

April 7, 2013
Sugimoto-Sensei Symp., Machikaneyama

High Intensity Beam Handling for Nuclear and Particle Physics

Kazuhiro TANAKA



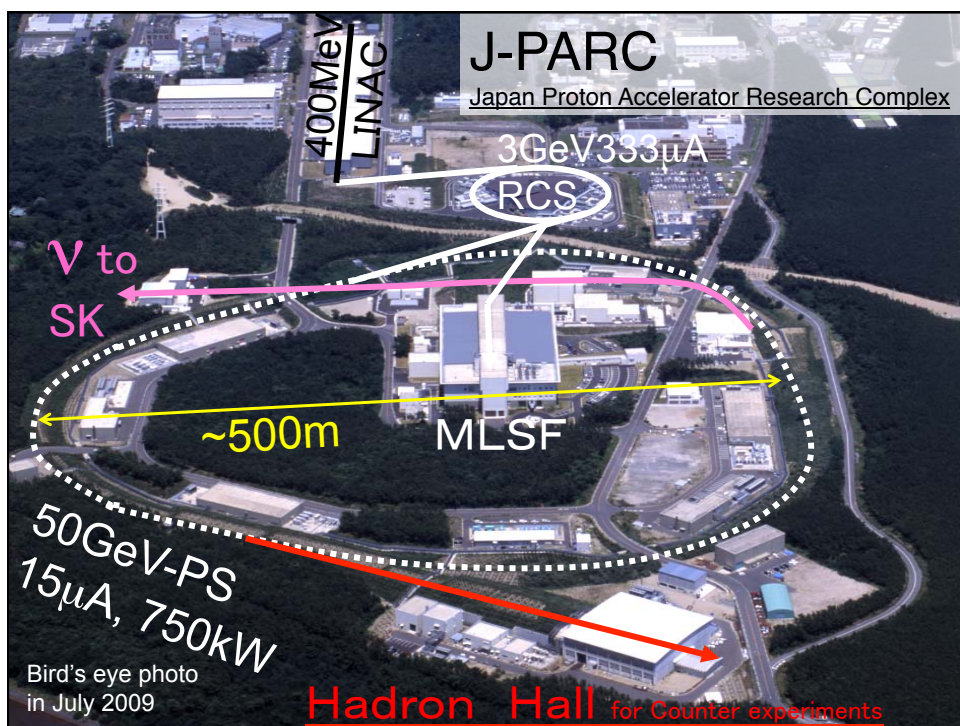
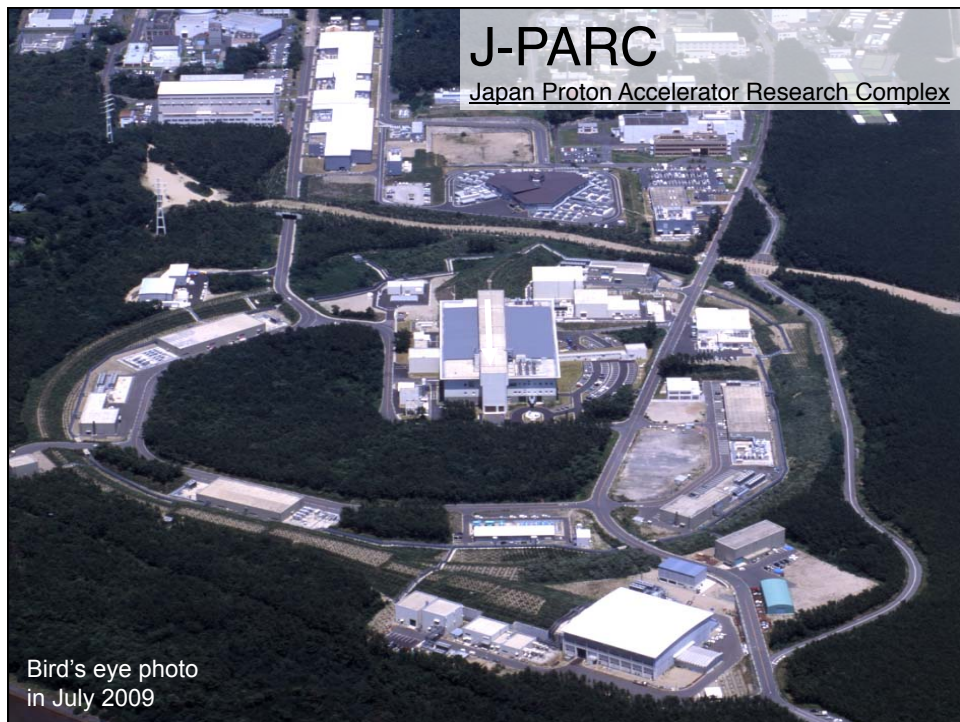
Particle and Nuclear Physics Division,
J-PARC Center,



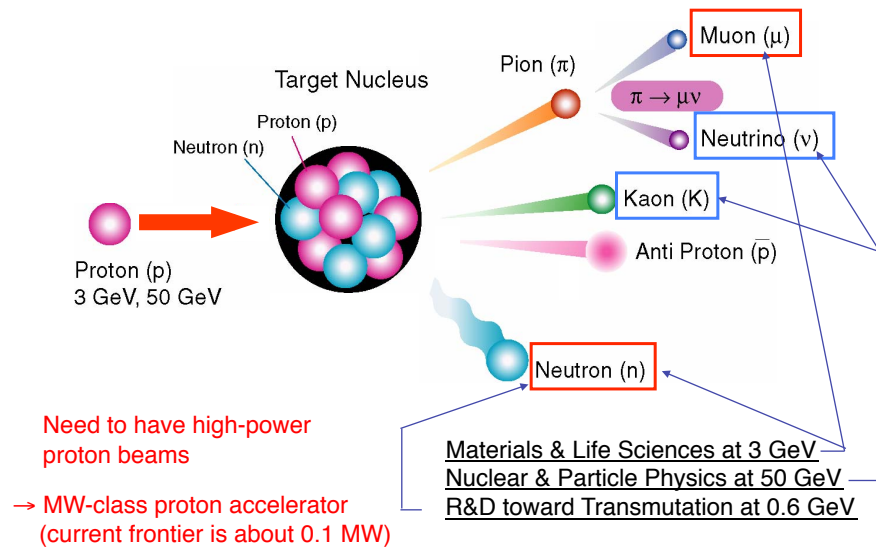
Institute of Particle and Nuclear Studies,
KEK: High Energy Accelerator
Research Organization,

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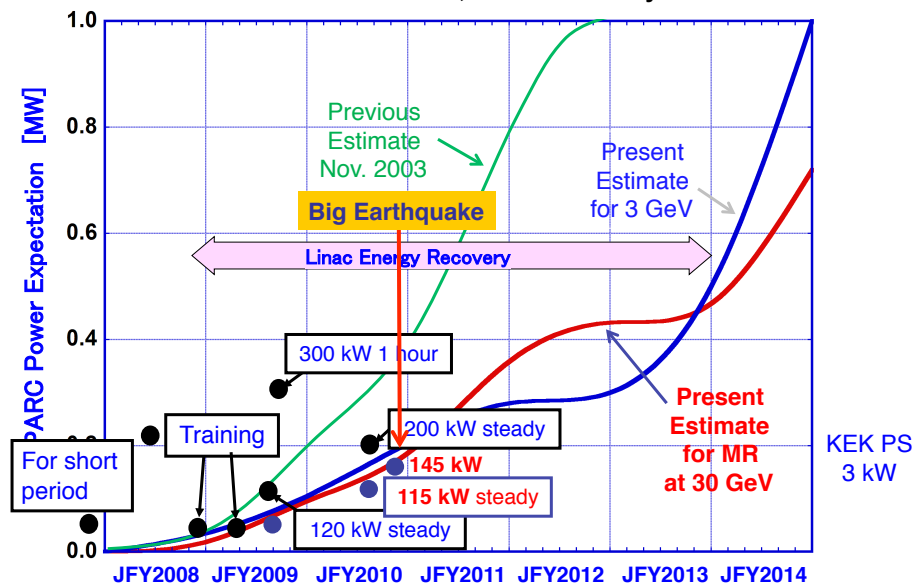


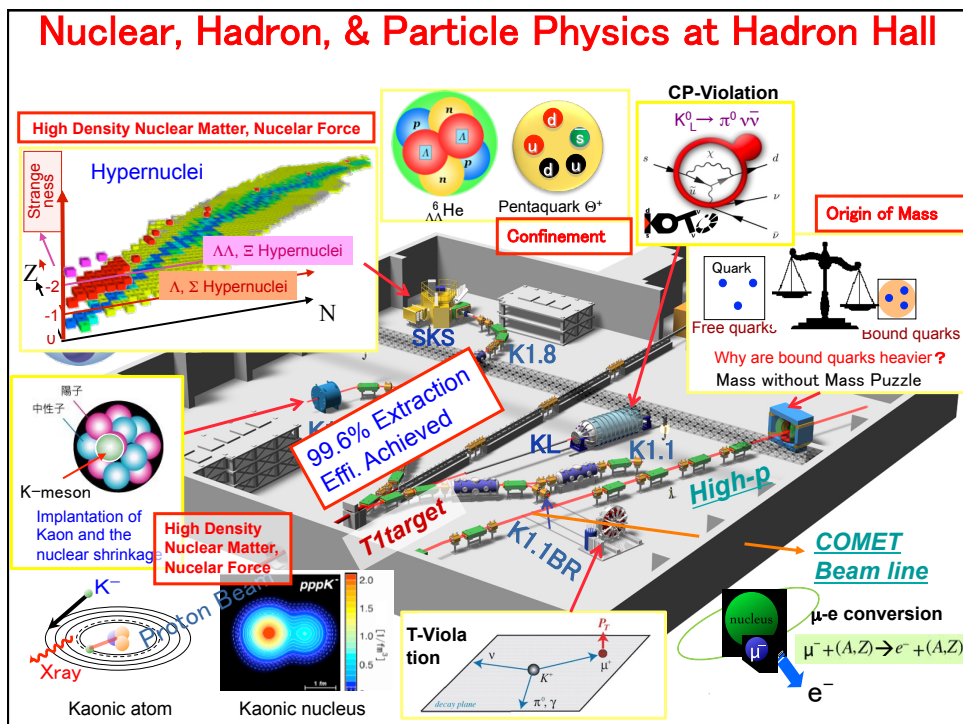
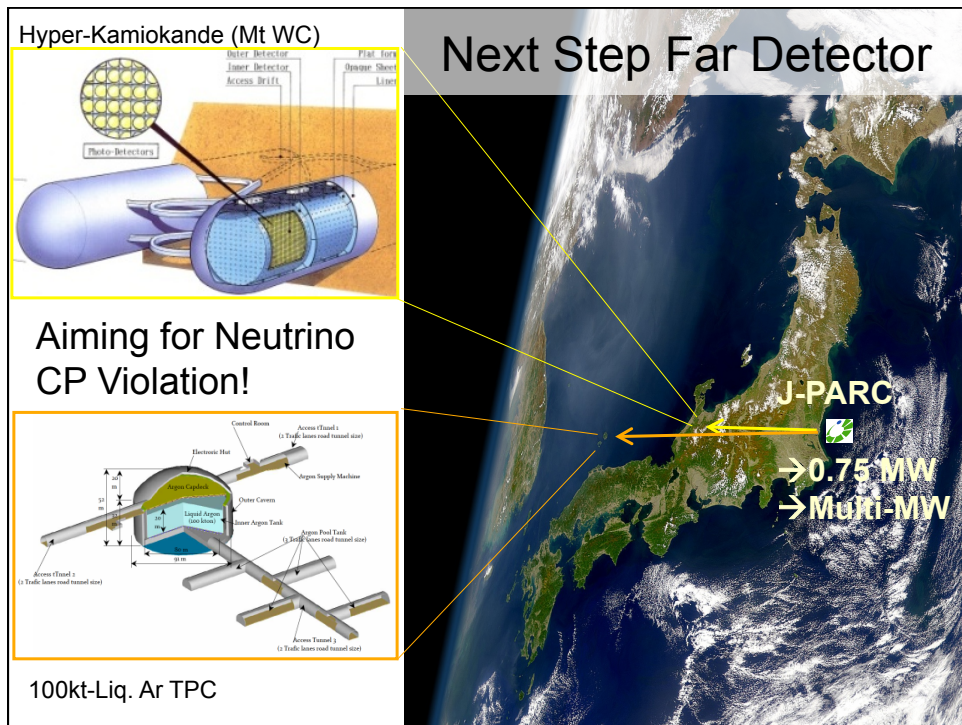
Goals at J-PARC

