al, ^{36}Cl, ^{129}I - AMS

Pilot beams (isobar)

$^{26}AlO^- \rightarrow {}^{26}MgO^-$

$^{36}Cl^- \rightarrow {}^{12}C_3^-$

$^{129}I^- \rightarrow {}^{97}MoO_2^-$

500 samples/year.

^{36}Cl-AMS by the Tsukuba AMS system

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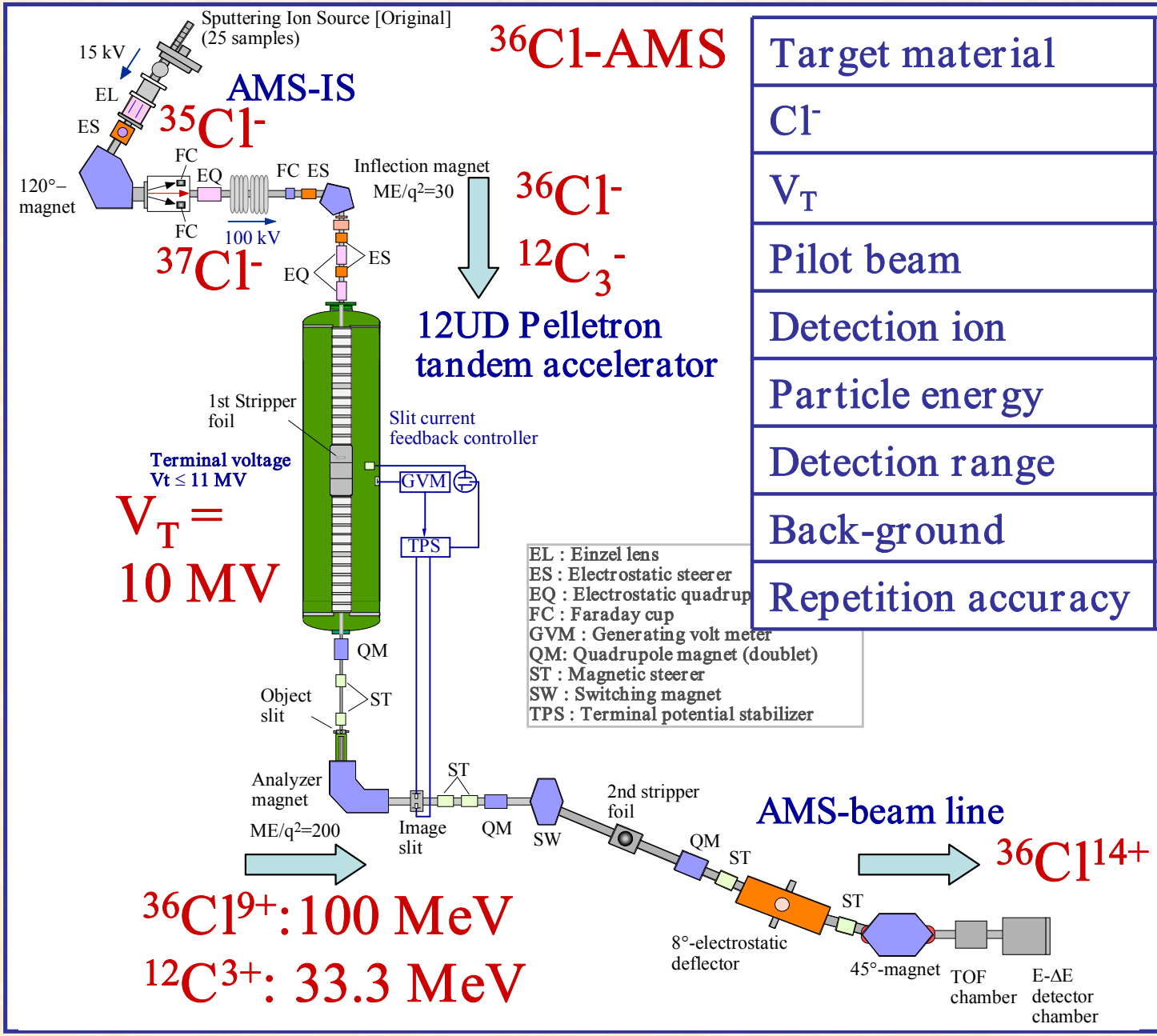

Target material	AgCl + C_{60}
Cl^-	~ 20 mA
V_T	10 MV
Pilot beam	$^{12}C_3^-$
Detection ion	$^{36}Cl^{14+}$
Particle energy	100 MeV
Detection range	$^{36}Cl/Cl = 10^{-10} \sim 10^{-14}$
Back-ground	$^{36}Cl/Cl < 10^{-15}$
Repetition accuracy	± 3 % ($^{36}Cl/Cl \sim 10^{-12}$)

