sPHENIX実験-INTTシリコン検出器用マイクロ同軸製読み出しケーブルの開発

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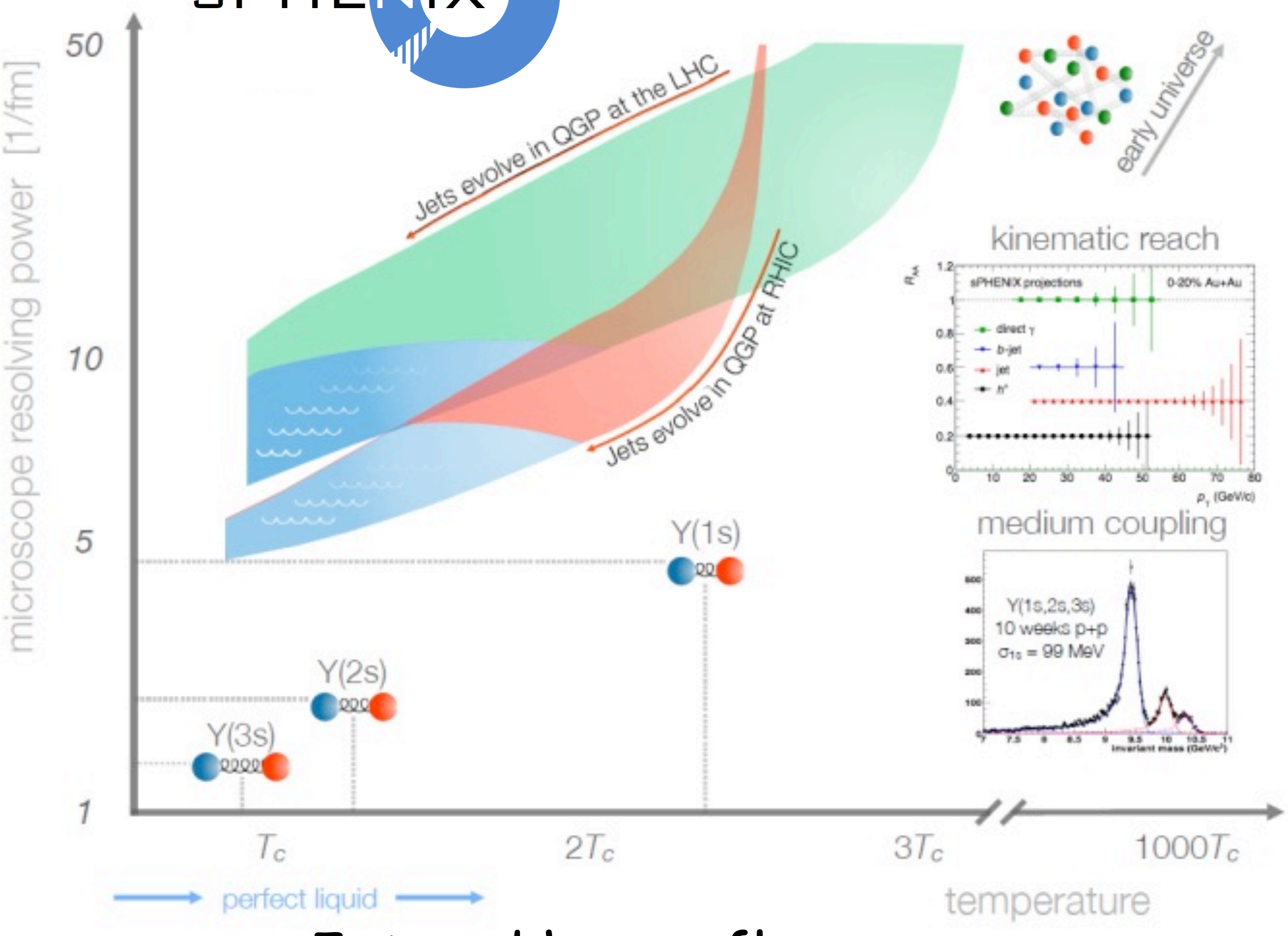
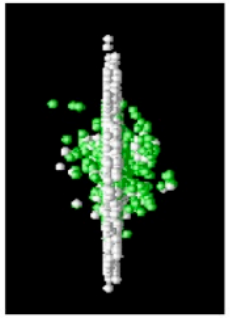
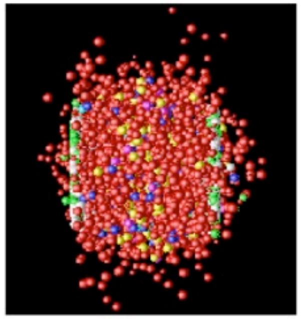
Ultimate Mission of sPHENIX

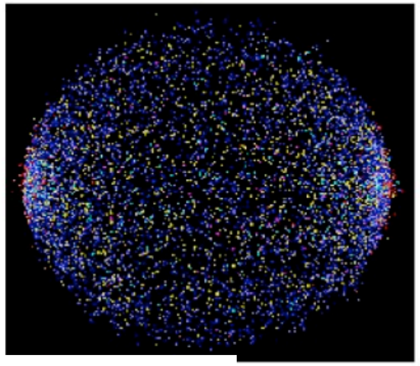
Completion of the Scientific Mission (QGP+Cold QCD) of RHIC !!



Jet and heavy flavor as proves



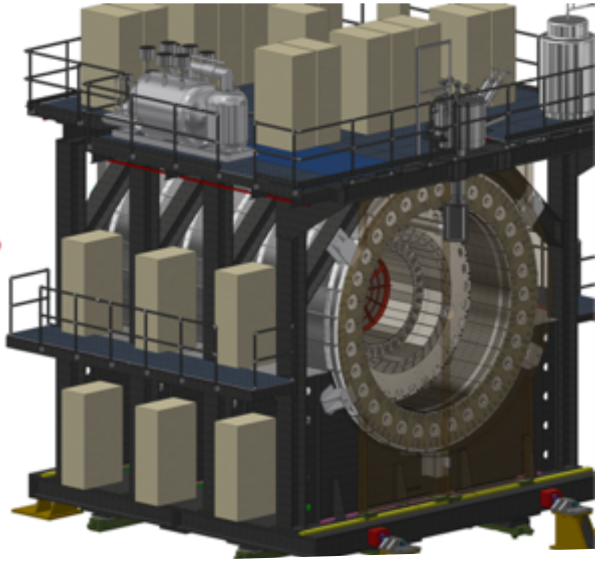




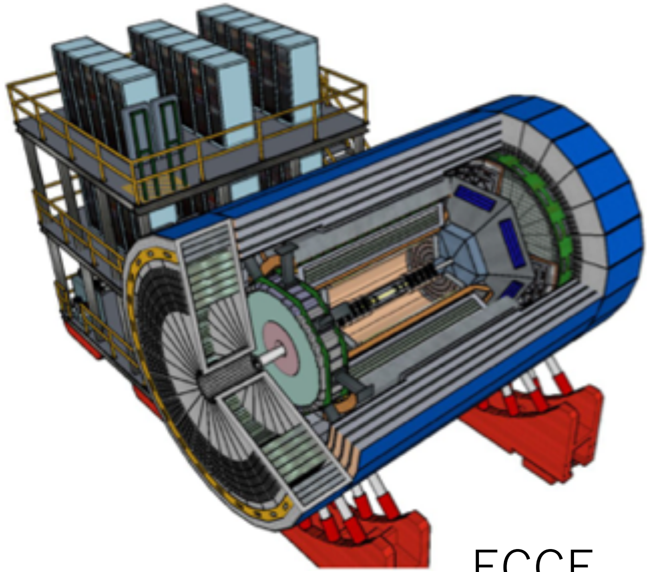
CD-0 Sept 2016
OPA CD-1 Review May 2018
Construction Phase Jul 2019
Ready for Beam Feb 2023