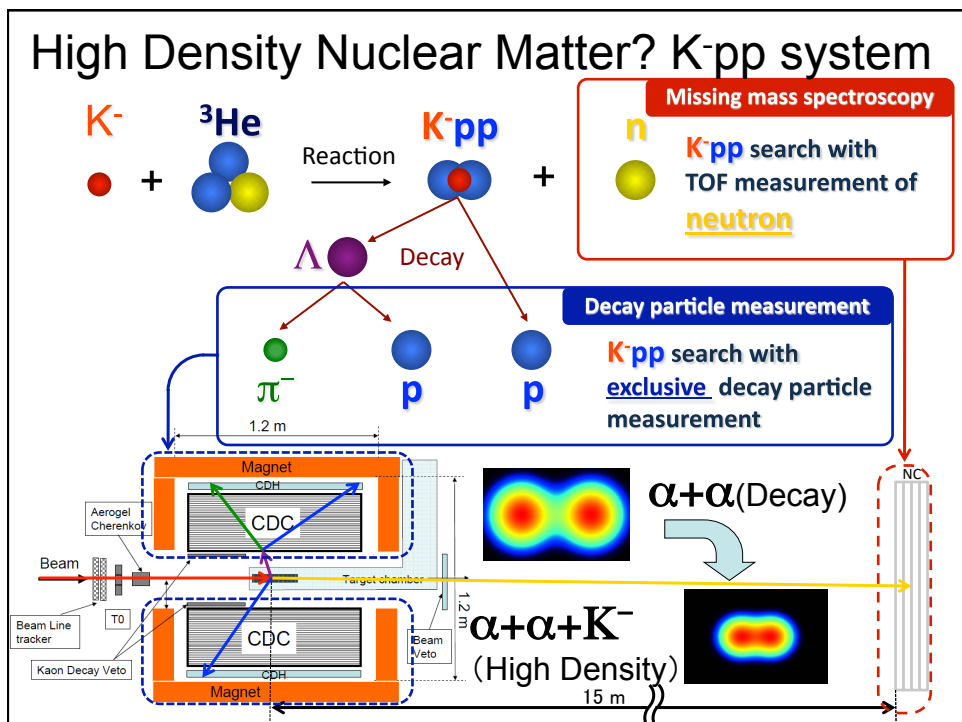


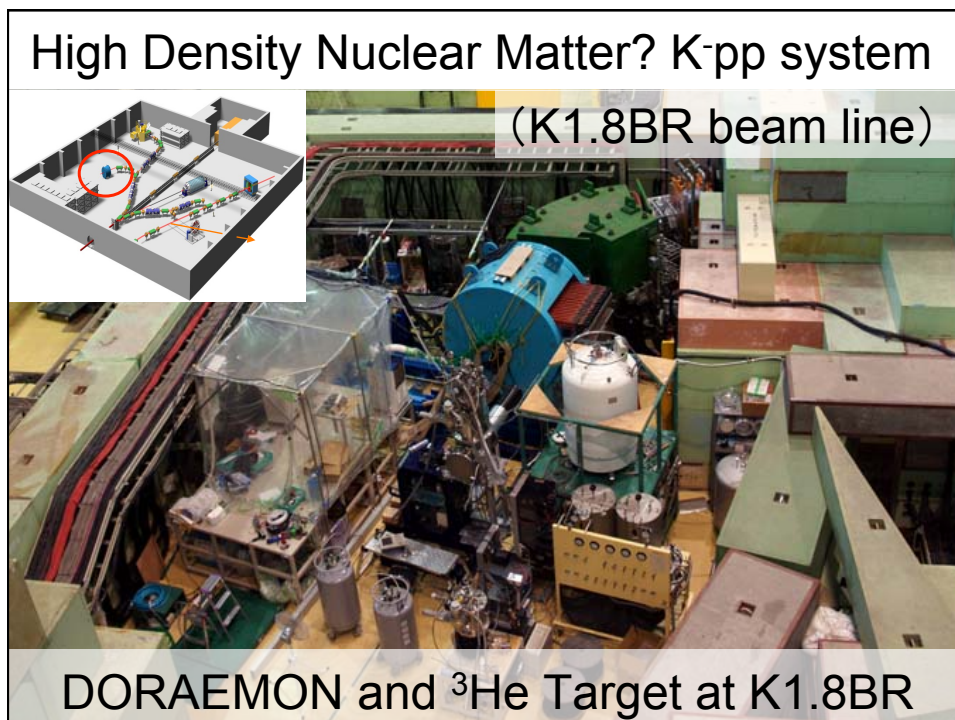
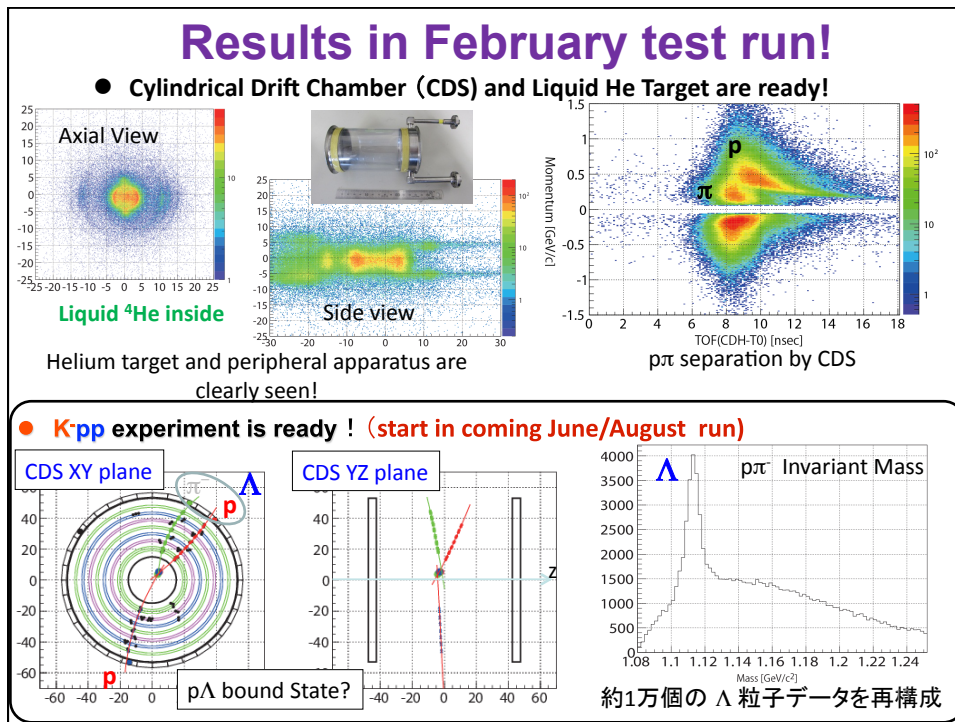
Power Capability of J-PARC

Slow Extraction; 99.6% efficiency for 5kW was achieved!



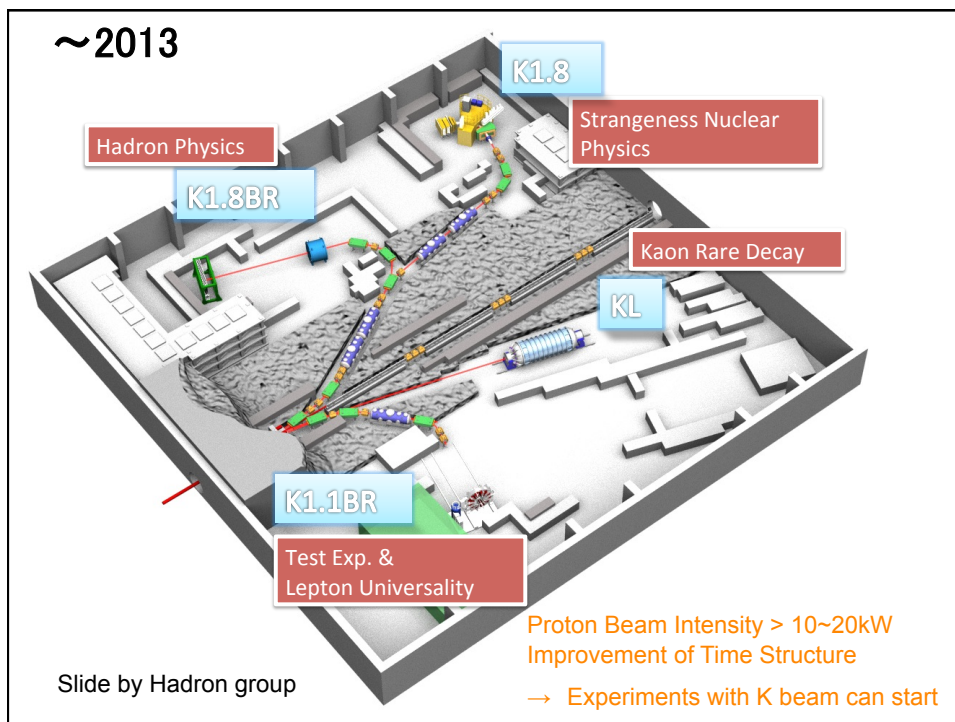


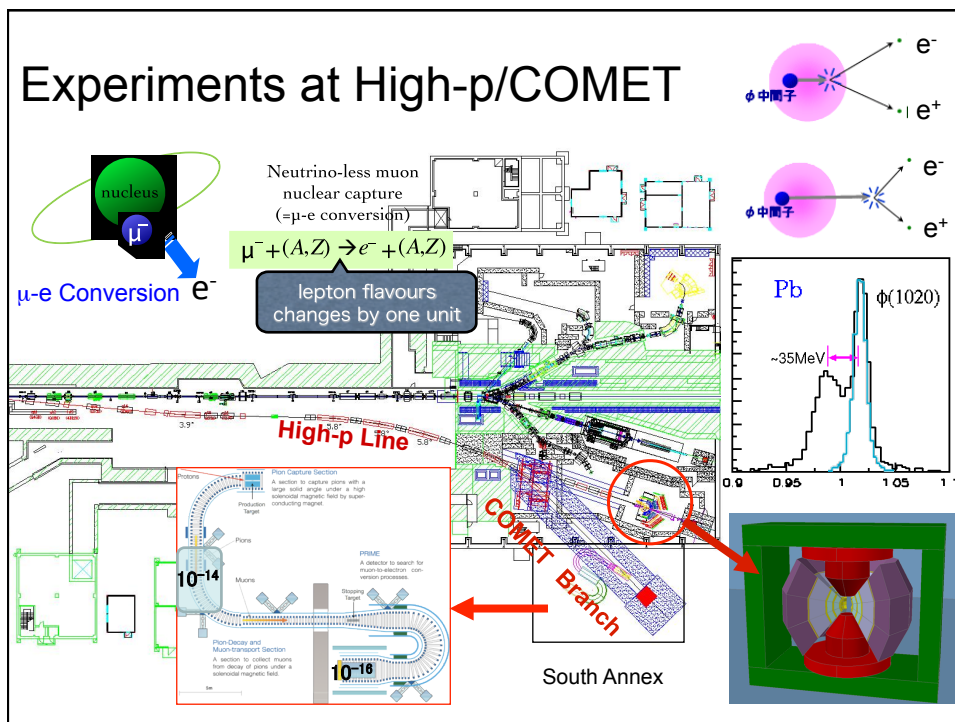
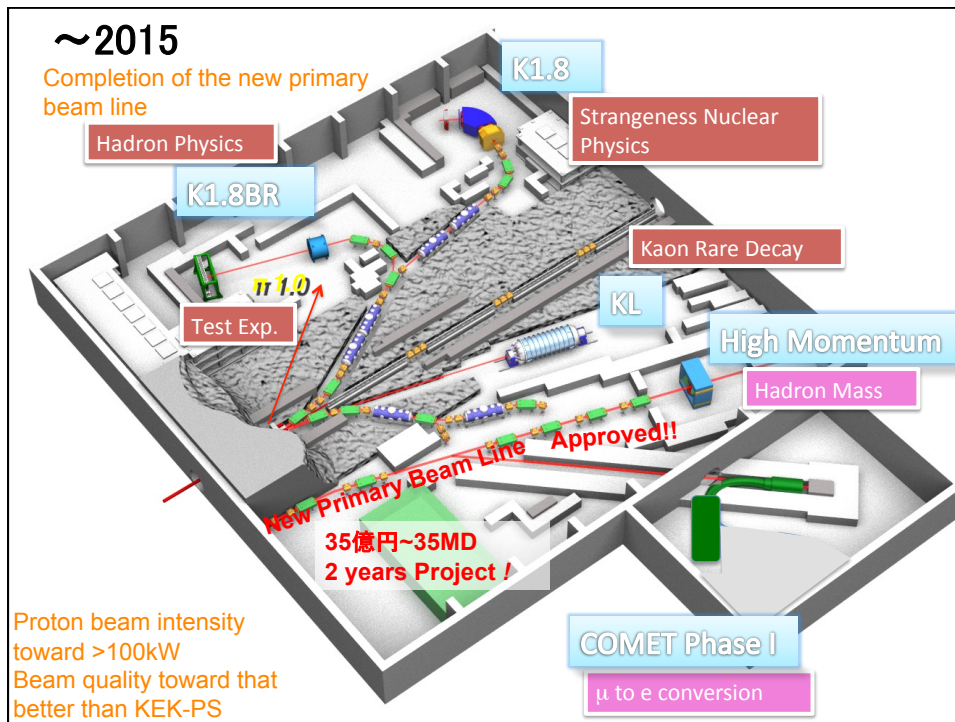




Big News in January 2013!

- Japanese Government approved the construction of New Primary Proton Beam Line!
- Then **High-p/COMET** beam will be ready in mid 2015.





High Intensity Beam Handling

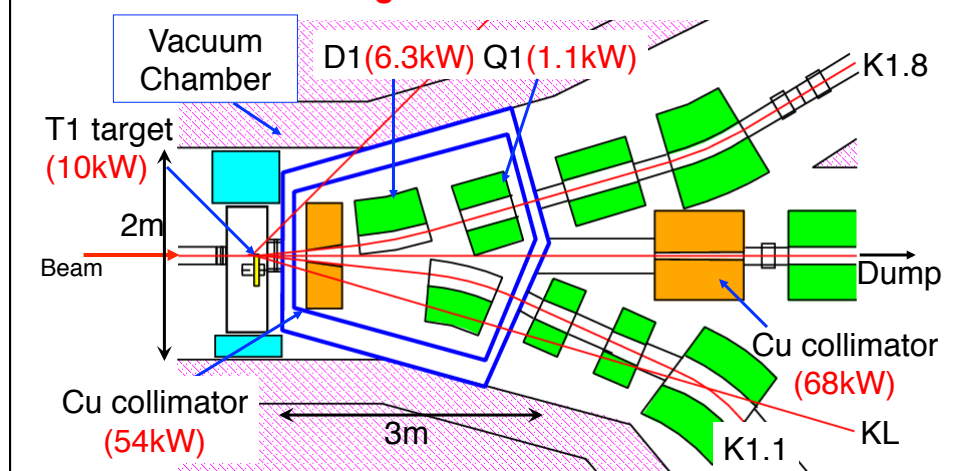
21

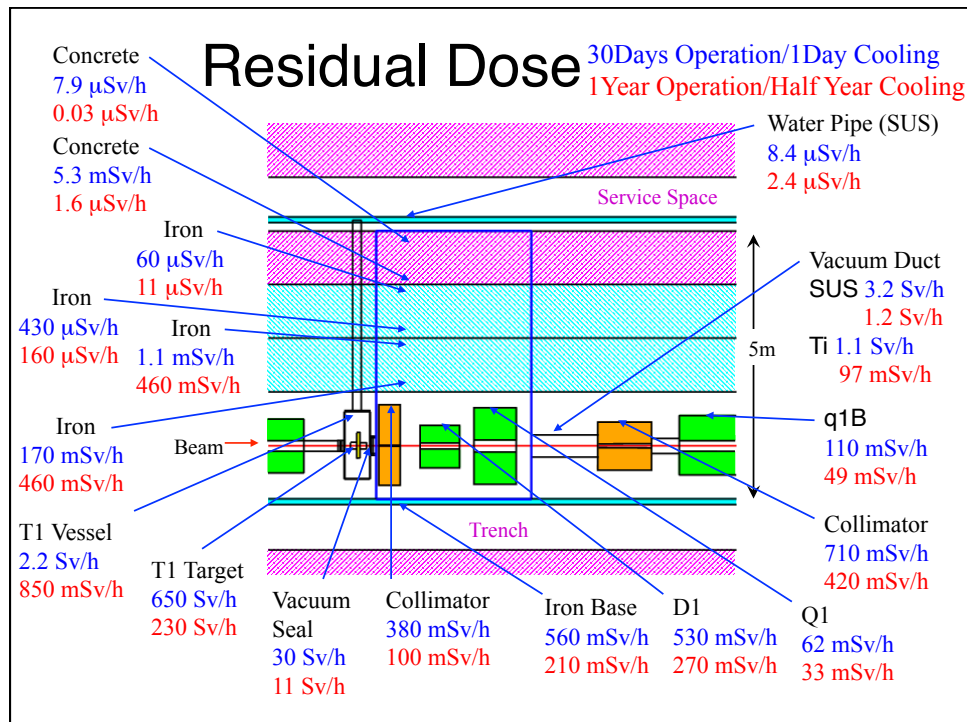
Downstream of T1 Target

How to solve 200kW Heat Problem?