AMS Cs sputtering ion source

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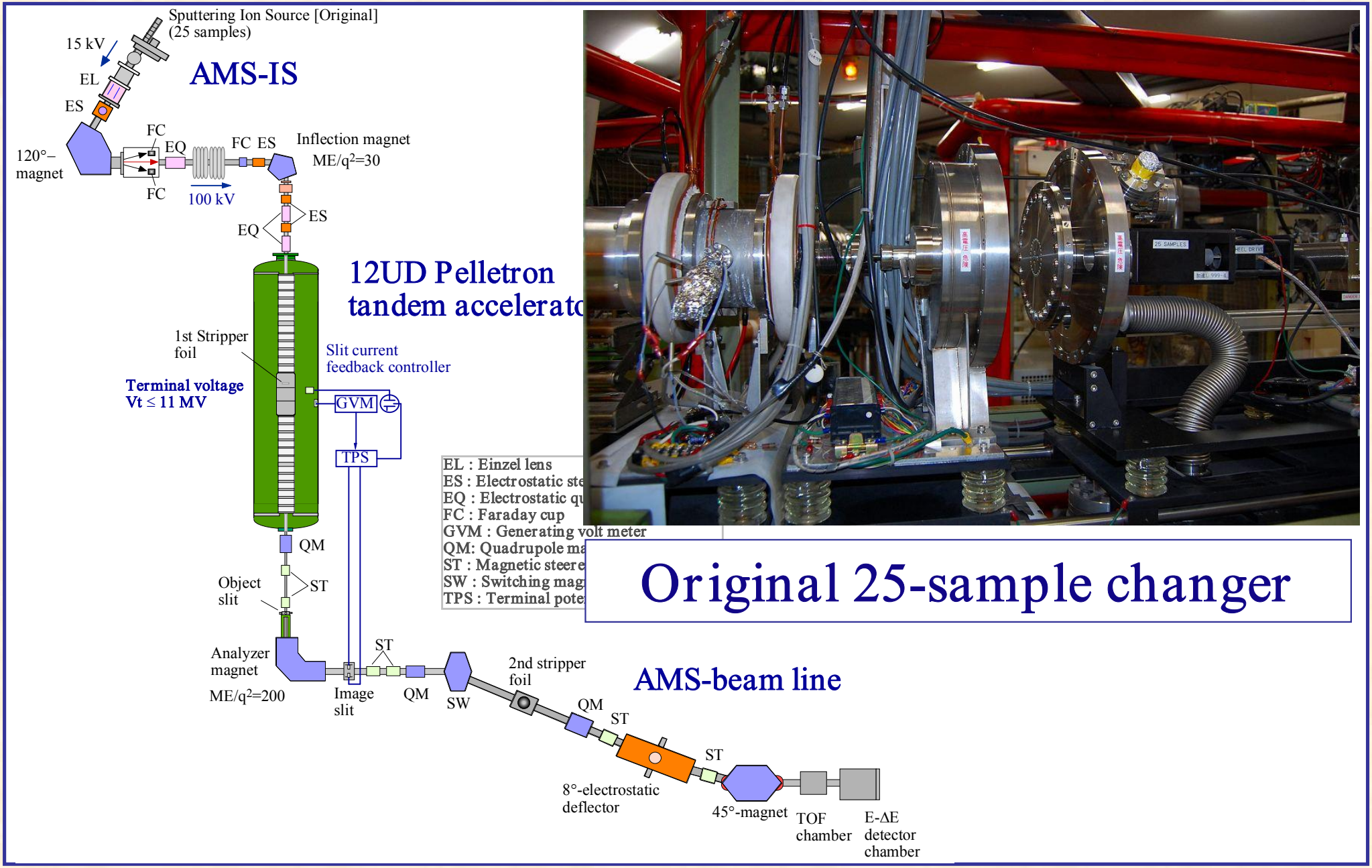
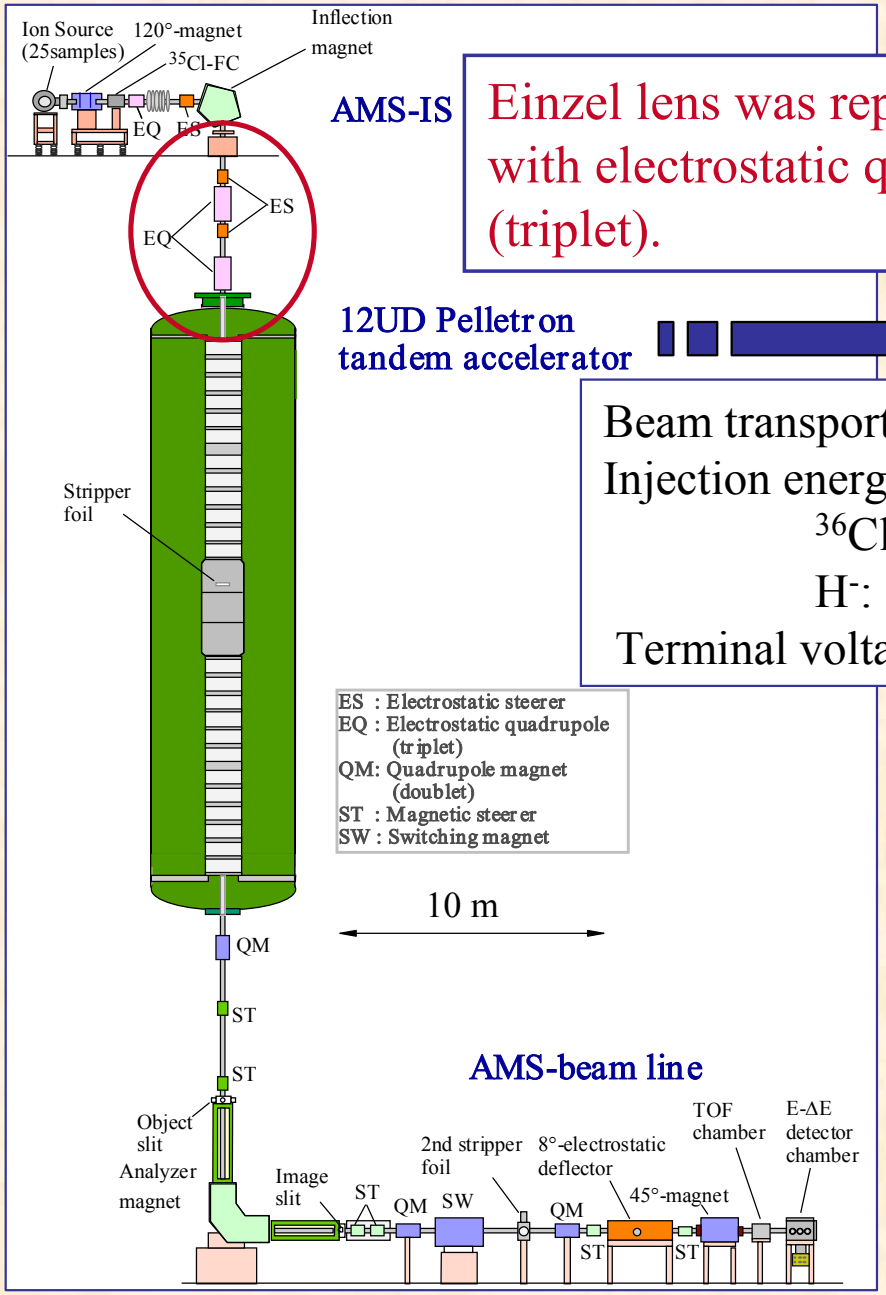