RHICのスケジュールと今後の予定

PHENIX



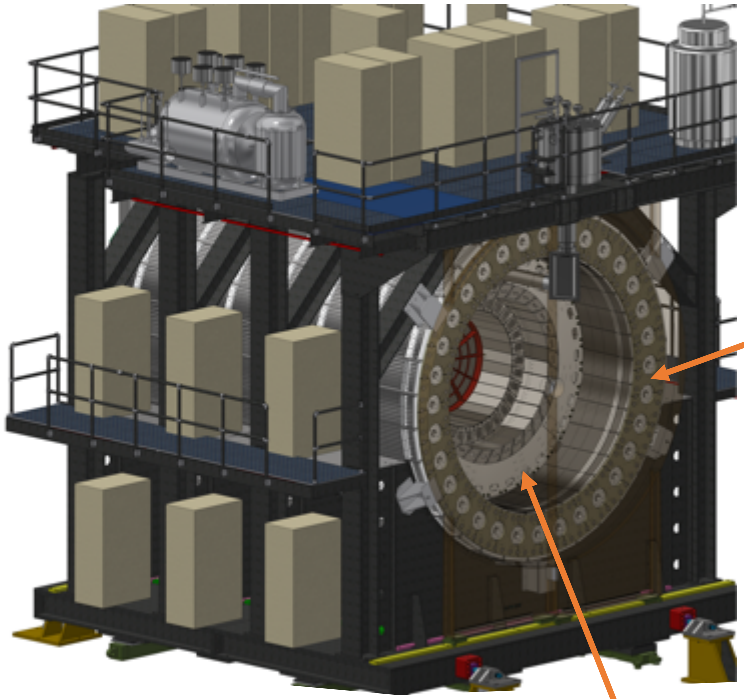
sPHENIX



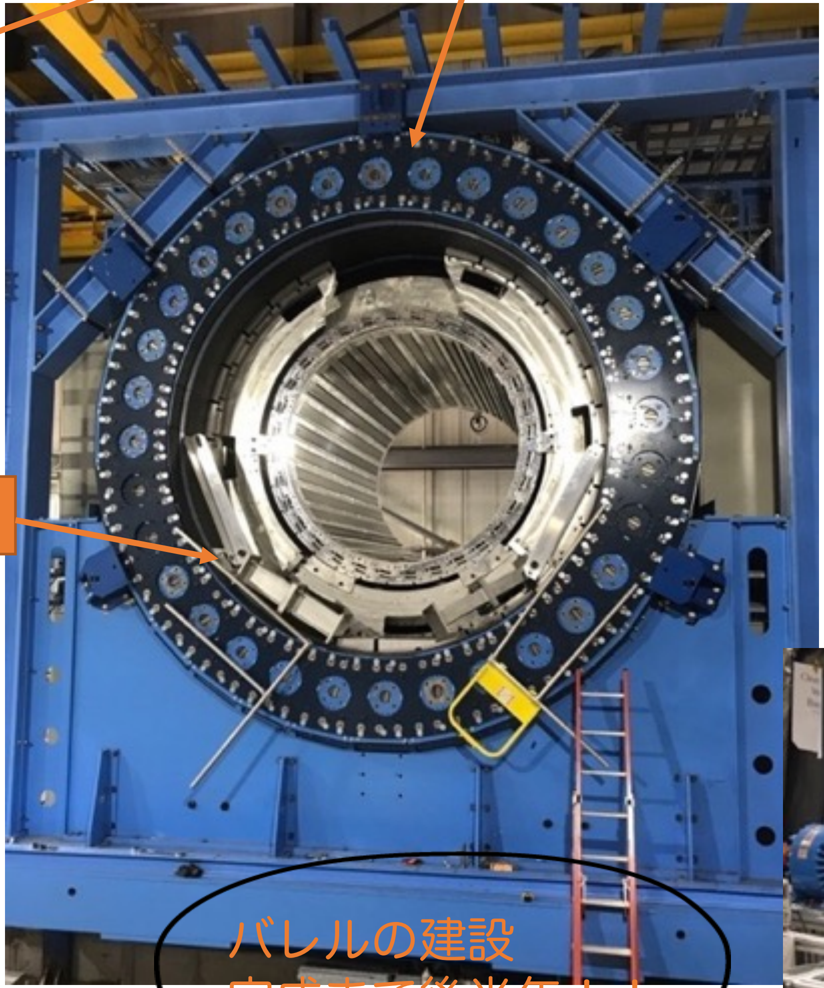
ECCE

sPHENIX建設状況

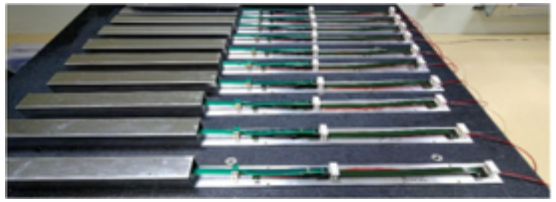
ハドロンカロリメータ



Babar電磁石



バレルの建設
完成まで後半年！！

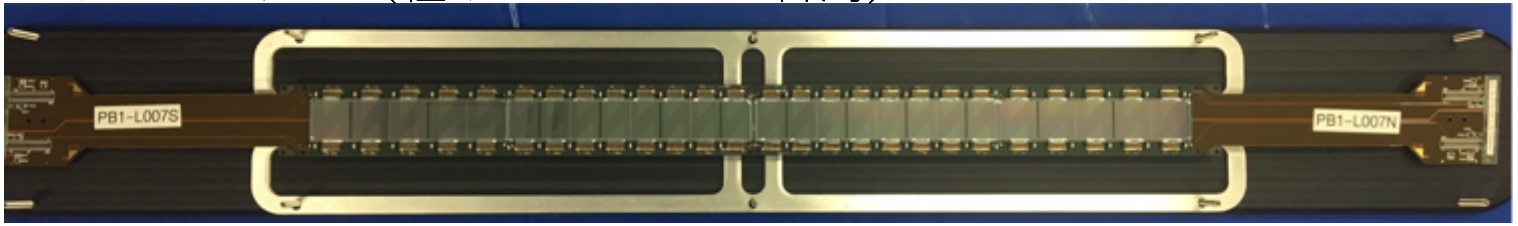


MVTX

TPC Outer Cage

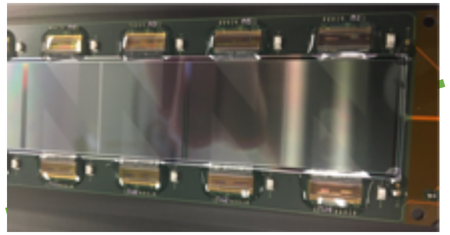
日本グループが参画するIntermediate Silicon Tracker (INTT)の現状