Magnets → **Upstream Collimator**

Beam Ducts → **Big Vacuum Chamber instead of Ducts**





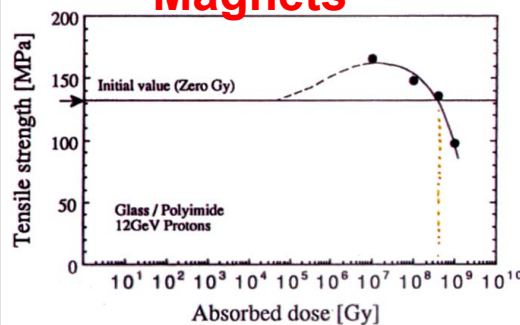
High Intensity Beam Handling

- Magnets etc. should be radiation/heat resistant.
- Magnets etc. should be replaced easily and quickly.
- High Intensity Handling should be considered as a system.
 - Power/water lines,
 - Vacuum line,
 - Daily operation/maintenance,
 - Radiation shields,

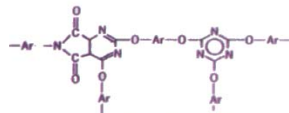
Beam Transport Magnets as a Beam Handling System.

- Radiation Resistant Magnet
- Chimney Magnet
- Radiation Resistant Magnet System
- Special Magnets near Target

Polyimide Insulation Magnets



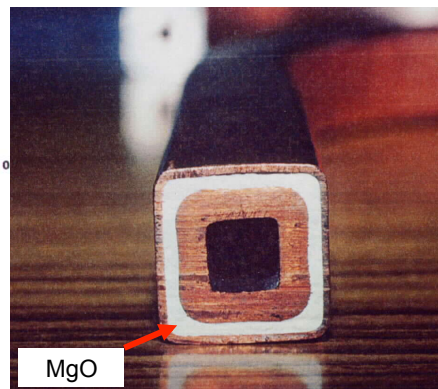
Tensile strength of a cured BT resin reinforced by Boron Free Glass Cloth.



BT resin, ten times RR than Epoxy

Up to 4×10^8 Gy

Magnets of Mineral Insulation Cable (MIC)



Up to 10^{11} Gy

日立 無機絶縁導体
HITACHI Mineral Insulation Cable (MIC)

1. 断面寸法

R1(シース外)・R2(シース内)・R3(導体外)・R4(導体内)

① シース
② インシュレータ
③ 導体
中空孔

寸法(mm)		中実タイプ		中空タイプ		
		MIHC-1000A-S	MIHC-2000A-S	MIHC-2000A-H	MIHC-2500A-H	MIHC-3000A-H
① シース	外径 A	14.0	18.0	19.8	23.8	28.0
	肉厚 T1	0.7	0.7	1.0	1.1	1.5
	外R R1	1.2	1.2	2.0	3.0	4.0
	内R R2	0.8	0.8	1.0	1.9	2.5
② インシュレータ	外径 B	12.6	16.6	17.8	21.6	25.0
	肉厚 T2	1.7	1.7	1.7	1.8	2.5
③ 導体	外径 C	9.2	13.2	14.4	18	20.0
	内径 D	—	—	10.0	10	10.0
	肉厚 T3	—	—	2.2	4.0	5.0
	外R R3	2.6	2.6	2.5	4.0	3.0
	内R R4	—	—	0.8	1.3	1.0
断面積 (mm ²)	① シース	36.6	47.8	72.6	95.3	150.6
	② インシュレータ	79.4	106.6	114.0	153.2	227.4
	③ 導体	78.8	168.4	101.4	208.8	293.1
	合 計	194.8	322.8	288.1	457.3	671.1
中空穴断面積 (mm ²)		—	—	99.5	98.5	99.1
重量 (kg/m)	① シース	0.327	0.427	0.649	0.852	1.347
	② インシュレータ	0.187	0.250	0.268	0.360	0.534
	③ 導体	0.705	1.506	0.907	1.667	2.621
	合 計	1.218	2.183	1.824	3.078	4.502
製造可能長さ (m)		60	60	60	60	30

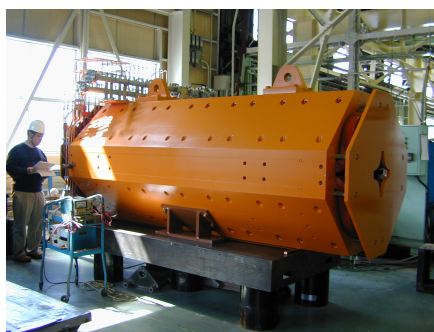
2. 仕様

品番・名称	仕 様	材 質	化学成分	硬度 (HV1kg)	導電率 (%20℃)
① シース		C1220-O	Cu 99.90%以上	40~50	-
② インシュレータ		MgO	MgO 98.0%以上	-	-
③ 導体		C1020-O	Cu 99.96%以上	40~50	100以上

3. 納入形態 外径φ1800程度のゼンマイ巻き

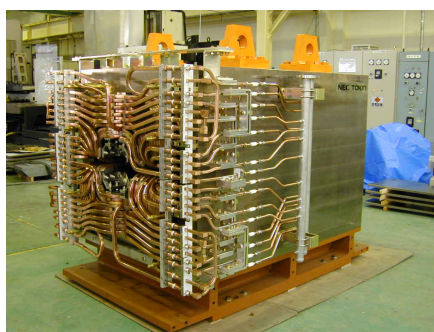
※「MIC」は、文部科学省 高エネルギー加速器研究機構・株式会社トーキン殿との共同開発品です

日立電線株式会社
土浦工場 技術部 TEL:0298-26-7426 FAX:0298-23-2442
茨城支店 仲商営業課 TEL:0294-24-4821 FAX:0294-22-3049

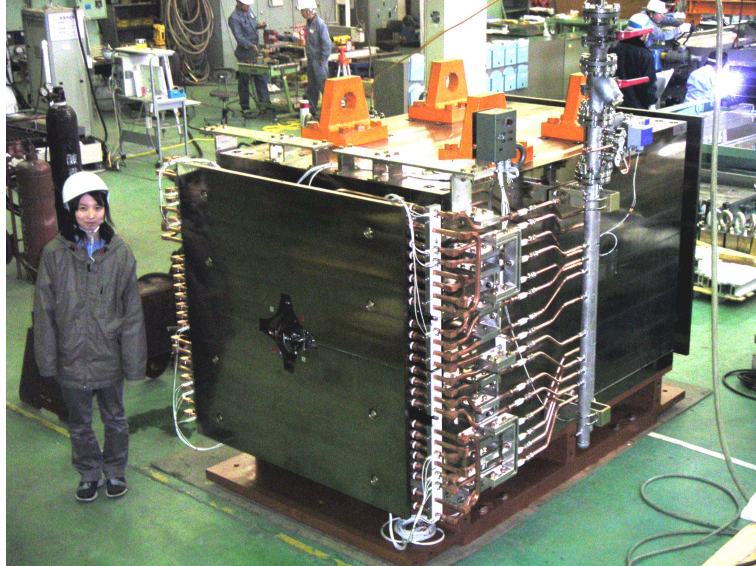


- Typical magnets for J-PARC neutrino beam line

	Q460	Q440MIC
Insulator	Polyimide~10 ⁸ Gy	MgO~10 ¹¹ Gy
Bore diameter	20cm	20cm
Current	2500A	2500A
Weight	32ton	32ton
Voltage	~160V	~230V
Length	3m	2m

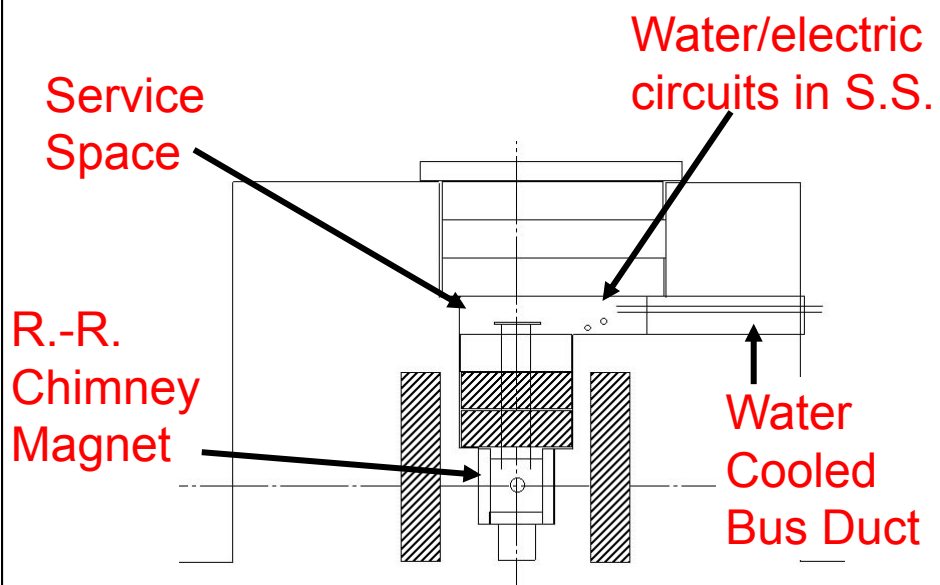


- We have already established the technology of radiation-resistant magnets



Radiation resistant magnet for J-PARC (Q440MIC)

Hadron Hall Systematization; as High Power Beam Facility



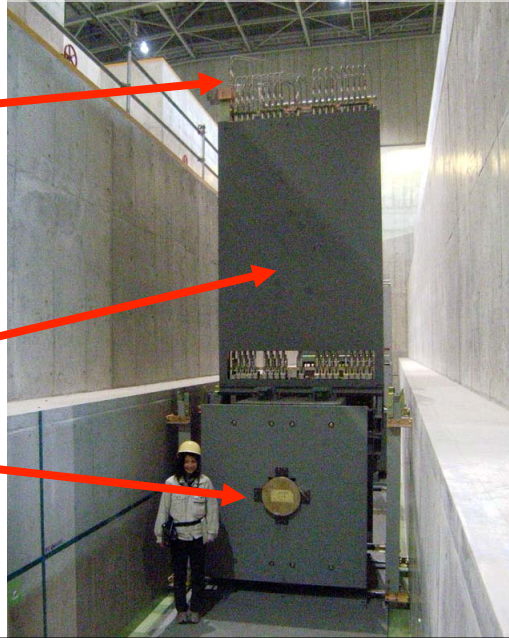
Radiation Resistant **Chimney** Magnet

Water Manifold &
Electric Connection
at Service Space Level

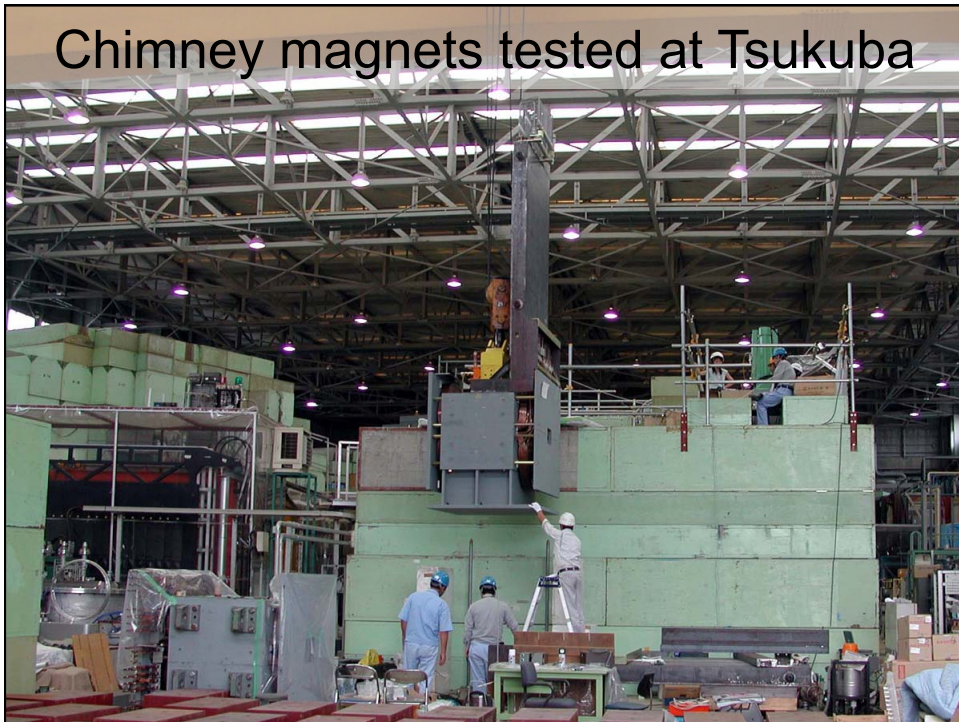
Completely Inorganic

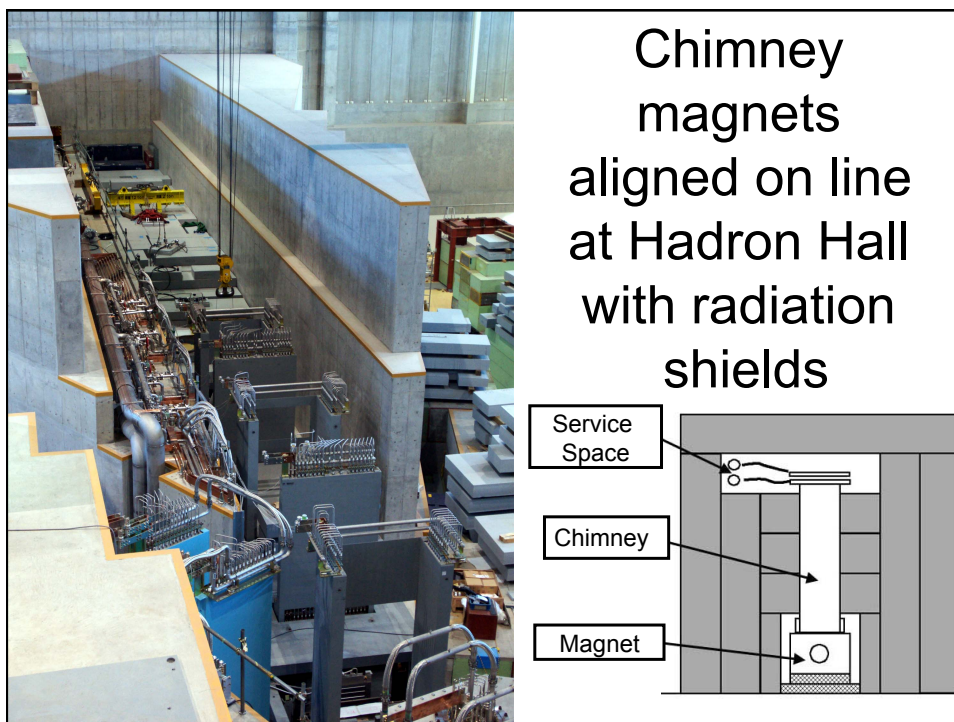
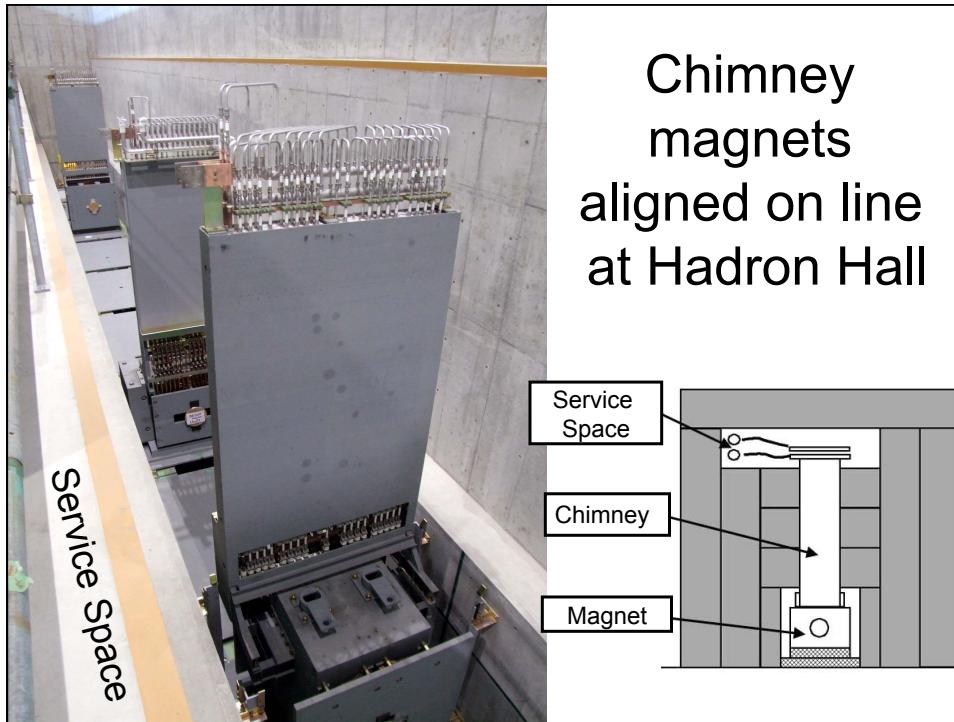
Chimney