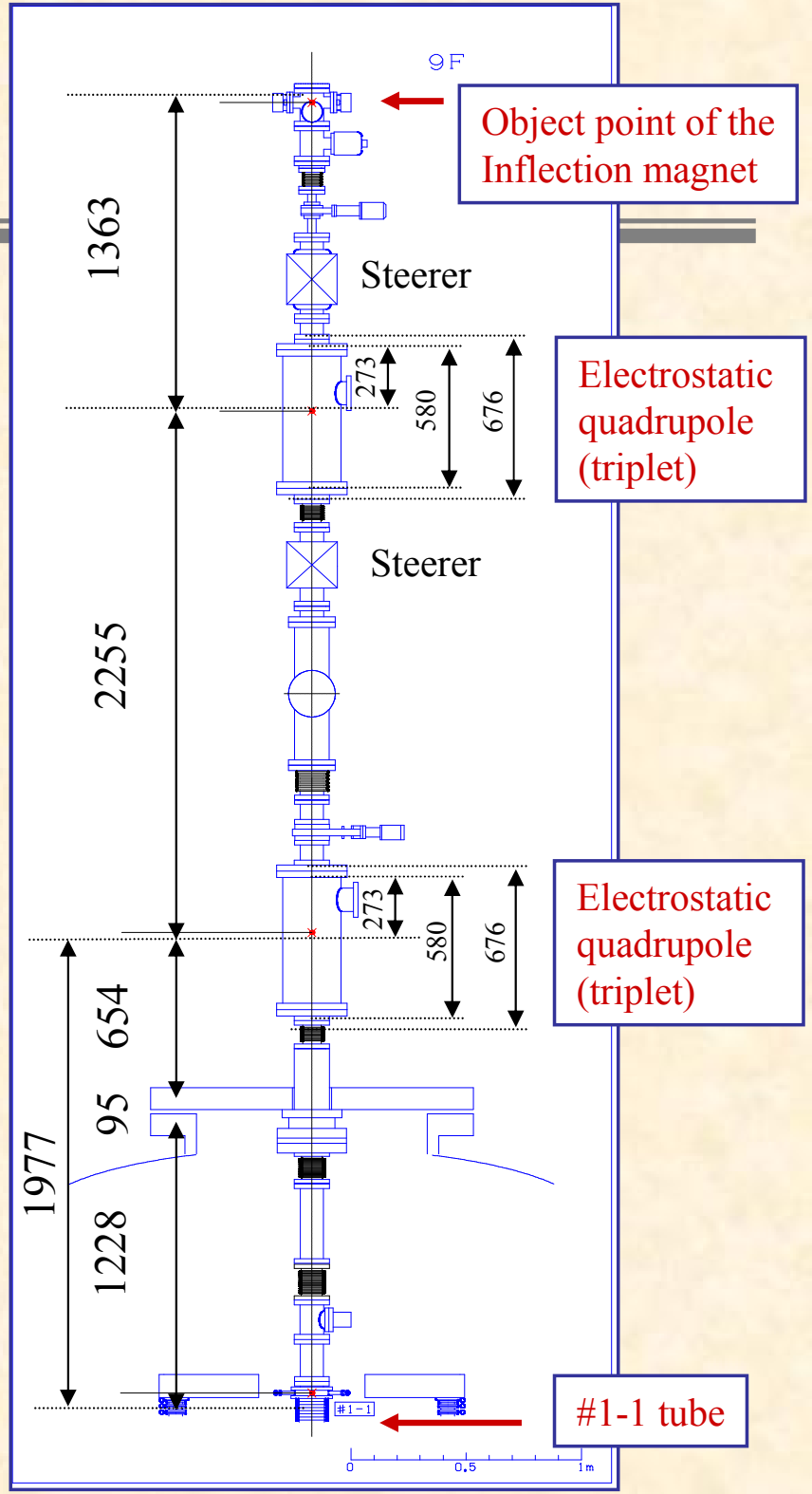
Original 25-sample changer

Upgrade of LEBT for 12UD Pelletron tandem accelerator



Einzel lens was replaced with electrostatic quadrupole (triplet).