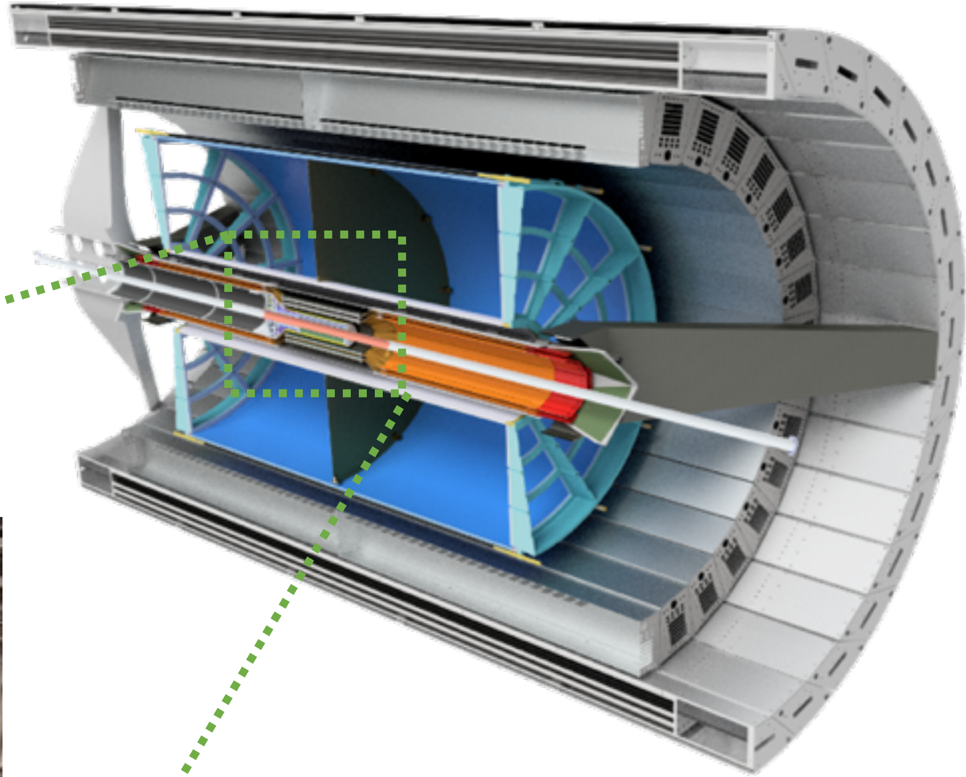
シリコンラダー（組み立て：BNL&台湾）



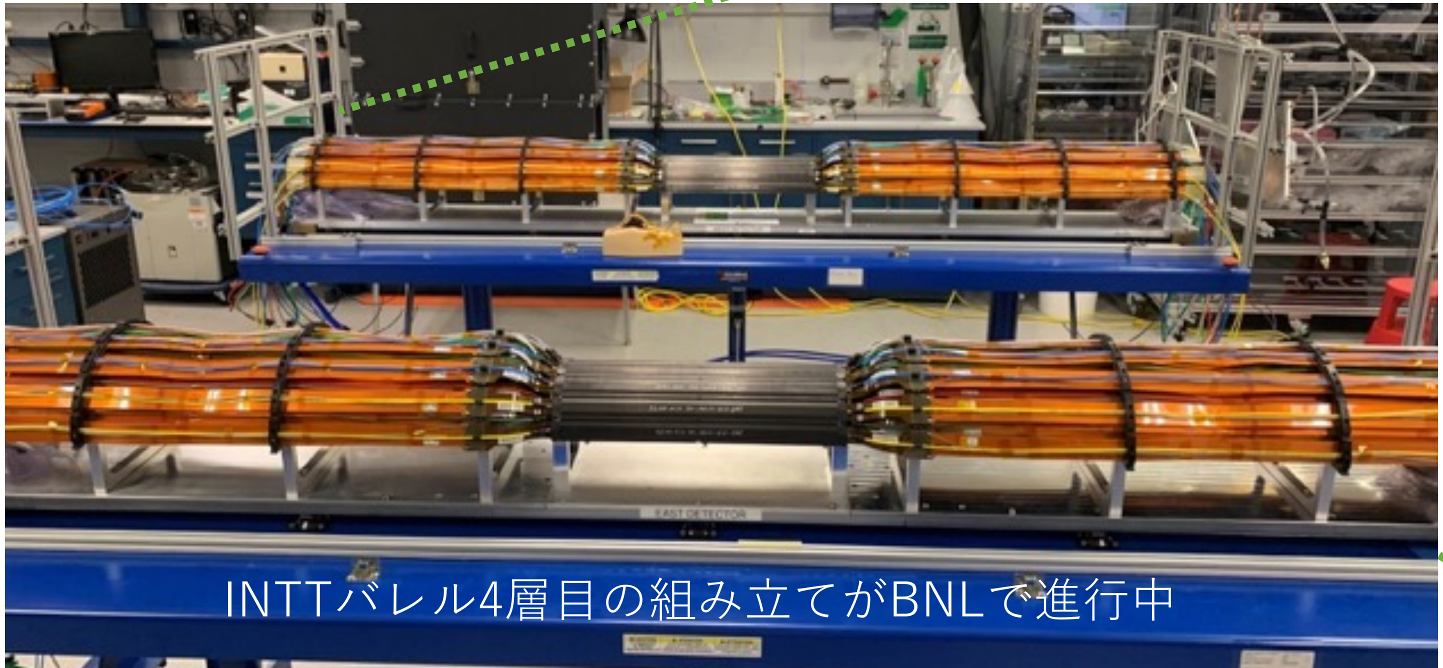
- 62 LVDSペア
- 400MHz
- 高信号密度伝送ケーブル

シリコンセンサー
(浜松フォトニクス社製)