MIC Magnet

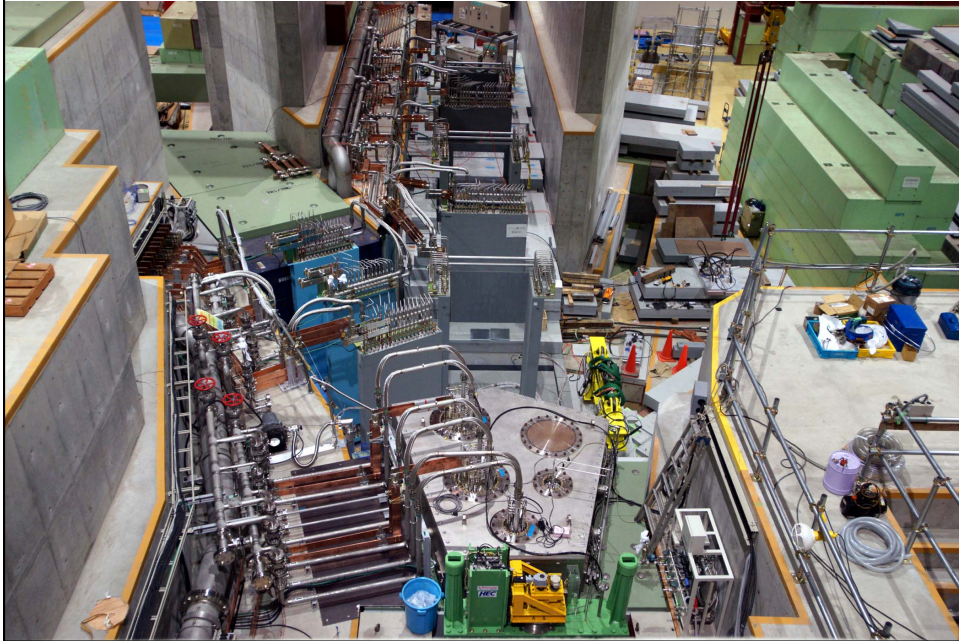


Chimney magnets tested at Tsukuba

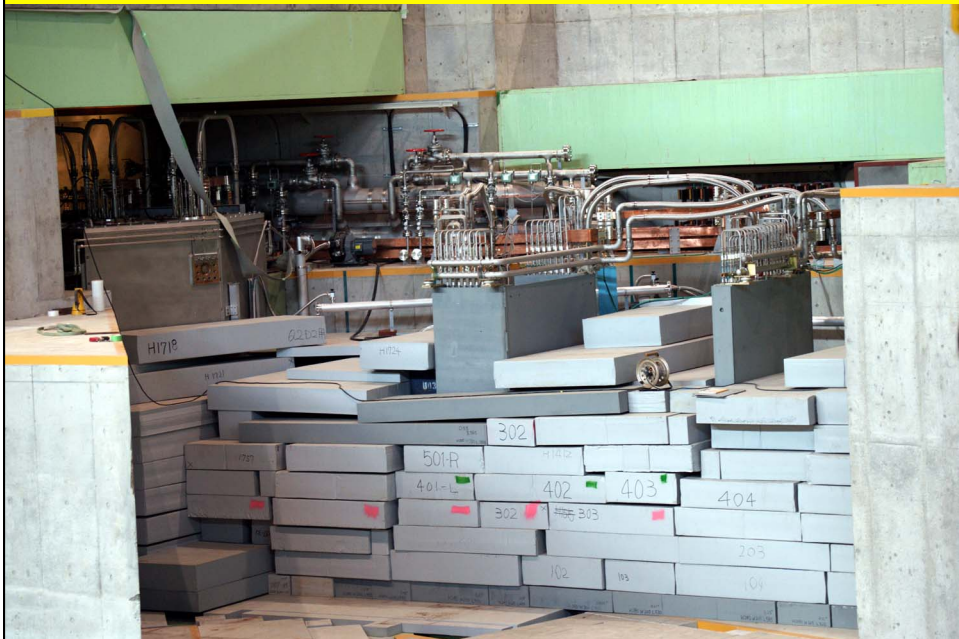


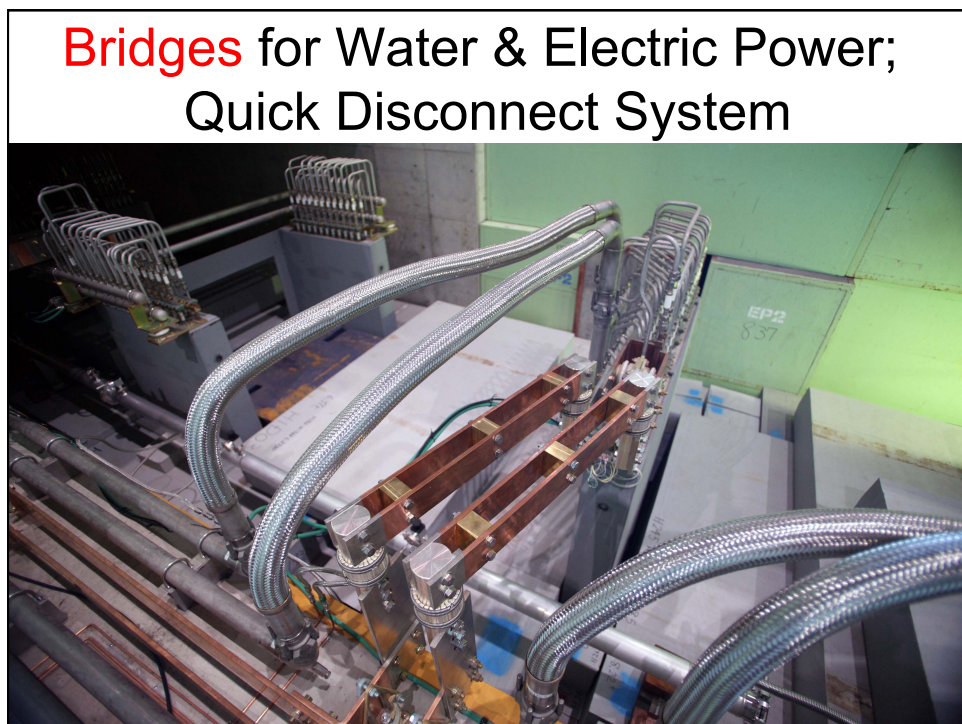
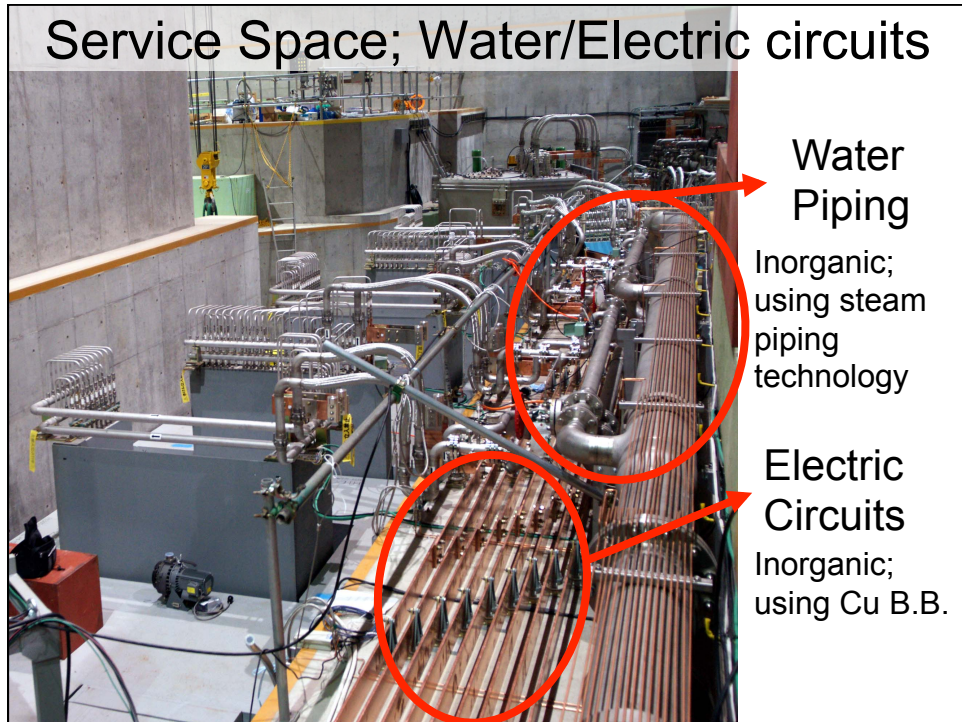


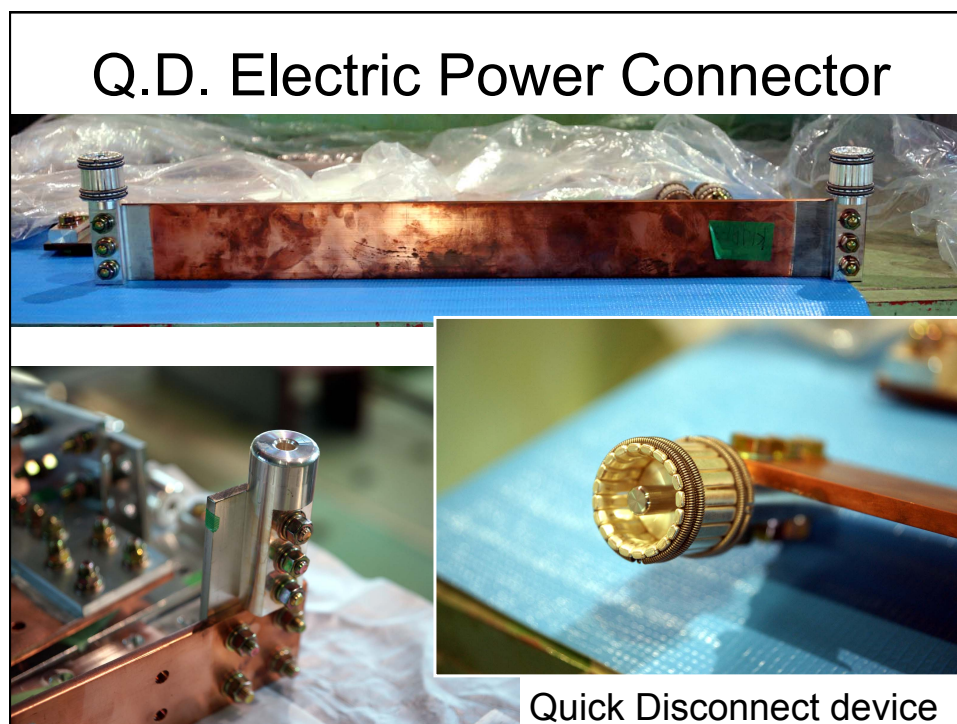
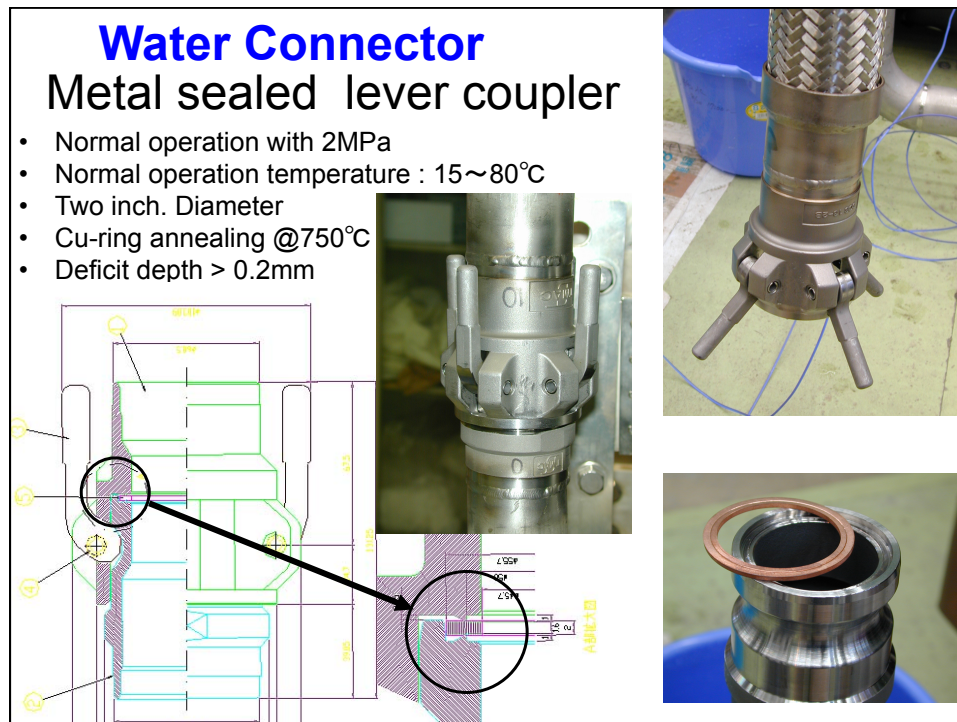
Chimney magnets near T1