Beam transport
Injection energy
$^{36}Cl^-$: 103 kV
H^-: 120 kV
Terminal voltage: 10 MV



Tsukuba 12UD first unit (2009)

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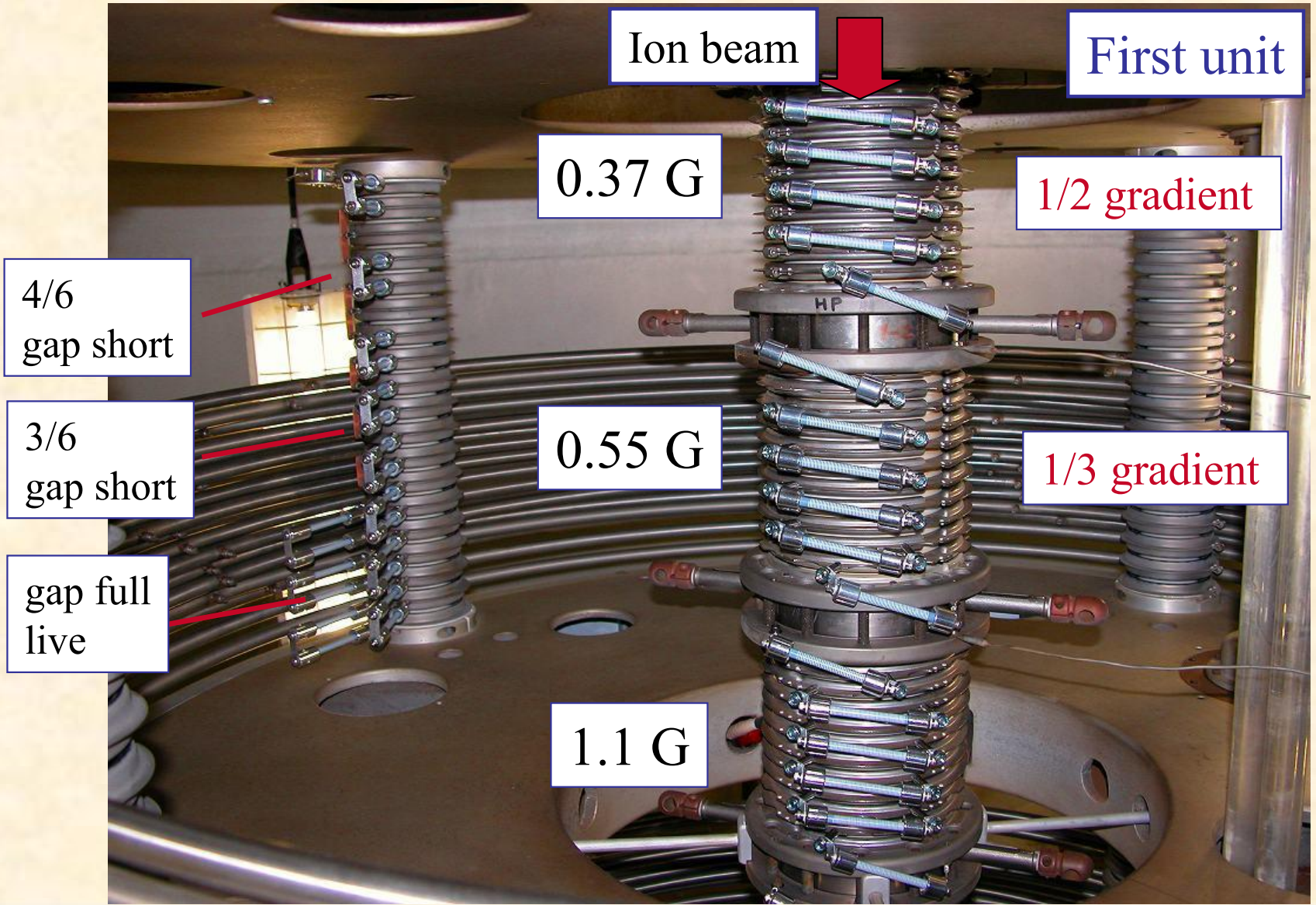
Lower resistance at the entrance.

Adjustment for the focusing effect



Terminal section (Charge exchange)