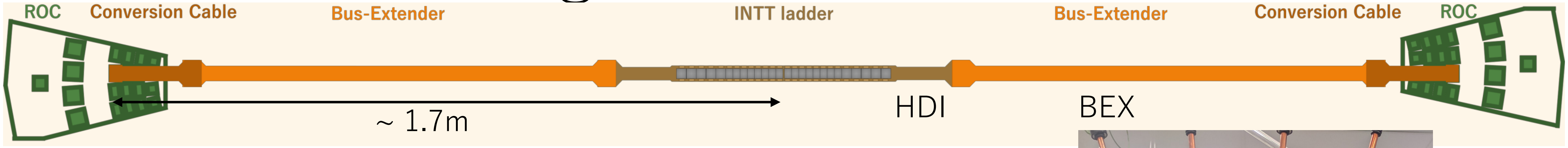


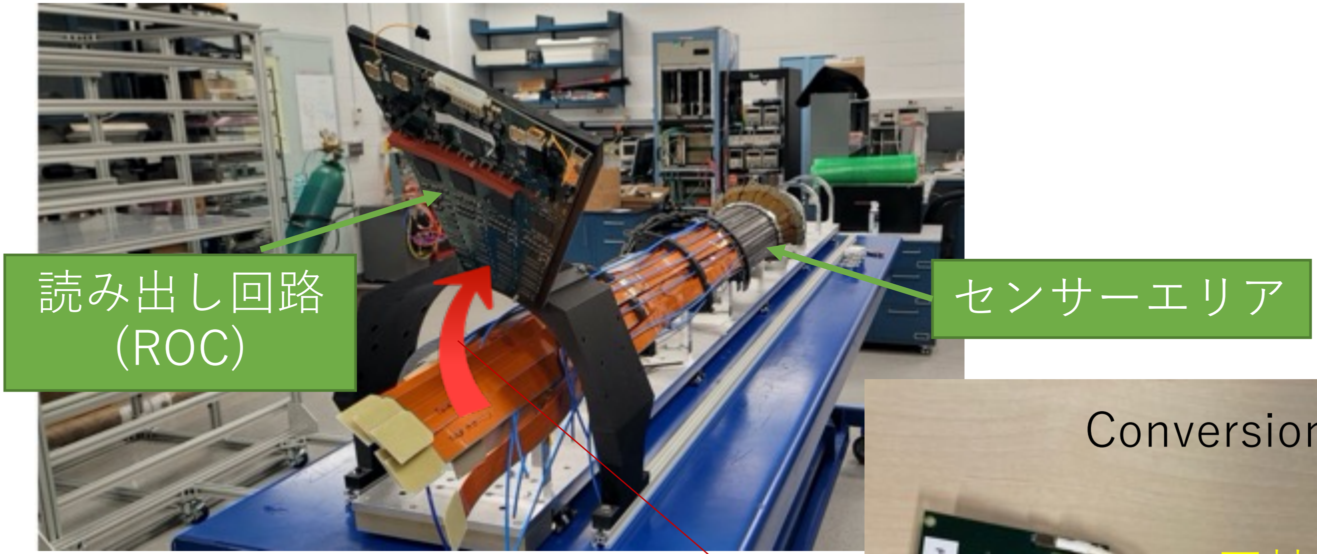
1層目：24ラダー
2層目：32ラダー
合計56ラダー

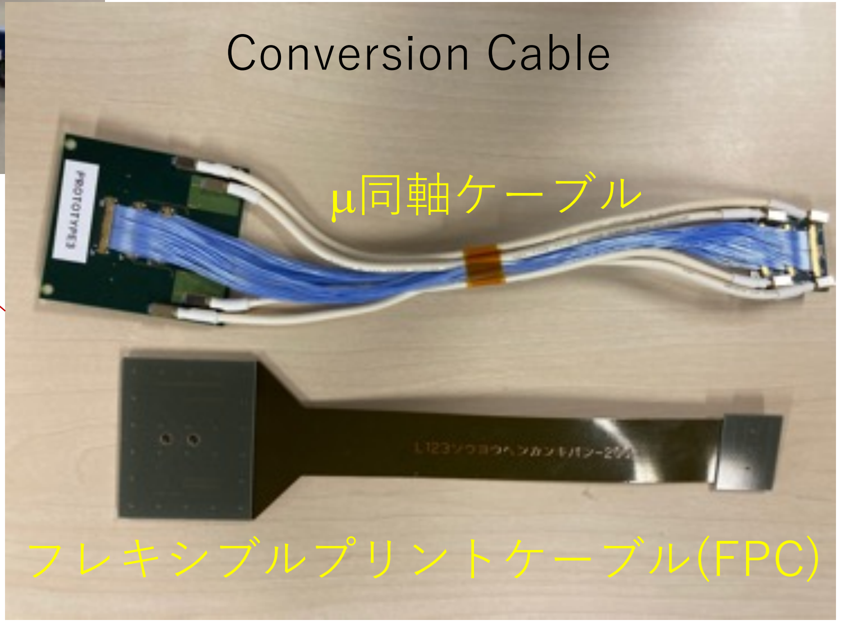


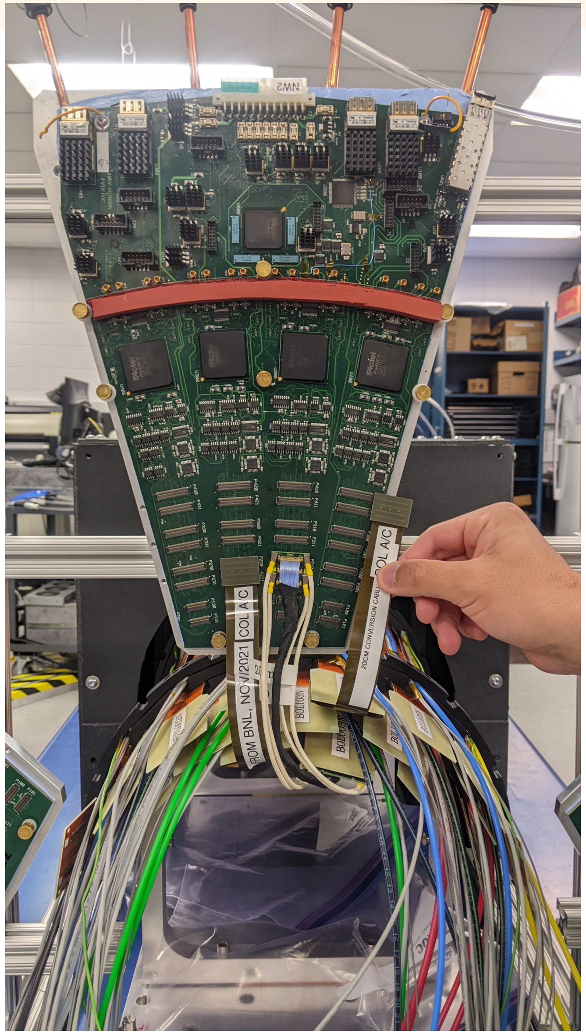
INTTバレル4層目の組み立てがBNLで進行中

Technical Challenge ~ INTT Readout Cable ~







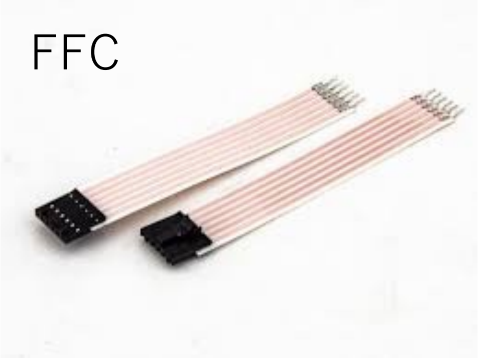


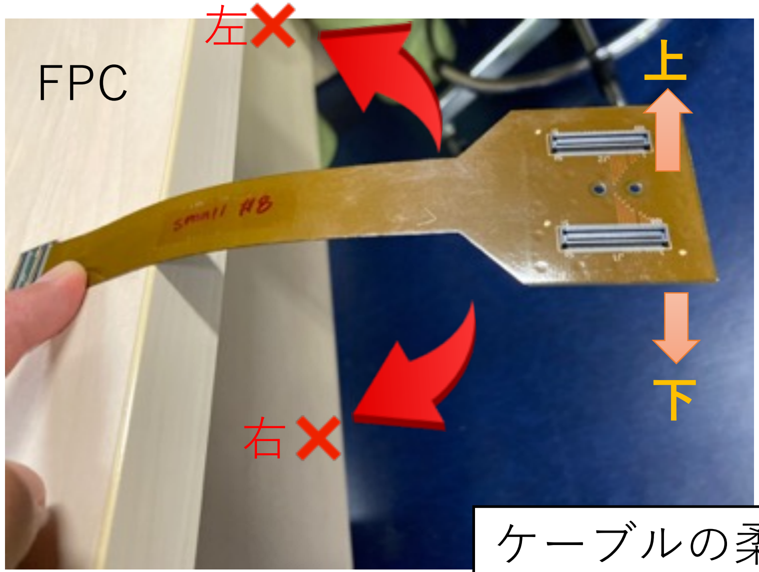
Conversion Cableの用途と要求：

- Bus Extenderから読み出し回路基板(ROC)に接続
- ３次元に柔軟性を持ち、ROCのコネクターにストレスがかからない。

Technology Choices

1. フレキシブルプリントケーブル(FPC)
2. フラットフレキシブルケーブル (FFC)
3. μ同軸ケーブル (μCC)