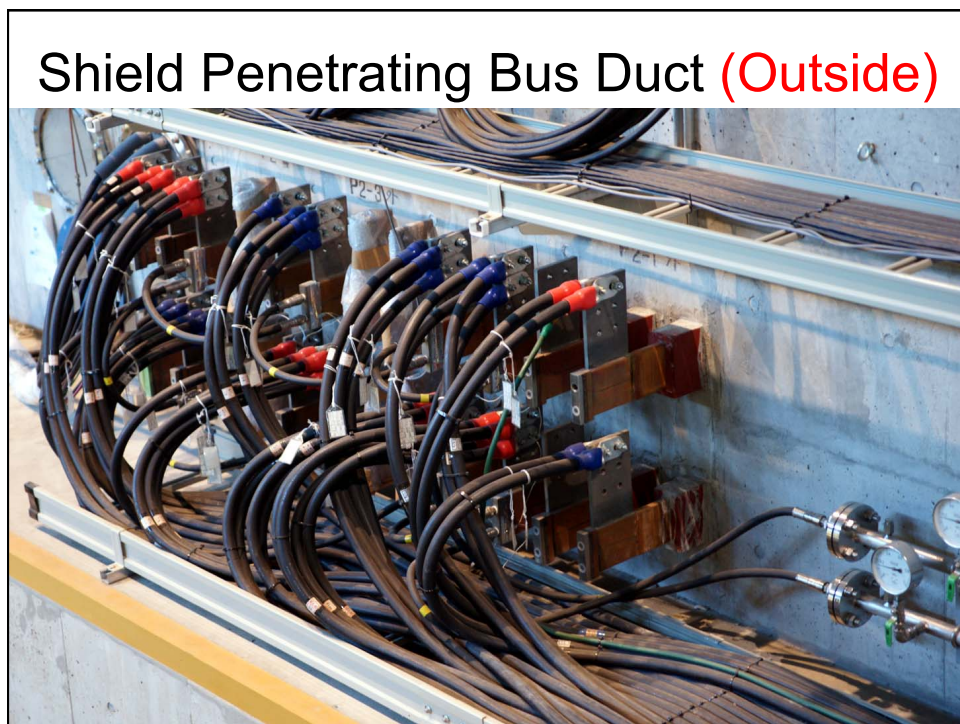
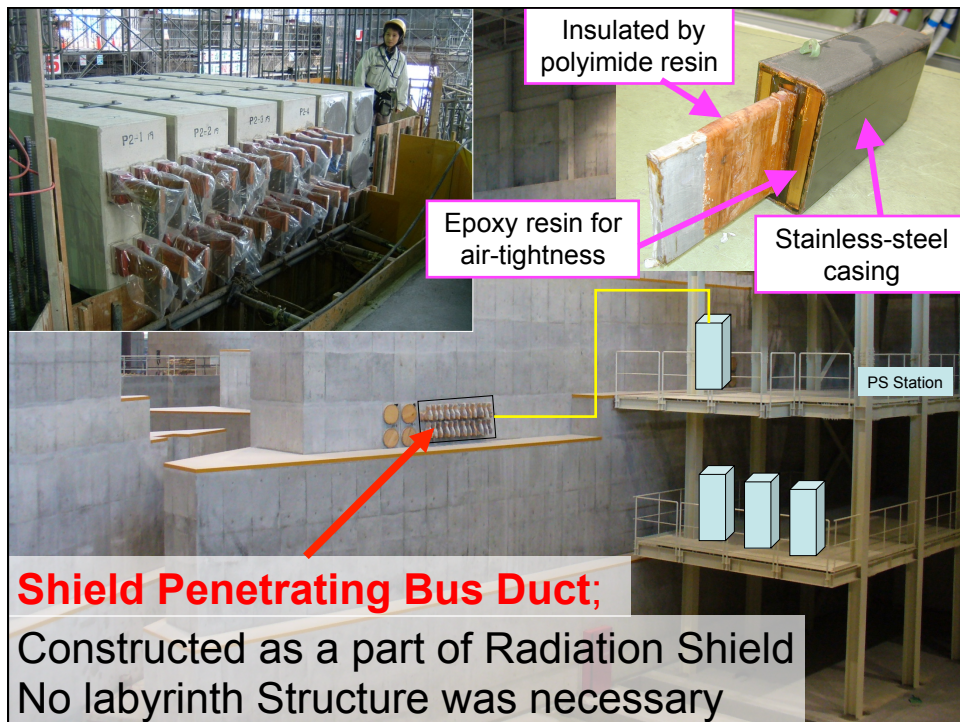


Chimney magnets near T1 (side view)

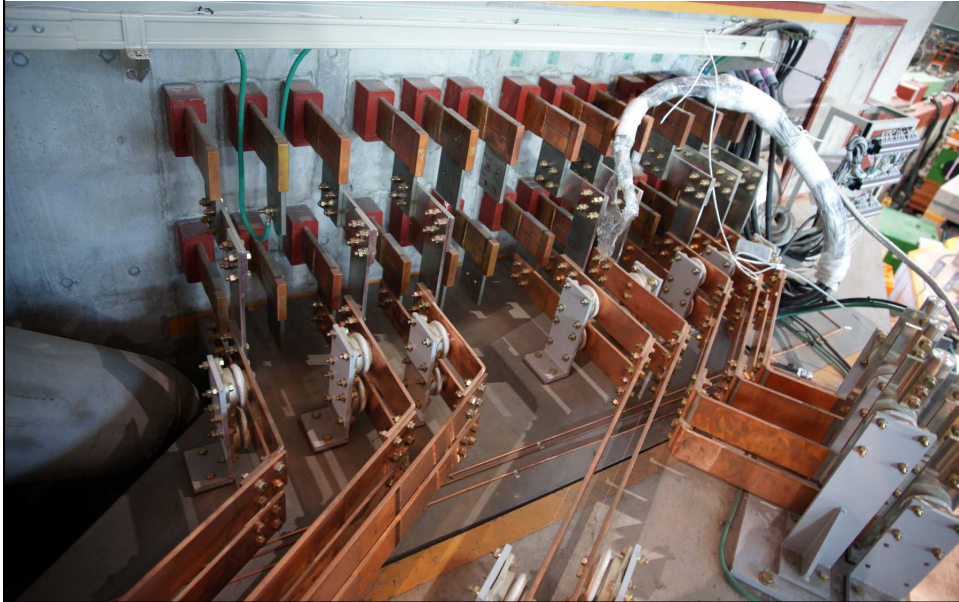




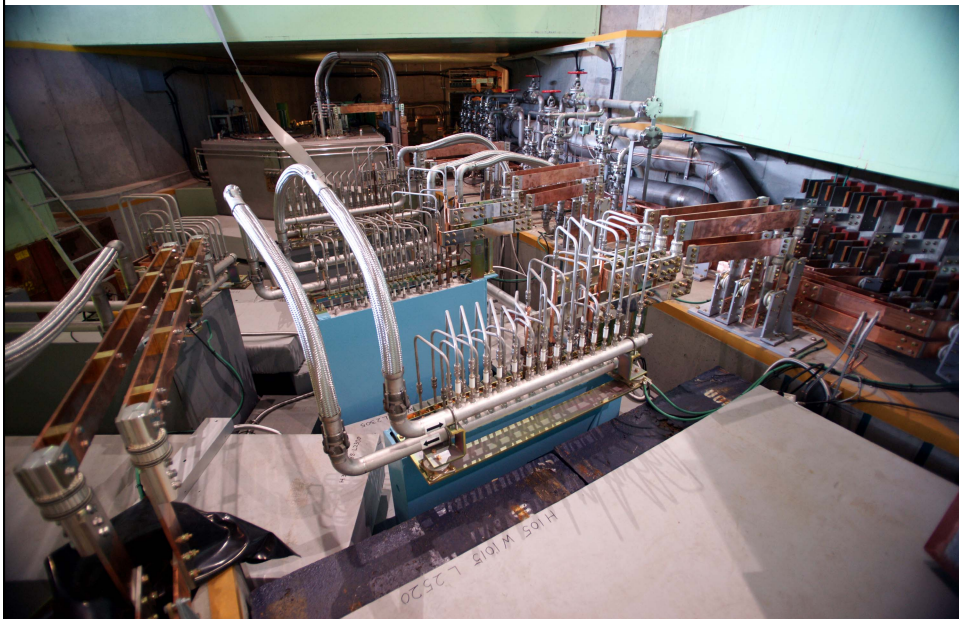




Shield Penetrating Bus Duct (Inside)



Service Space near T1 Target



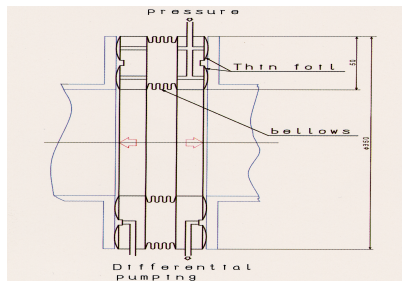
Pillow Seal for Vacuum Connection



Our first one (1989) for KEK-PS
Effective Dia. = 30cm, Leak rate $\sim 10^{-8} \text{Pa} \cdot \text{m}^3/\text{s}$

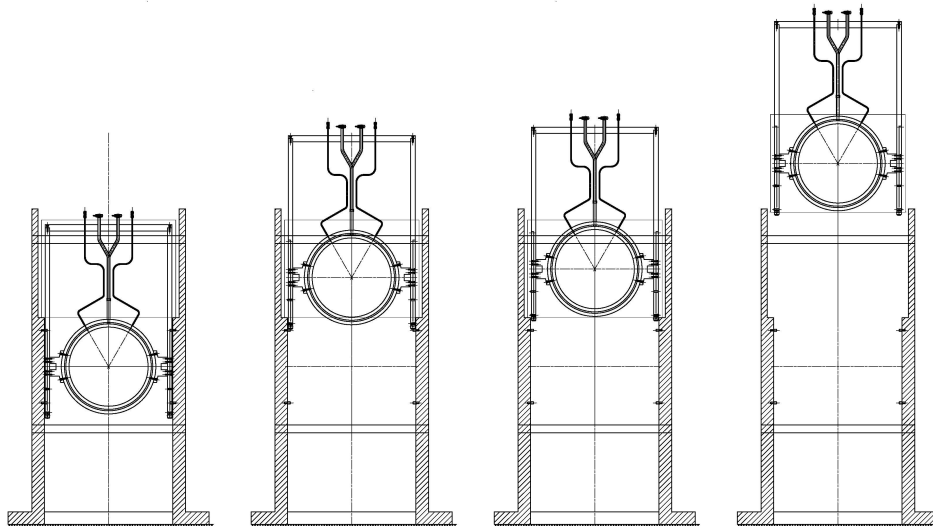


On non-flat... On dust....