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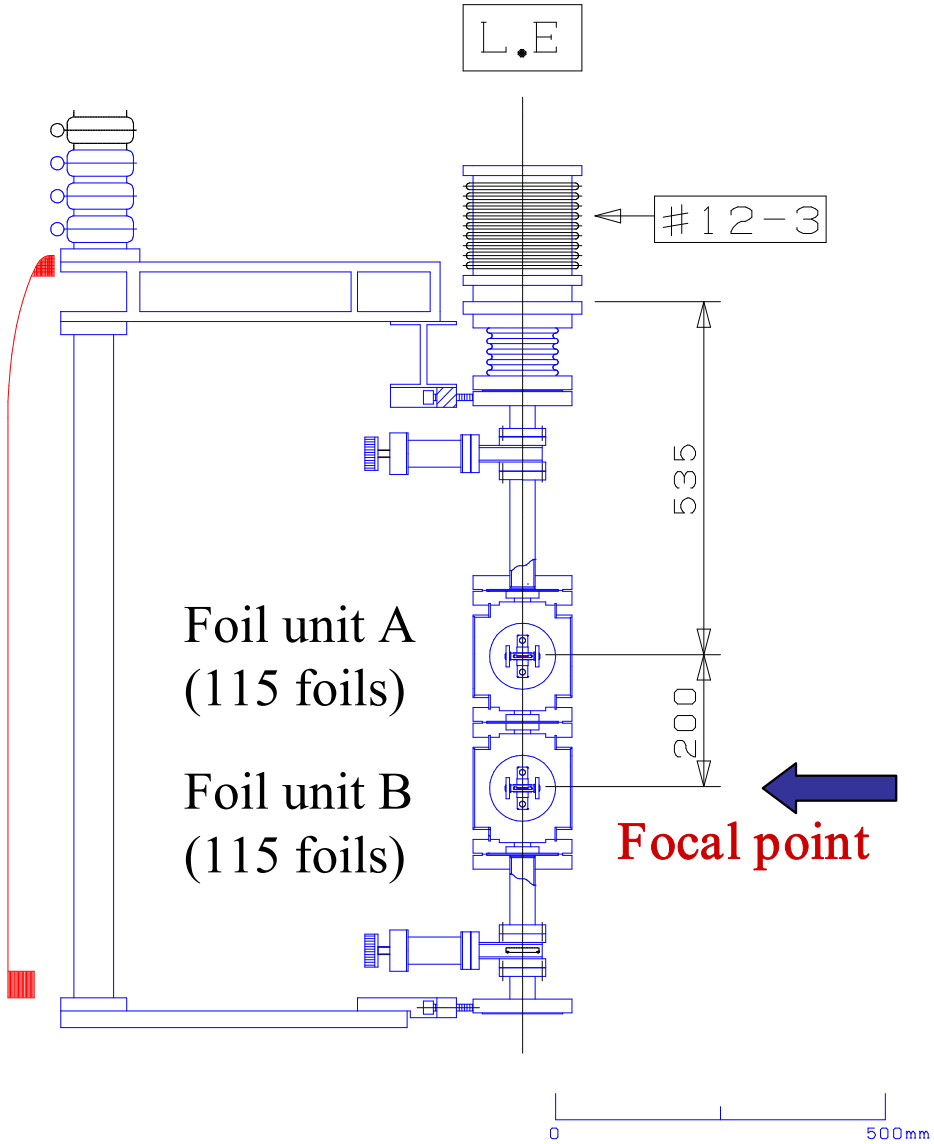
Terminal section was modified to the large aperture canal (ϕ20) in 2004.

Carbon foil for AMS: 5 mg/cm^2



Mass separator beam line

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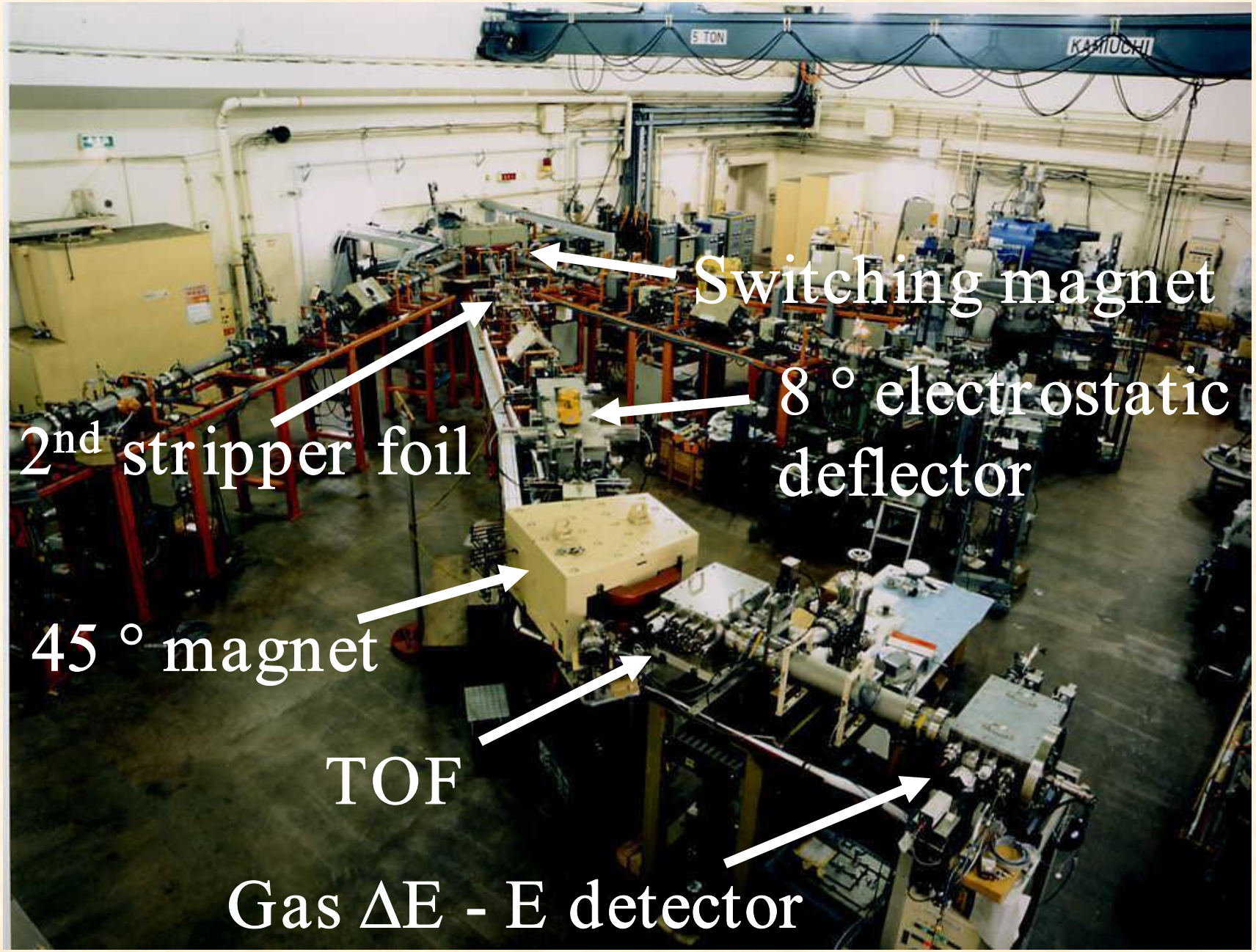