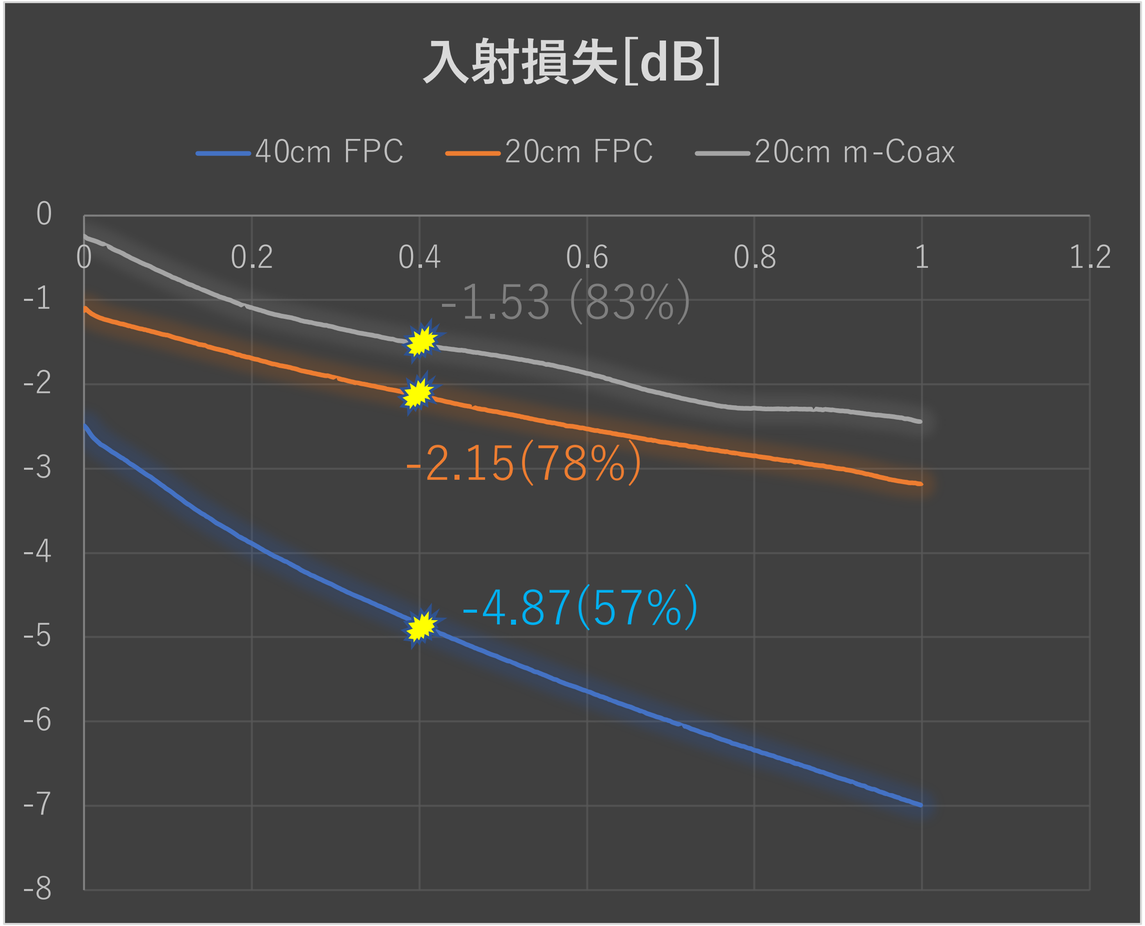


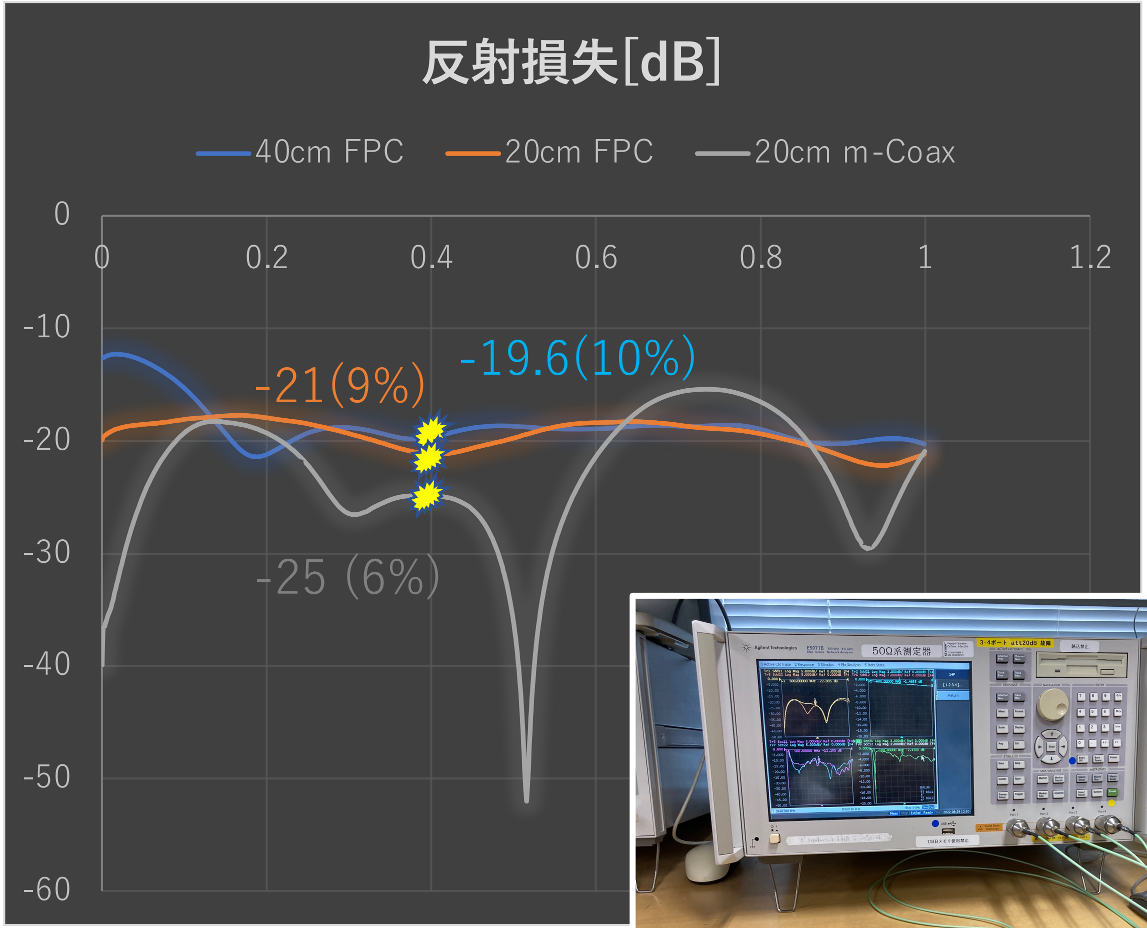
３次元の柔軟性

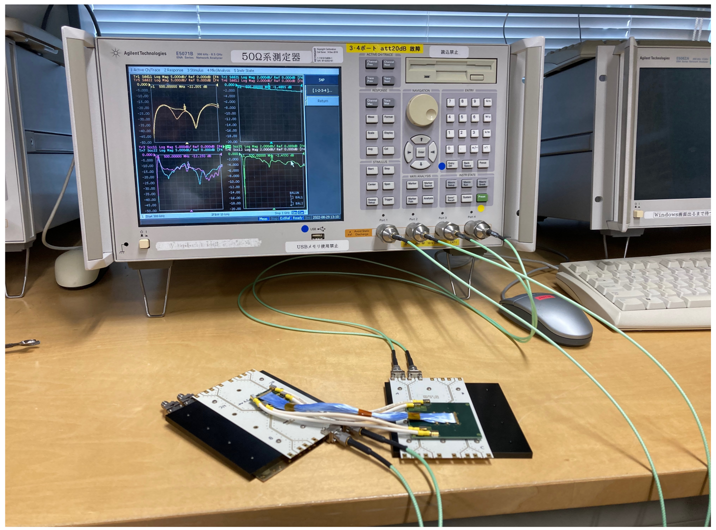
ケーブルの柔軟性比較

	FPC	FFC	μCC
信号線ピッチ [um]	60	500	250
シールド	Shielded	Not Shielded	Shielded
柔軟性	2D	2D	3D

Bus Extender + Conversion Cableの信号伝送性能





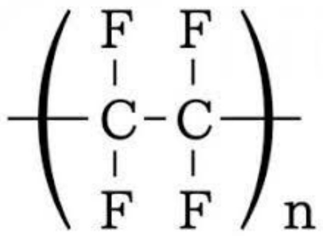


FPCよりも信号線路の断面積は大きいため、入射損失はμ同軸の方が少ない。

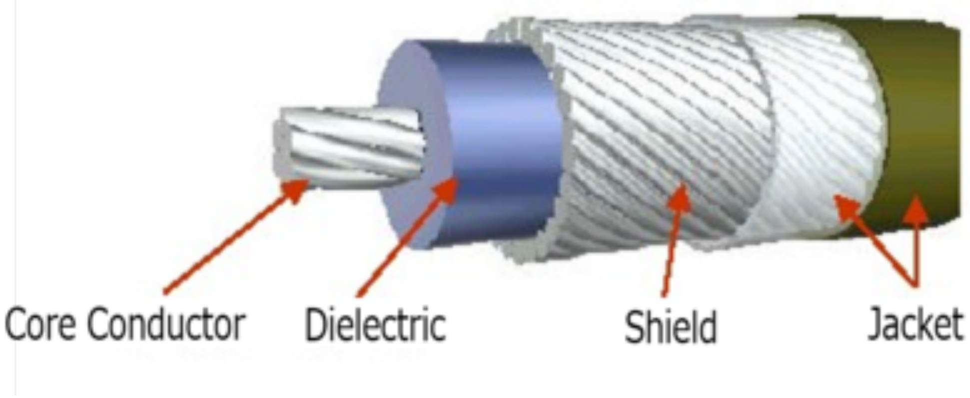
μ同軸ケーブルの構造

2. Construction and material Material Breakdown of micro-Coax

Item		Unit	Specified Value
Inner conductor	Material	-	Silver plated Copper Alloy wire
	AWG size	-	44
	Stranding	No./mm	7/0.02
	Dia.(approx.)	mm	0.06
Insulation	Material	-	PFA
	Thick.(nom.)	mm	0.037
	Dia. (approx.)	mm	0.134
	Color	-	Black
Outer Conductor	Material	-	Tinned copper alloy wire
	Type	-	Wrap(Right-hand lay)
	Strand Dia. (approx.)	mm	0.02
Jacket	Material	-	PFA
	Thick.(nom.)	mm	0.025
	Dia. (Max.)	mm	0.22(0.23)
	Color	-	Brown , Green