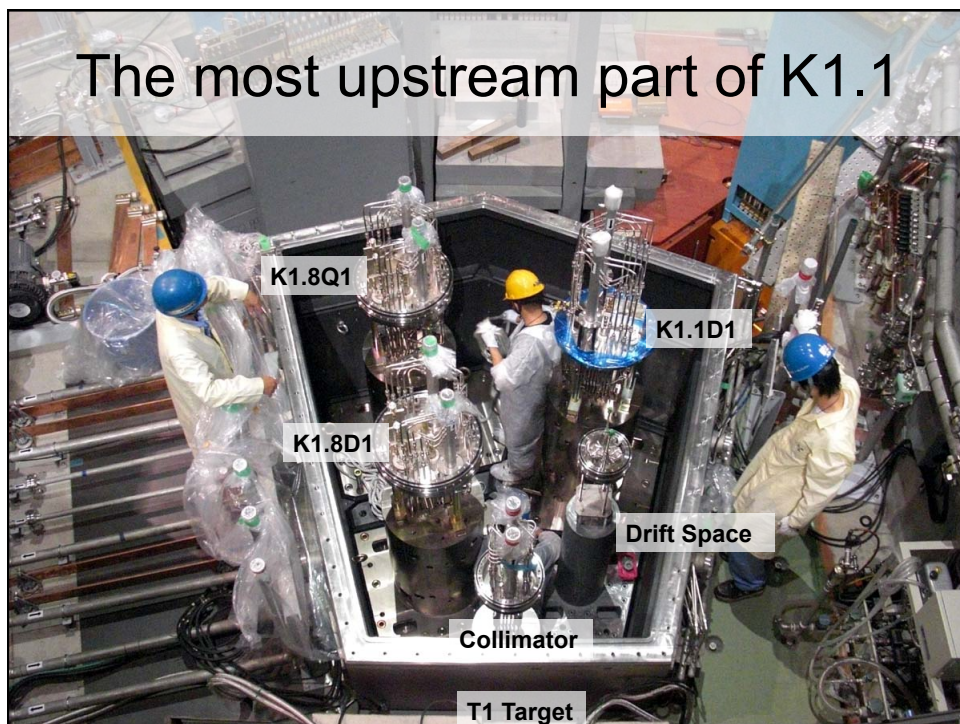


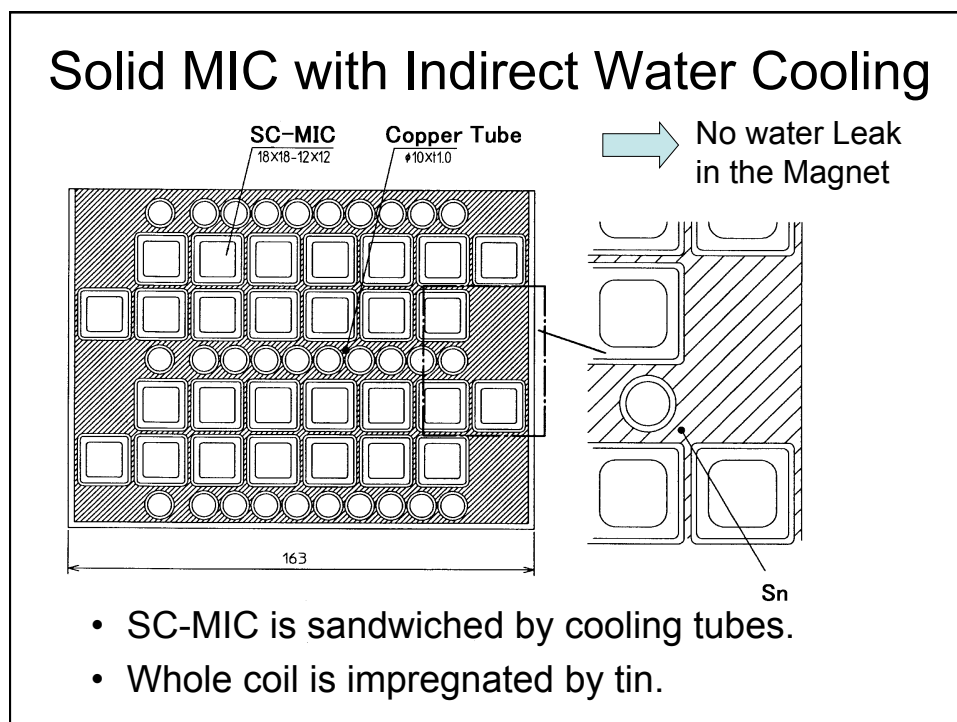
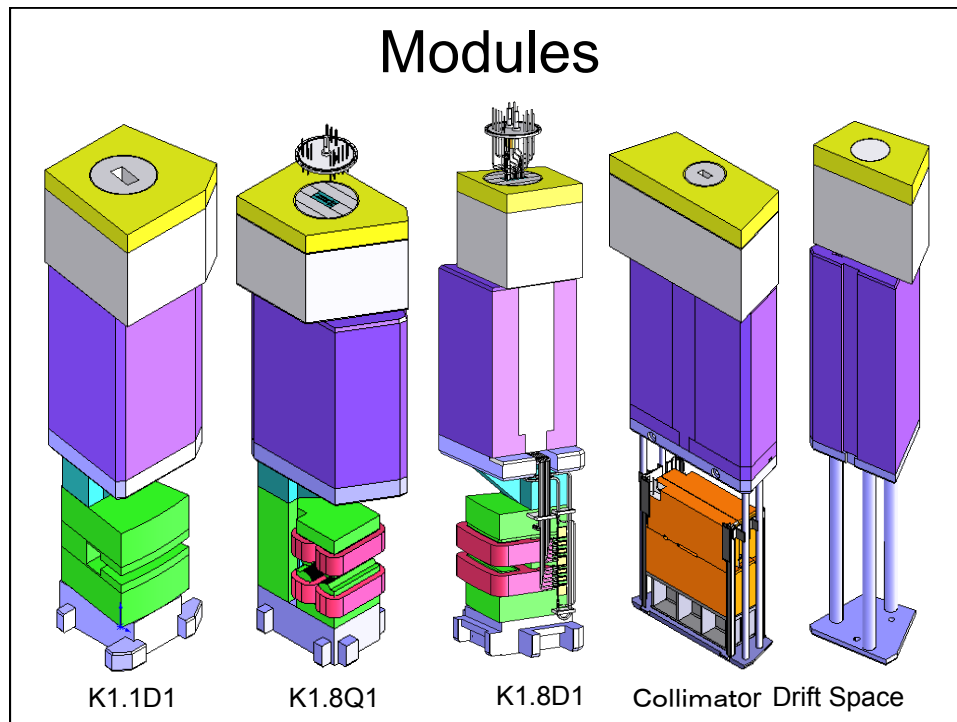
- Now, Leak rate is $\sim 4 \times 10^{-12} \text{Pa} \cdot \text{m}^3/\text{s}$
- Effective Dia. >50cm

Pillow Seal for Vacuum Connection

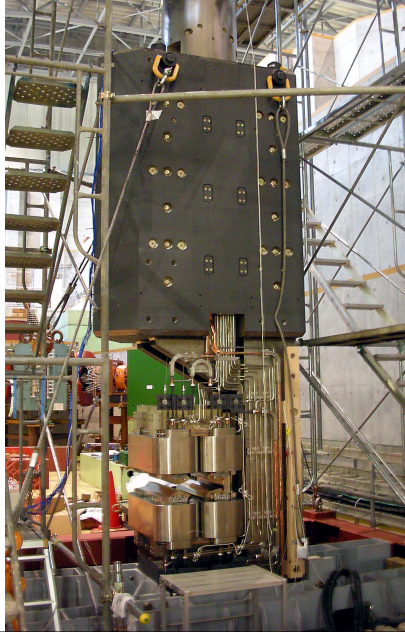


Special Magnets for T1 Area





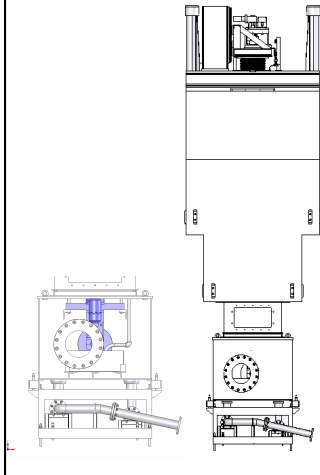
Super Radiation Hard Magnet: K1.8Q1



Central Vacuum Chamber



T1 Target Area



Conclusions 1

- Primary proton beam line of J-PARC Hadron Experimental Hall was constructed as Radiation Resistant Magnet System.
- R.-R. Magnet **with Chimney** was a key technology of the R.-R. Magnet System.
(This is important, however, insufficient!)
- All the peripherals were re-designed and constructed as a part of true R.-R. Magnet System.
- For this purpose, **Service Space** was prepared within the radiation shield.

Conclusions 2

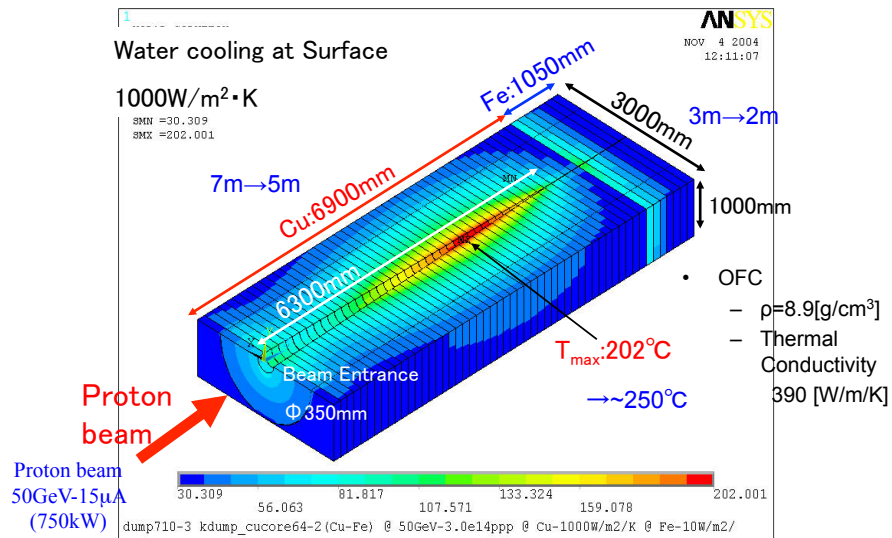
- **Electric Power Distribution Circuits** in S.S. were assembled by Copper Bus Bars. No cables were inside.
- **Water Distribution Circuits** in S.S. were constructed as inorganic piping system by using steam piping technology.
- **Shield Penetrating Water Cooled Bus Duct** was initially installed as a part of radiation Shield. No labyrinth Structure was necessary.
- **Bridges between Chimney and S. S. circuits** were made with quick disconnect devices.

Beam Dump

Beam Dump - Heat analysis by MARS & ANSYS

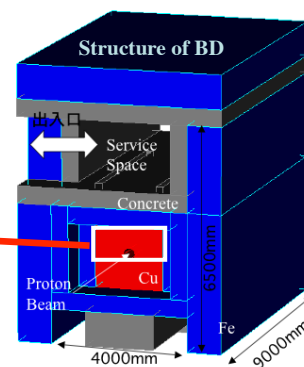
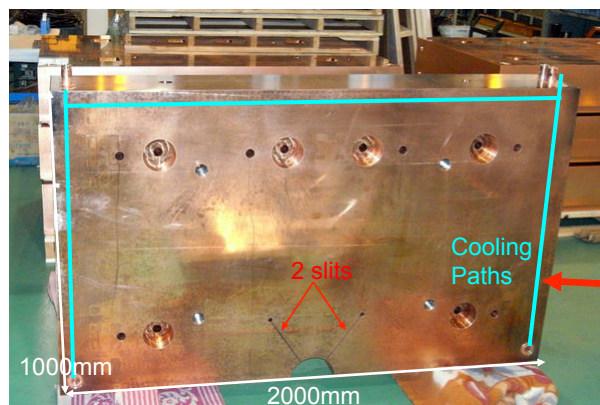
K. Agari

(calculated by A. TOYODA & M. MINAKAWA)



We have to reduce the volume of Cu...

750kW Full Beam Dump

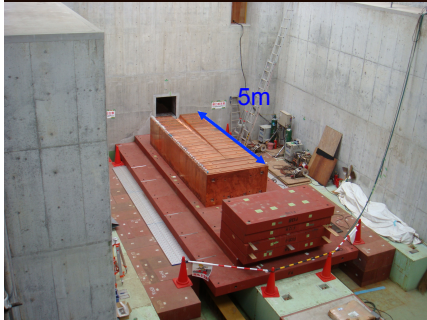
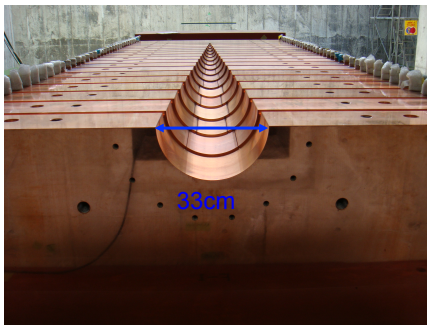


Conical hole and Temp. analysis with 1/4 model

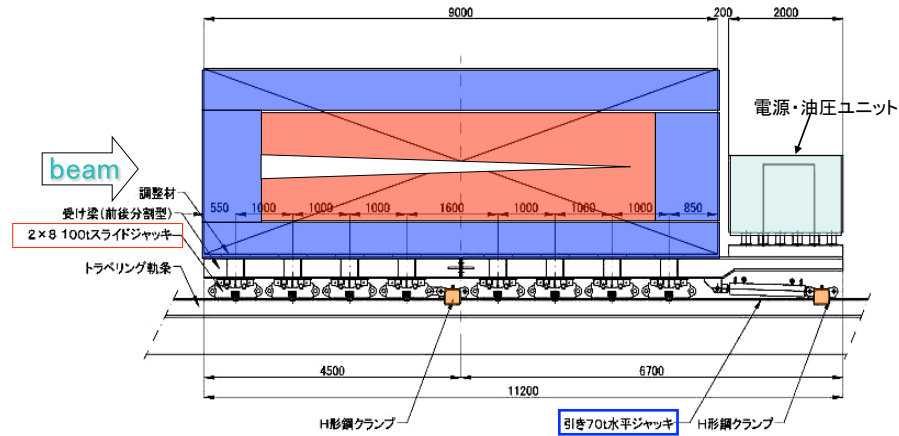
- Manufacture of Copper core (2m x 2m x 5m)
- 250 mm thick Copper plates
- 1/3 in FY 2006, 2/3 in FY 2007, set in FY2008
- 100% of Iron Blocks were purchased in 2006
- Concrete blocks will be transferred from Tsukuba in 2008.



ビームダンプ設置工事



Structure of traveling devices

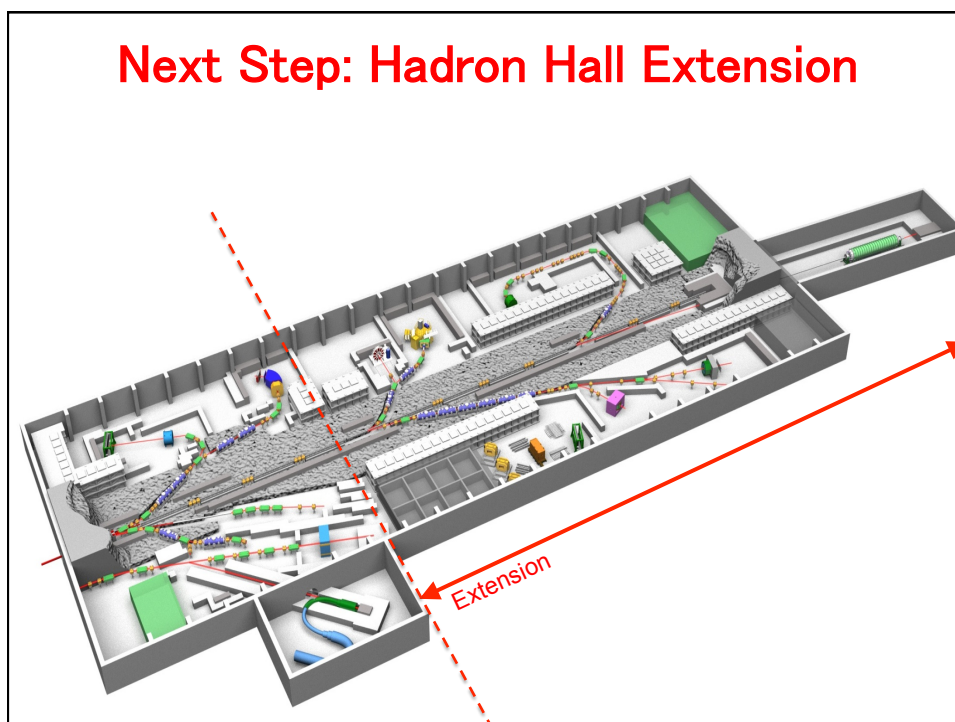
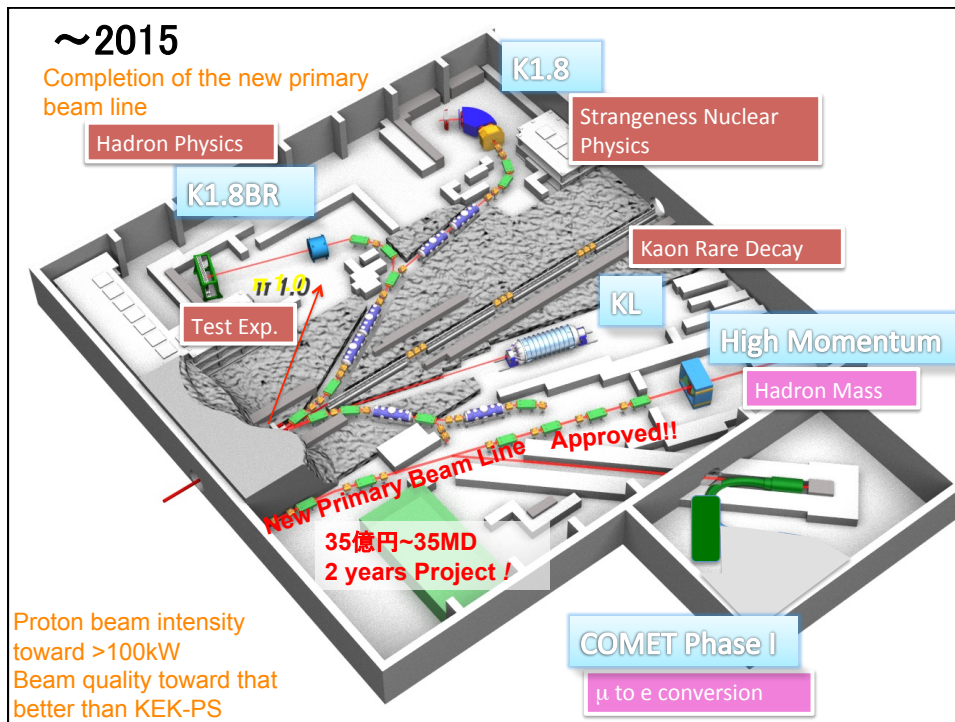


An "Inchworm" Method.