Gas E-ΔE detector

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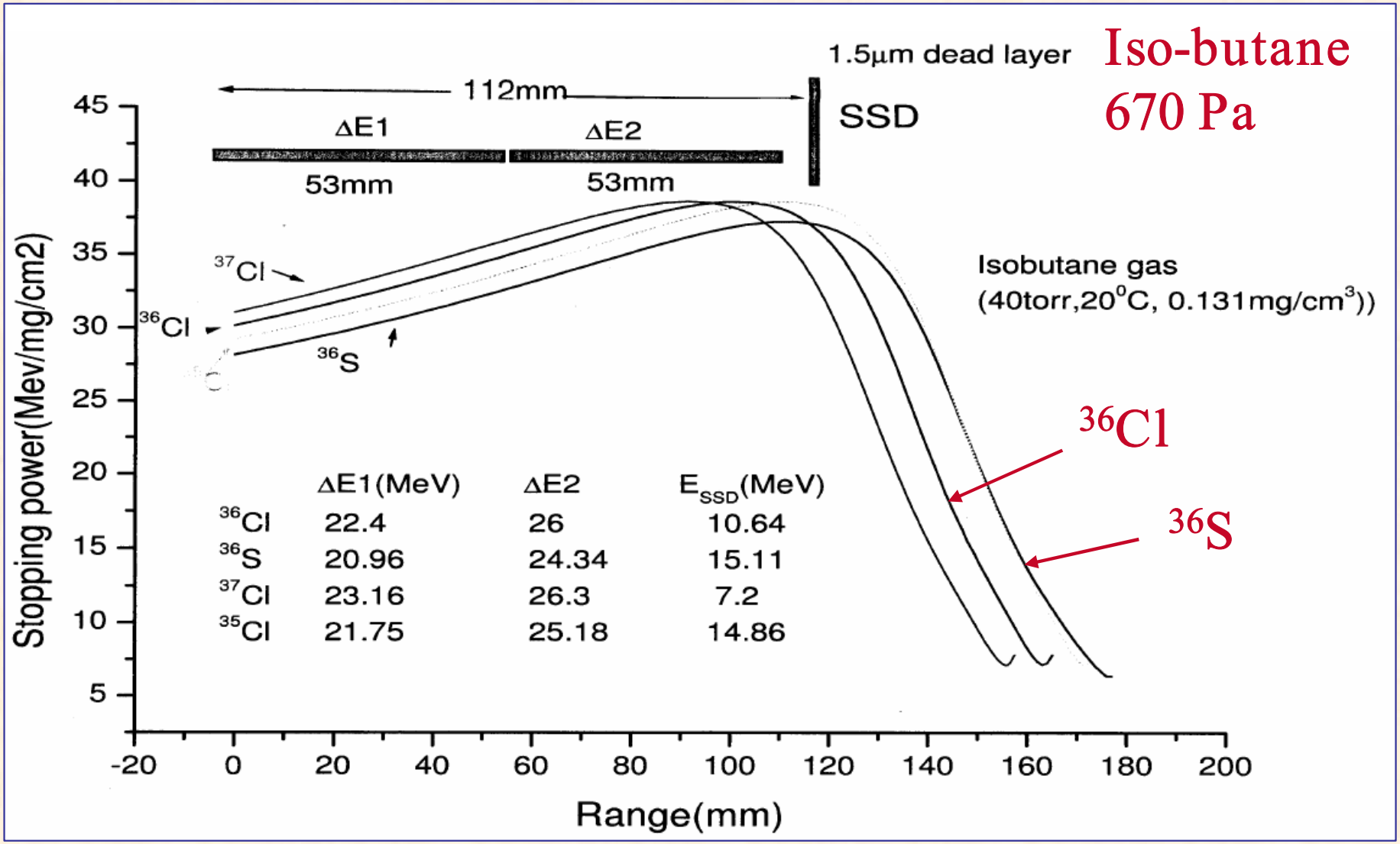

	ΔE1(MeV)	ΔE2	E_{SSD}(MeV)
^{36}Cl	22.4	26	10.64
^{36}S	20.96	24.34	15.11
^{37}Cl	23.16	26.3	7.2
^{35}Cl	21.75	25.18	14.86

100 MeV ^{36}Cl in the gas detector.

^{36}Cl-AMS (2-dimensional spectrum)