PTFE 化学式

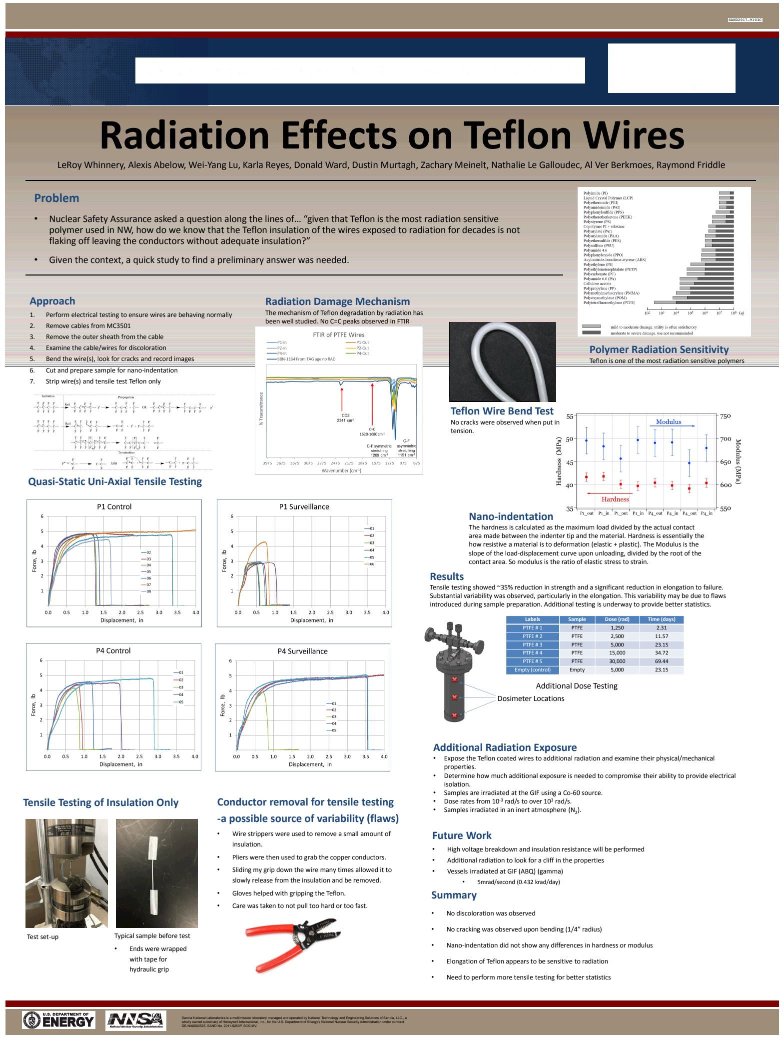


PFA（フッ素樹脂）=**パーフルオロアルコキシアルカン**
四フッ化エチレン・パーフルオロアルコキシエチレン共重合樹脂

http://www.diced.jp/~KAZU/syousya.txt.htm

絶縁体フッ化樹脂の放射線耐性

https://www.osti.gov/servlets/purl/1467983


Radiation Effects on Teflon Wires

LeRoy Whinnery, Alexis Abelow, Wei-Yang Lu, Karla Reyes, Donald Ward, Dustin Murtagh, Zachary Meinelt, Nathalie Le Galloudec, Al Ver Berkmoes, Raymond Friddle

Problem

- Nuclear Safety Assurance asked a question along the lines of… "given that Teflon is the most radiation sensitive polymer used in NW, how do we know that the Teflon insulation of the wires exposed to radiation for decades is not flaking off leaving the conductors without adequate insulation?"
- Given the context, a quick study to find a preliminary answer was needed.

Approach

1. Perform electrical testing to ensure wires are behaving normally
2. Remove cables from MC3501
3. Remove the outer sheath from the cable
4. Examine the cable/wires for discoloration
5. Bend the wire(s), look for cracks and record images
6. Cut and prepare sample for nano-indentation
7. Strip wire(s) and tensile test Teflon only

Radiation Damage Mechanism

The mechanism of Teflon degradation by radiation has been well studied. No C=C peaks observed in FTIR

Polymer Radiation Sensitivity

Teflon is one of the most radiation sensitive polymers

Teflon Wire Bend Test

No cracks were observed when put in tension.

Quasi-Static Uni-Axial Tensile Testing

Nano-indentation

The hardness is calculated as the maximum load divided by the actual contact area made between the indenter tip and the material. Hardness is essentially the how resistive a material is to deformation (elastic + plastic). The Modulus is the slope of the load-displacement curve upon unloading, divided by the root of the contact area. So modulus is the ratio of elastic stress to strain.

Results

Tensile testing showed ~35% reduction in strength and a significant reduction in elongation to failure. Substantial variability was observed, particularly in the elongation. This variability may be due to flaws introduced during sample preparation. Additional testing is underway to provide better statistics.

Labels	Sample	Dose (rad)	Time (days)
PTFE # 1	PTFE	1,250	2.31
PTFE # 2	PTFE	2,500	11.57
PTFE # 3	PTFE	5,000	23.15
PTFE # 4	PTFE	15,000	34.72
PTFE # 5	PTFE	30,000	69.44
Empty (control)	Empty	5,000	23.15

Additional Dose Testing

Dosimeter Locations

Additional Radiation Exposure

- Expose the Teflon coated wires to additional radiation and examine their physical/mechanical properties.
- Determine how much additional exposure is needed to compromise their ability to provide electrical isolation.
- Samples are irradiated at the GIF using a Co-60 source.
- Dose rates from 10³ rad/s to over 10⁵ rad/s.
- Samples irradiated in an inert atmosphere (N_2).

Tensile Testing of Insulation Only

Test set-up

Typical sample before test

- Ends were wrapped with tape for hydraulic grip

Conductor removal for tensile testing -a possible source of variability (flaws)

- Wire strippers were used to remove a small amount of insulation.
- Pliers were then used to grab the copper conductors.
- Sliding my grip down the wire many times allowed it to slowly release from the insulation and be removed.
- Gloves helped with gripping the Teflon.
- Care was taken to not pull too hard or too fast.