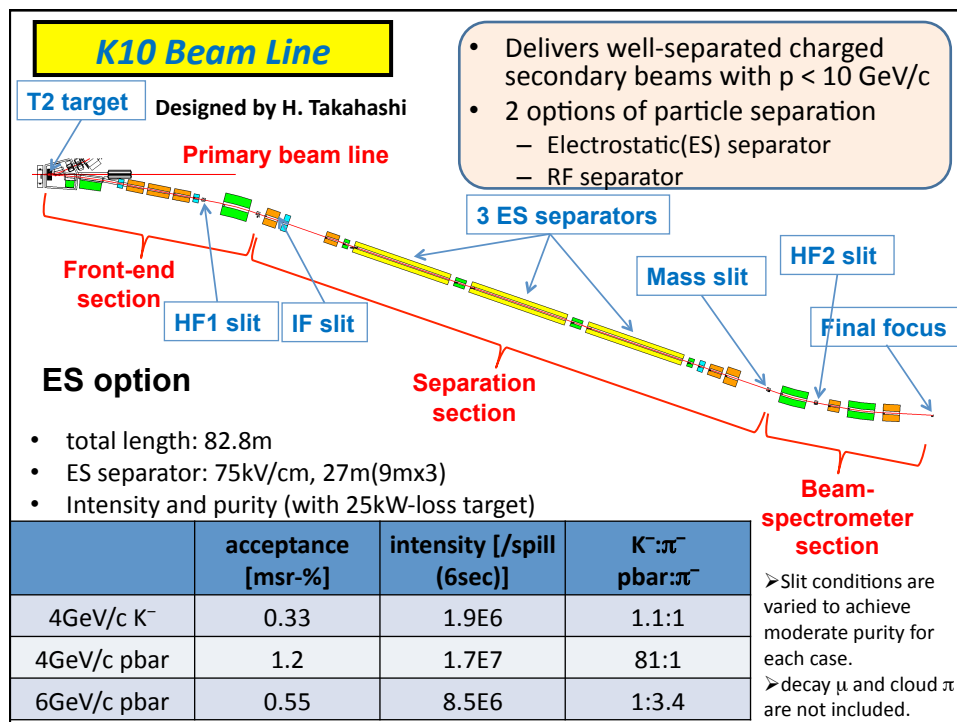
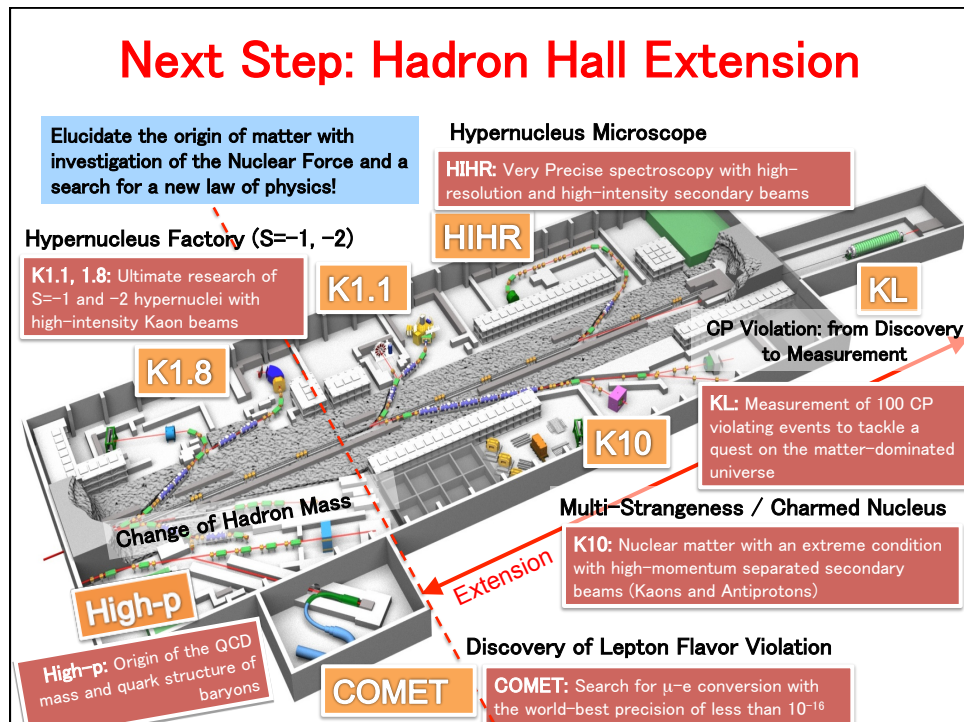
Complete remote operation with just LAN Cable!

First Step has been funded!

We should go to the NEXT STEP



Next Step: Hadron Hall Extension



Program at K10 Line

$K^\pm, \pi^\pm, p^{\text{bar}} < 10 \text{ GeV}/c$ (id: $K^\pm < 4 \text{ GeV}/c, p^{\text{bar}} < 6 \text{ GeV}/c$)

$K^- N \rightarrow \Xi^* K^+, \Omega^* K^+ K^0, \dots [K^{\text{bar}} K^{\text{bar}}] K^+$

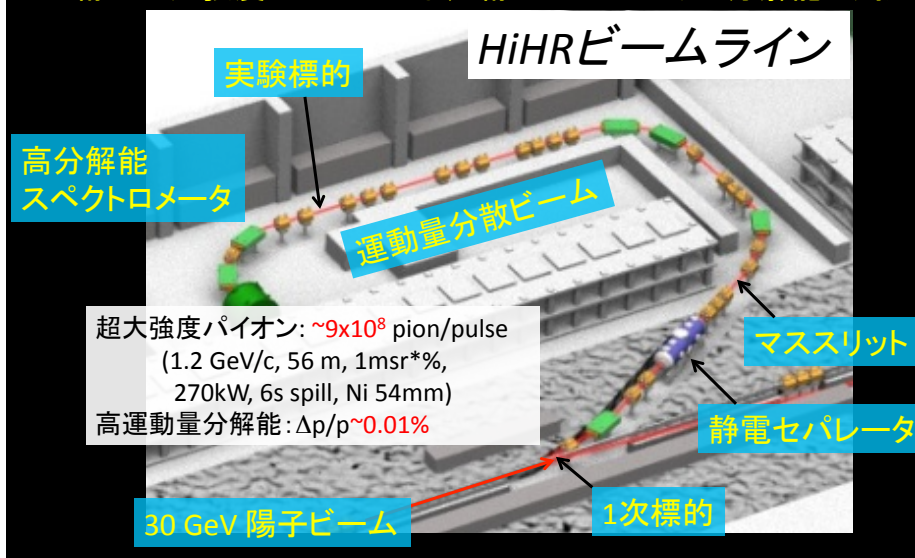
- Ξ^*, Ω^* Spectroscopy -> *How to understand excited hadrons*
- $\Lambda\Sigma, \Sigma\Sigma, \Lambda\Xi, \Sigma\Xi$ interactions -> *Complete Octet-Octet force*
- Ω nucleus -> *Decouplet-Octet force*
- Multi K mesons in nuclei -> *high density nuclear matter*

$p^{\text{bar}} p \rightarrow J/\psi, \eta_c, DD^{\text{bar}}, YY^{\text{bar}}, \text{glueball}, \dots$

- Charmonium Spectroscopy -> *q-q^{bar} potential*
- Charmonium in nuclei -> *Color Van der Waals force*
- D mesons in nuclei -> *Chiral symmetry restoration*

HiHR; ハイパー核顕微鏡

RCNPのお家芸である運動量分散整合技術を用いて、
2桁上の大強度ビームによる、1桁上のエネルギー分解能に到達

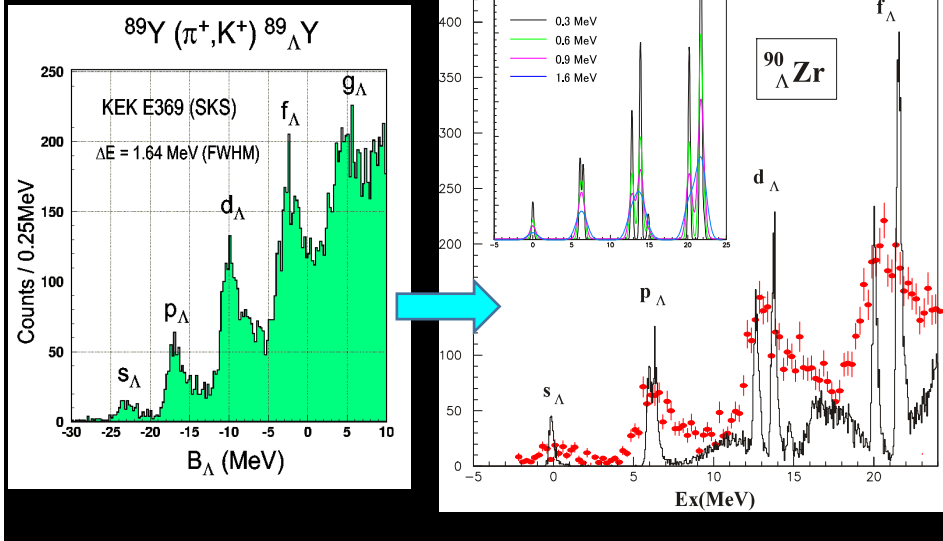


ハイパー核顕微鏡

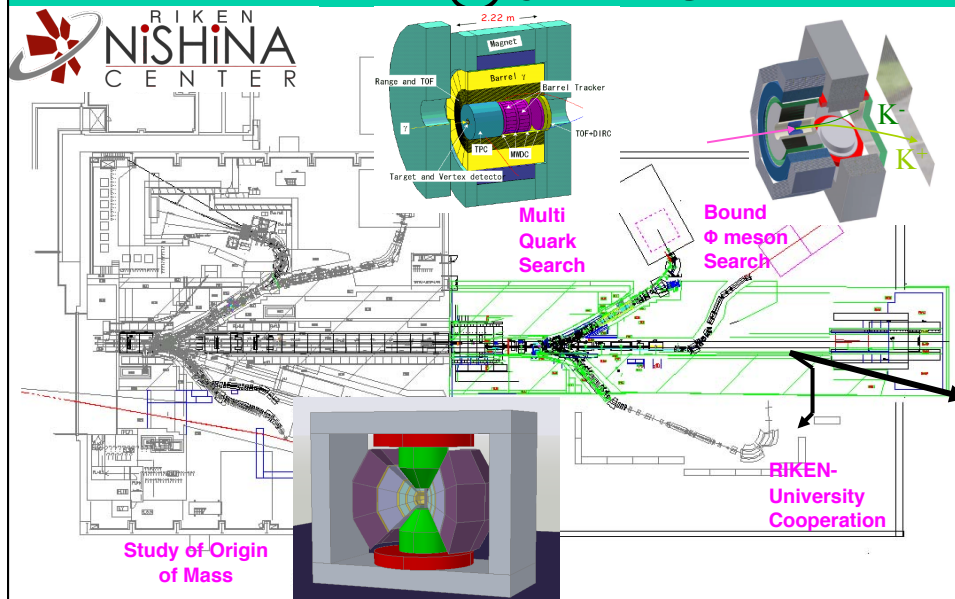
1桁上のエネルギー分解能

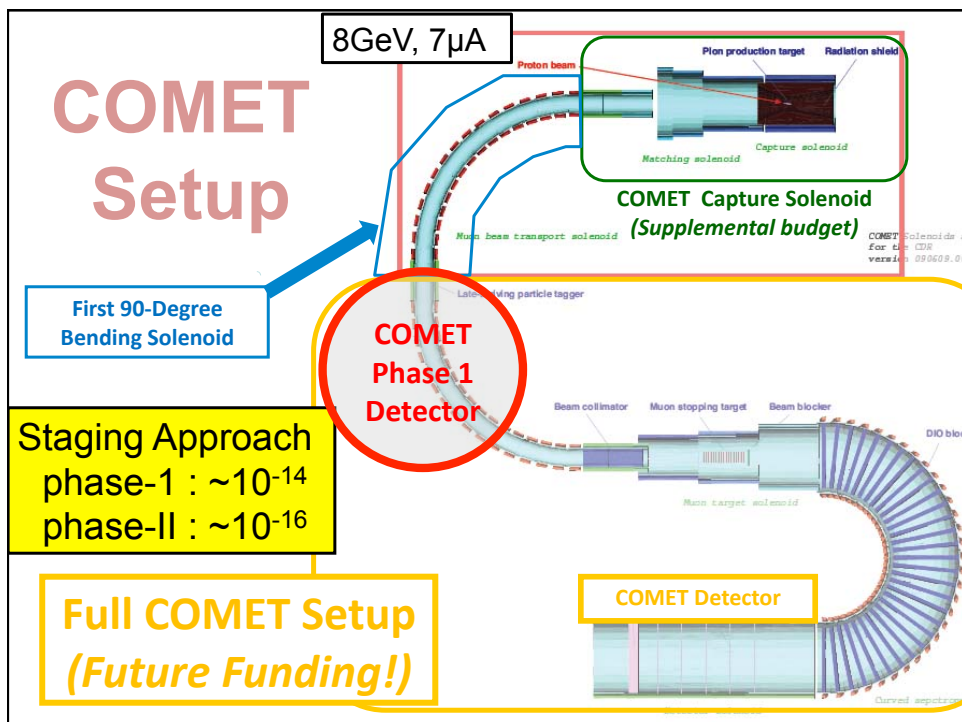
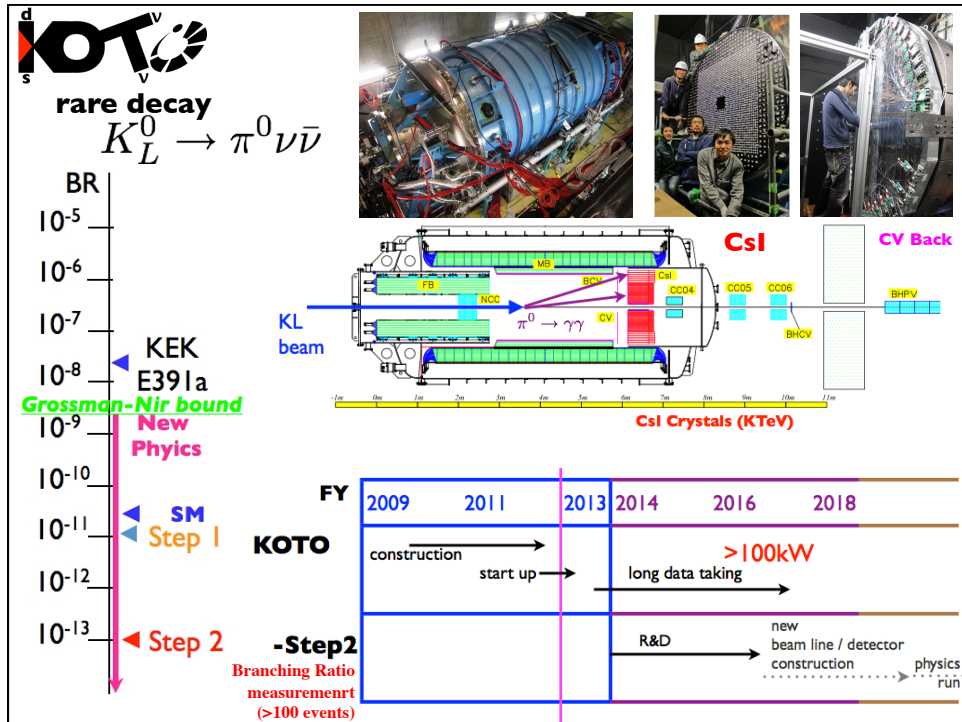
核物質の性質(状態方程式)は未だ理解されていない:

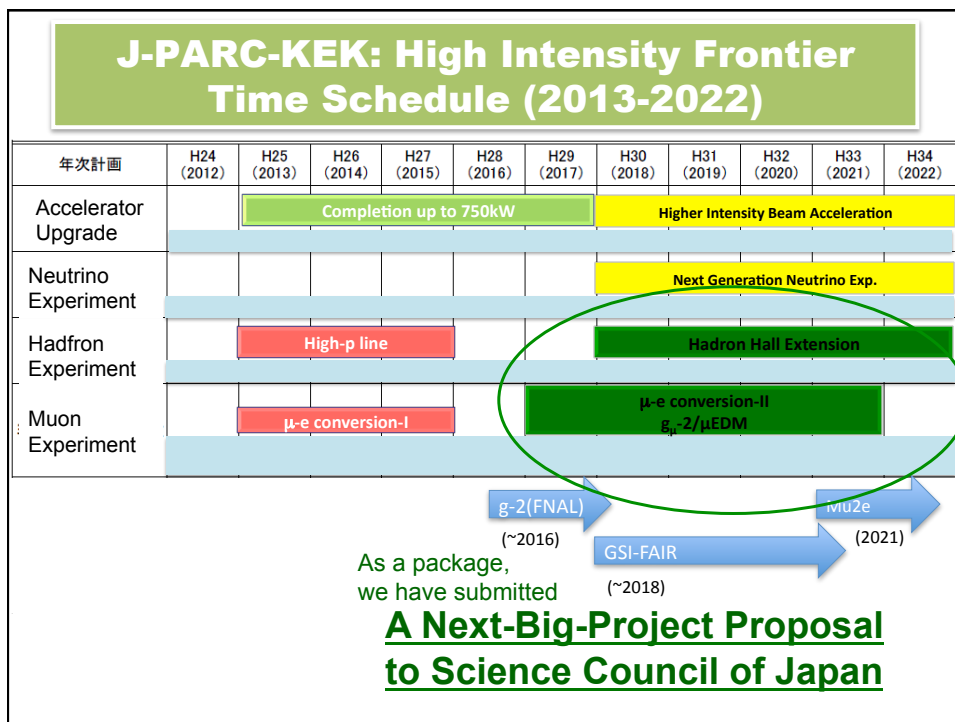
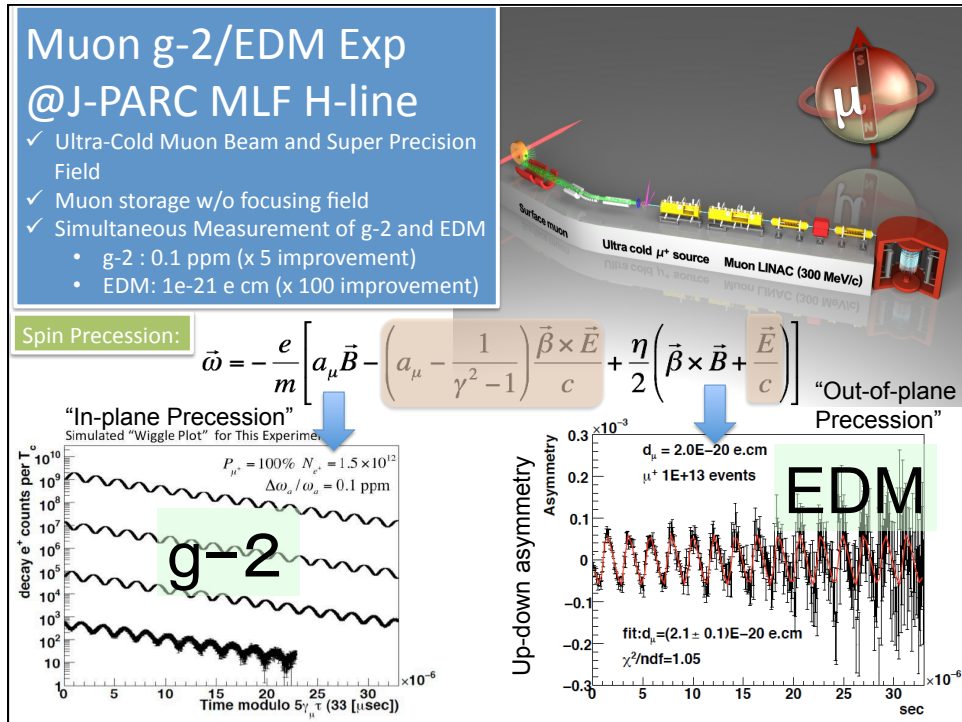
→原子核の表面から内部まで進入する Λ の単一粒子エネルギーを詳細に測定し、核物質の性質に迫る



Very Tentative Plan for RIKEN @ J-PARC







Summary

- Now in the Hadron Experimental Hall, slow beam experiments such as Hypernuclear Spectroscopy and KOTO are running and/or ready.
- The first step of the Roadmap has been funded!
 - High-p/COMET beam will be ready in mid 2015 since Japanese Government approved the project.

Next Step is Hadron Hall Extension.

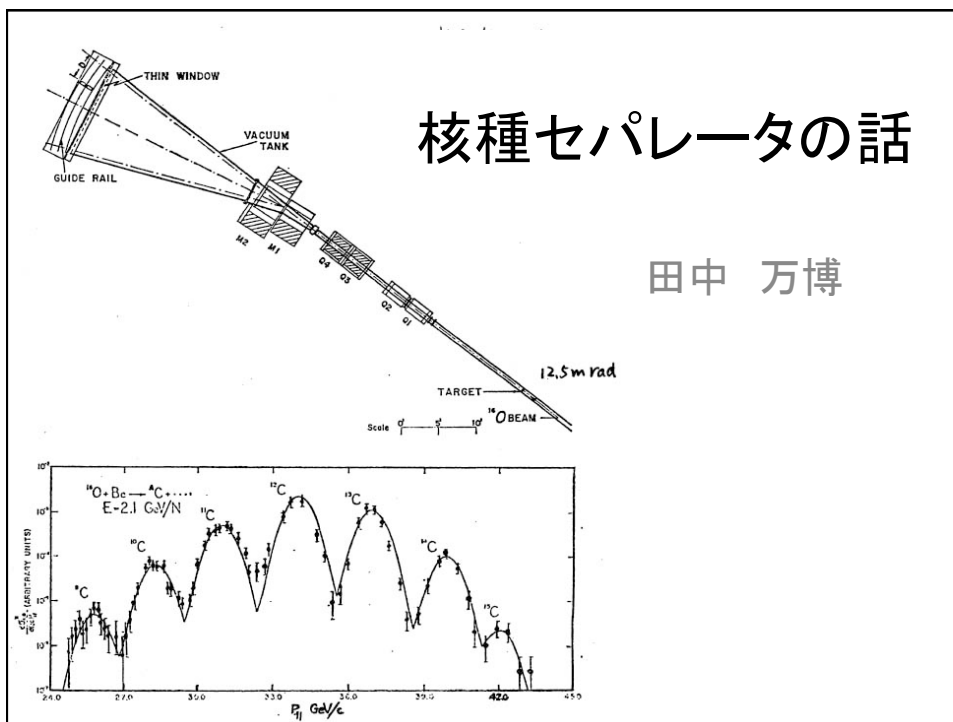
- Two more target stations, more unique secondary beam lines, wider space for experiments, efficient beam time usage.....
- KEK decided to submit a new Next-Big-Project Proposal to Science Council of Japan, combining Hadron Hall Extension including KOTO step II and COMET with $g-2/\mu\text{EDM}$ performed at MLF.
- We would like to start this Next-Big-Project immediately after the completion of High-p/COMET construction.

昔話

77

核種セパレータの話

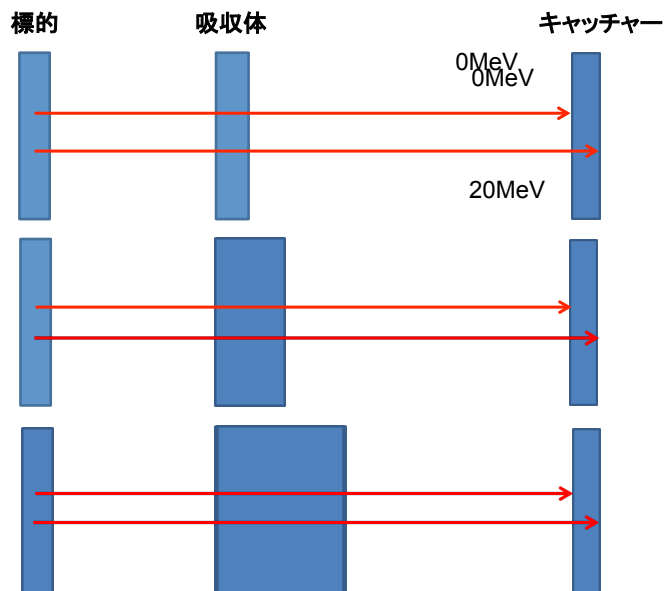
田中 万博



Projectile fragmentation Data from Bevatron

- ニューマトロンの非中心課題だったけれど・・・。
- 中井先生の講義で衝撃。
- ^{12}C なんてものが簡単に出来る。
- 生成核の速度は入射粒子の速度と同じ。
- Magnetic Analysis: Z/A の分離が可能、のみ！
いかに A, Z 独立に生成核を分離、収集するか？

飛程分析法



飛程、あるいは dE/dx は Z^2/A の分析になる。

Projectile fragmentation Data from Bevatron

いかにA,Z独立に生成核を分離、収集するか？

- 飛程、あるいは dE/dx は Z^2/A の分析になる。
- 磁場分析と飛程分析の組み合わせで二次方程式が解ける！
- 1980年のStevensonの実験
 - 磁場分析と飛程分析の組み合わせのデモ。
 - 見事にA,Zの分離、収集が可能であることを実証。

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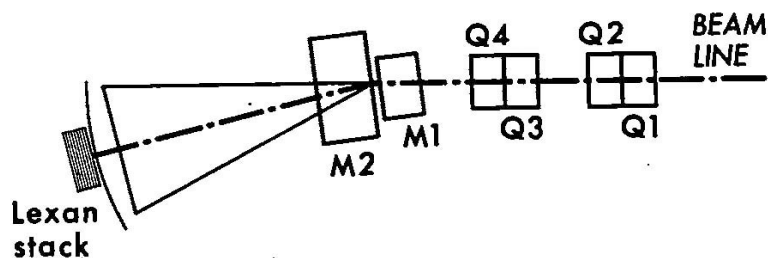
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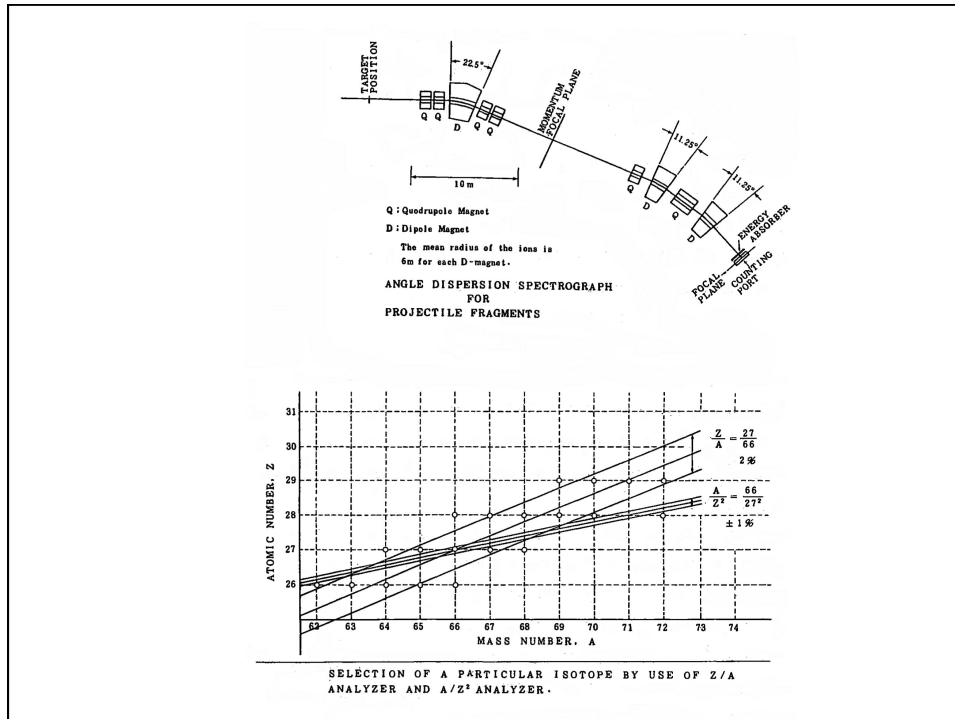
IMAGING AND IDENTIFICATION OF RELATIVISTIC PROJECTILE FRAGMENTS WITH LEXAN SPECTROMETRY

J.D. STEVENSON *, P.B. PRICE * and M.P. BUDIANSKY

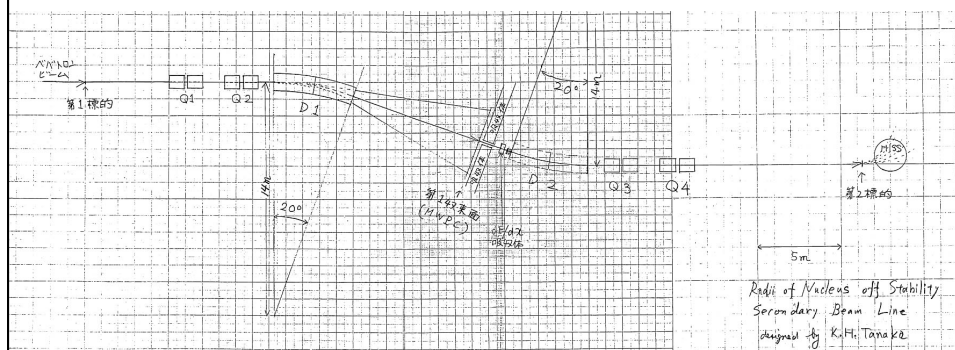
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HISSでの不安定核の半径の実験



- アンバランスダイポールとエネルギー吸収体の組み合わせで、A,Zの独立した分離が可能。
- 以降30年、世界で流行ってめでたい。
- そろそろ別の工夫が出て良いのでは？