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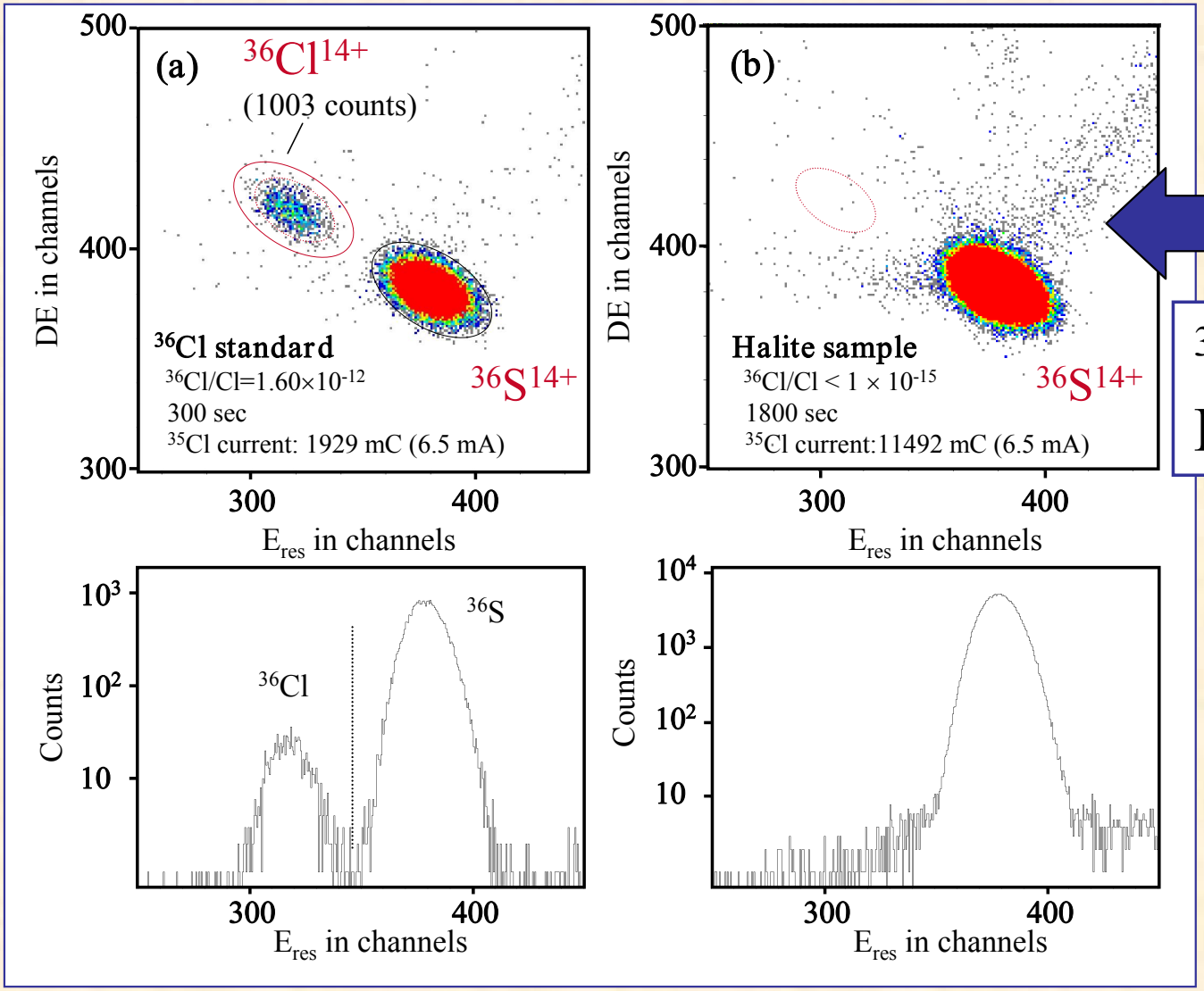

^{36}Cl/Cl
Background: ~ 1 × 10^{-15}

Standard sample
^{36}Cl/Cl=1.60 × 10^{-12}

Blank sample

^{26}Al-AMS (2-dimensional spectrum)