Future Work

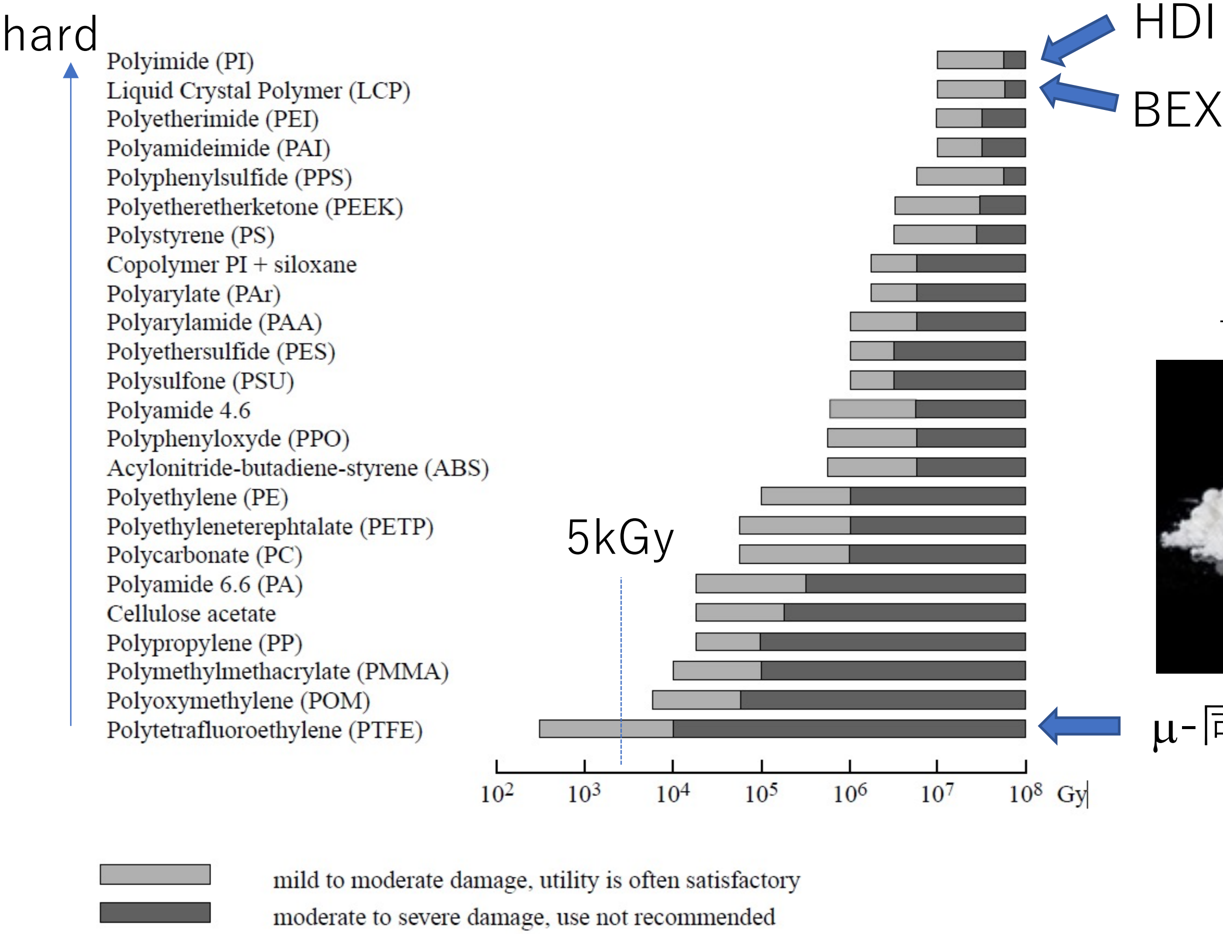
- High voltage breakdown and insulation resistance will be performed
- Additional radiation to look for a cliff in the properties
- Vessels irradiated at GIF (ABQ) (gamma)
  - 5mrad/second (0.432 krad/day)

Summary

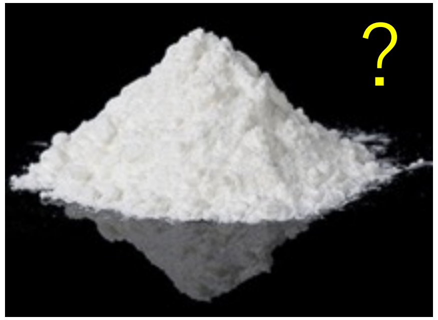
- No discoloration was observed
- No cracking was observed upon bending (1/4" radius)
- Nano-indentation did not show any differences in hardness or modulus
- Elongation of Teflon appears to be sensitive to radiation
- Need to perform more tensile testing for better statistics

U.S. DEPARTMENT OF ENERGY NNSA

Dielectric material



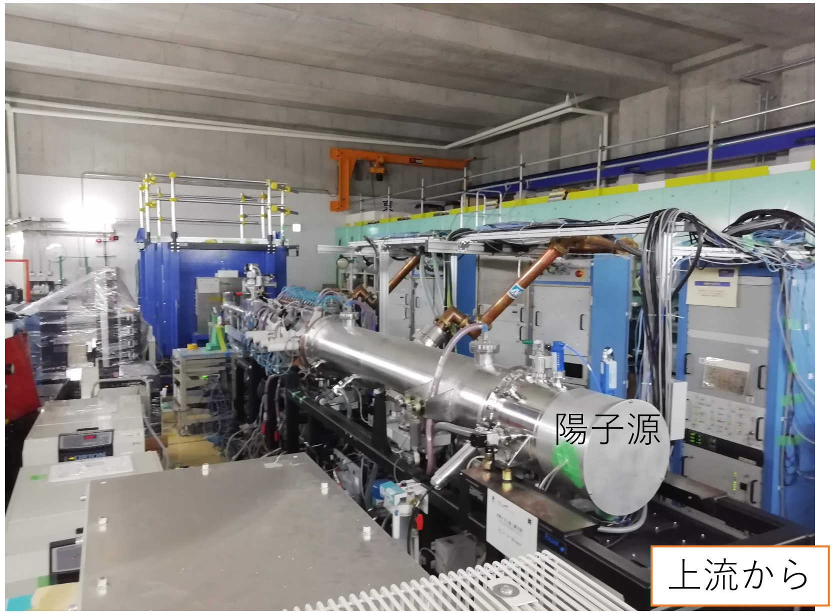
Torn into pieces?



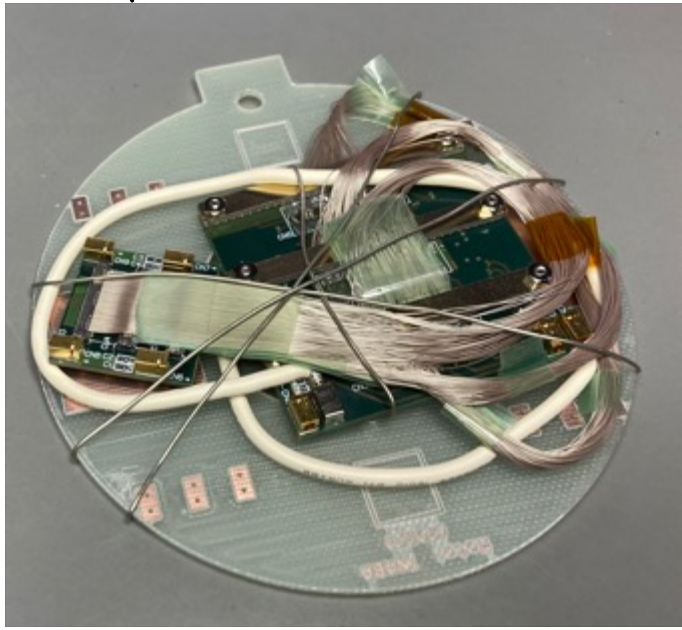
一般的にフッ化樹脂は放射線耐性が弱いとされる

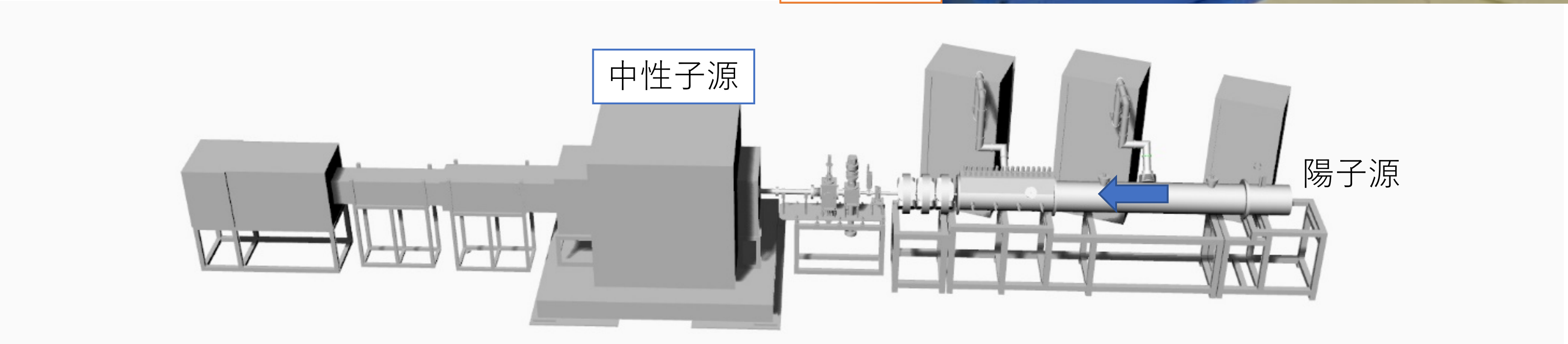
μ-同軸ケーブルの放射線耐性テスト

RIKEN Accelerator-driven compact Neutron Source: RANS実験施設



μ同軸照射サンプル

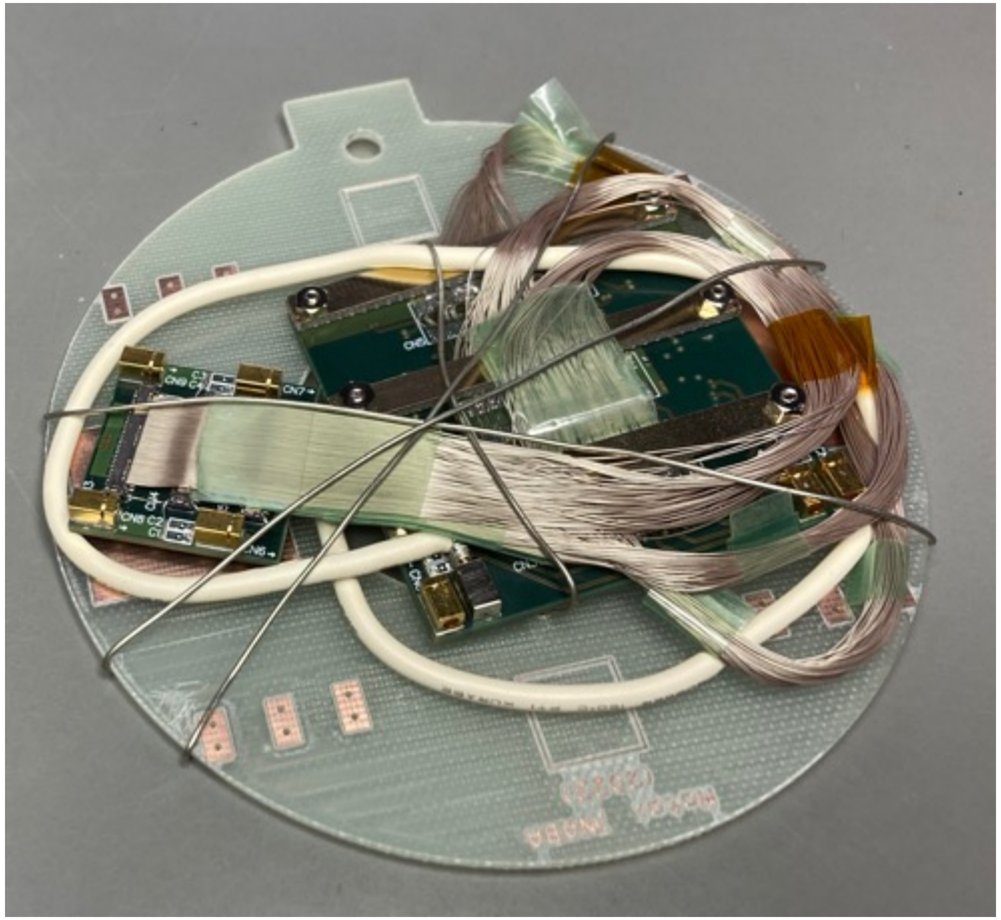




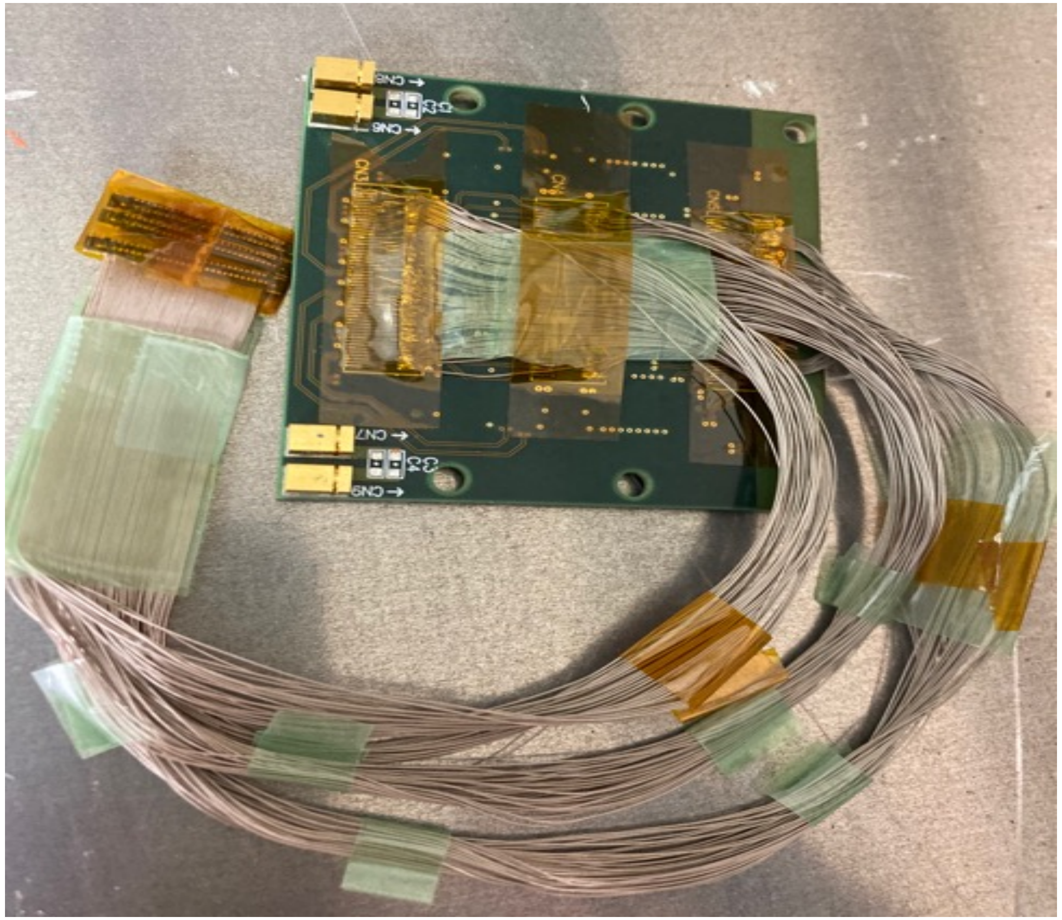
2022年3月に９時間照射
合計中性子フラックス：1.7×10^{13}
放射線耐性を評価する。

放射線によるダメージ

照射前



照射後



外観検査の範囲では、明らかなダメージは見受けられない。今後伝送特性などを測定する。

まとめ

- sPHENIX実験-INTTシリコン検出器用の読み出しケーブルを開発した。
- 高信号線密度・高伝送性能、且つ３次元の柔軟性を満たす技術としてマイクロ同軸を採用した。
- 試作の結果、これらの要求性能を満たすことを確認できた。
- 残す課題として、放射線耐性を検証する。