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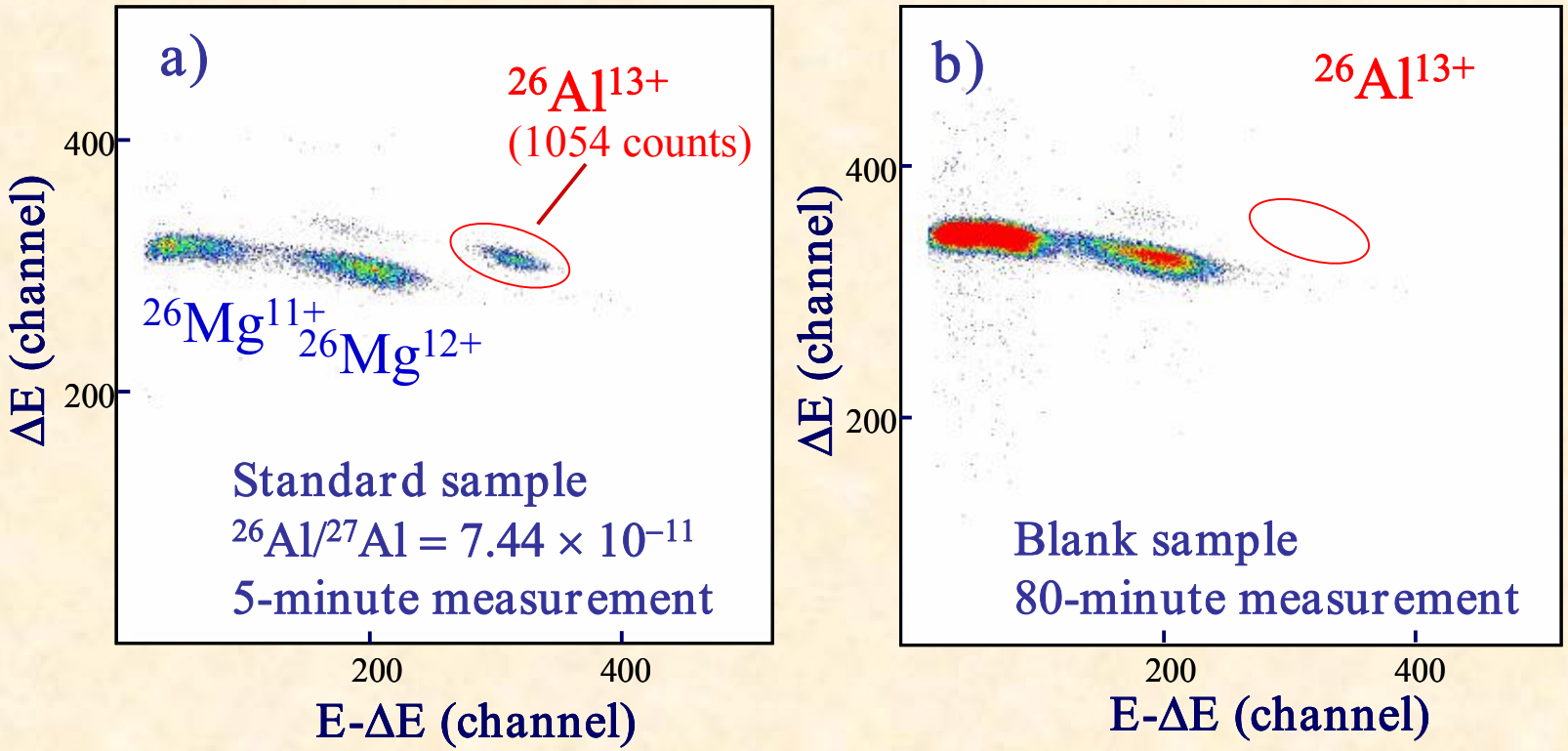

-Full stripping technique
- Pilot beam: $^{26}MgO^-$
- Beam current of AlO^- from Al_2O_3 sample : ~1.5 mA

- ^{26}Al is very clearly separated from ^{26}Mg.
- Background of the ^{26}Al-AMS: $< 1 \times 10^{-15}$.

Performance of the Tsukuba AMS system

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A pilot beam method is used to stabilize the terminal voltage.

^{26}Al-AMS

Target material	V_T	Injection ion	Pilot beam	Detection ion	Particle energy	Back-ground
Al_2O_3+$^{26}MgO_2$+Ag	10.2 MV	$^{26}AlO^-$	$^{26}MgO^-$	$^{26}Al^{13+}$	78 MeV	$< 1 \times 10^{-15}$

^{36}Cl-AMS

Target material	V_T	Injection ion	Pilot beam	Detection ion	Particle energy	Back-ground
AgCl+C_{60}	10 MV	$^{36}Cl^-$	$^{12}C_3^-$	$^{36}Cl^{14+}$	100 MeV	$<1 \times 10^{-15}$

^{129}I-AMS

Target material	V_T	Injection ion	Pilot beam	Detection ion	Particle energy	Back-ground
AgI+MoO_2+Nb	9.7 MV	$^{129}I^-$	$^{97}MoO_2^-$	$^{129}I^{26+}$	126 MeV	$< 1 \times 10^{-13}$

Applications by the Tsukuba AMS system

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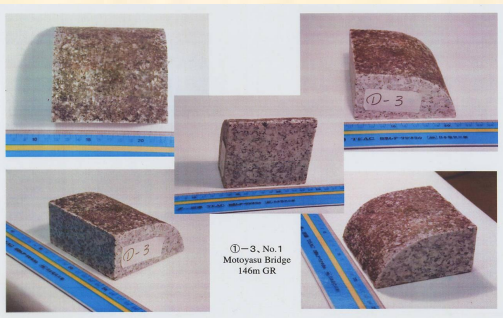
Mainly for earth and environmental sciences.

Nuclear safety research Atomic bomb, neutron fluence	Soil sediment	Rock meteorite	Groundwater, rain, ice	Biological sample



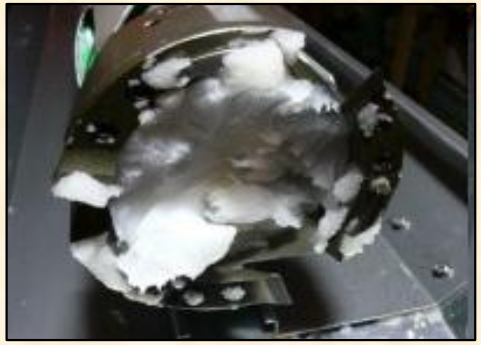
Hiroshima A-bomb sample

Soil

Limestone

Meteorite

Rain water



Ice core

Human hair

Summary and future plans

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- 12UD Pelletron tandem at the University of Tsukuba

  We have upgraded the 12UD Pelletron tandem.

  ⇒ LEBT, divided resister system, terminal stripper.

  The beam time for AMS research has increased to about 42% of the total operation time.

- Tsukuba AMS system

  We are able to measure long-lived radioisotopes of ^{26}Al, ^{36}Cl and ^{129}I by employing a molecular pilot beam method that stabilize the terminal voltage with 0.02% accuracy.

  ⇒ Main research fields are earth and environmental sciences.

Future plans

- GVM control system
- New injection beam line (MC-SNICS)

Thank you for your kind attention.