Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Visualizing Particles at the Tandem Van De Graaff Accelerator

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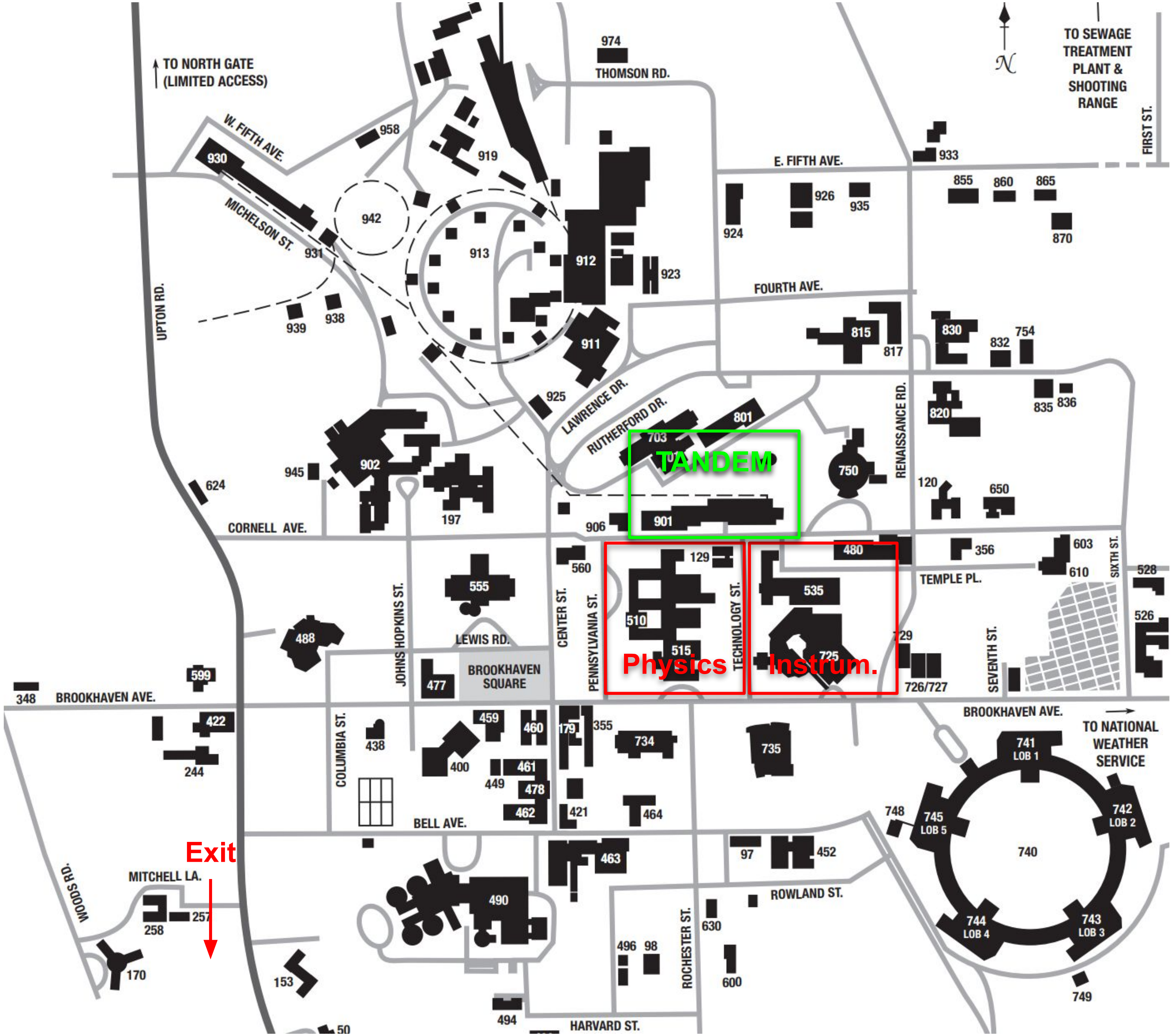
Map



TO NORTH GATE (LIMITED ACCESS)
TO SEWAGE TREATMENT PLANT & SHOOTING RANGE
THOMSON RD.
W. FIFTH AVE.
MICHELSON ST.
E. FIFTH AVE.
FOURTH AVE.
UPTON RD.
LAWRENCE DR.
RUTHERFORD DR.
RENAISSANCE RD.
FIRST ST.
CORNELL AVE.
TANDEM
Physics
Instrum.
TEMPLE PL.
SIXTH ST.
SEVENTH ST.
JOHNS HOPKINS ST.
LEWIS RD.
CENTER ST.
PENNSYLVANIA ST.
TECHNOLOGY ST.
BROOKHAVEN SQUARE
BROOKHAVEN AVE.
TO NATIONAL WEATHER SERVICE
COLUMBIA ST.
BELL AVE.
Exit
MITCHELL LA.
WOODS RD.
ROWLAND ST.
ROCHESTER ST.
HARVARD ST.
LOB 1
LOB 2
LOB 3
LOB 4
LOB 5

The Tandem Van de Graaff

Accelerator overview

Introduction

Brookhaven National Laboratory's large **Tandem Van de Graaff** facility consists of two 15-Megavolt electrostatic accelerators

Can produce ion beams of most chemical elements (from protons accelerated to 29 MeV to gold ions accelerated to 337 MeV

The facility delivers these beams to various irradiation chambers available to users from academia, industry, and other research institutions

Introduction

BROOKHAVEN BULLETIN

Published by the Brookhaven National Laboratory Public Relations Office

Volume 24, Number 45 November 19, 1970

BNL Linac Makes High Energy Record

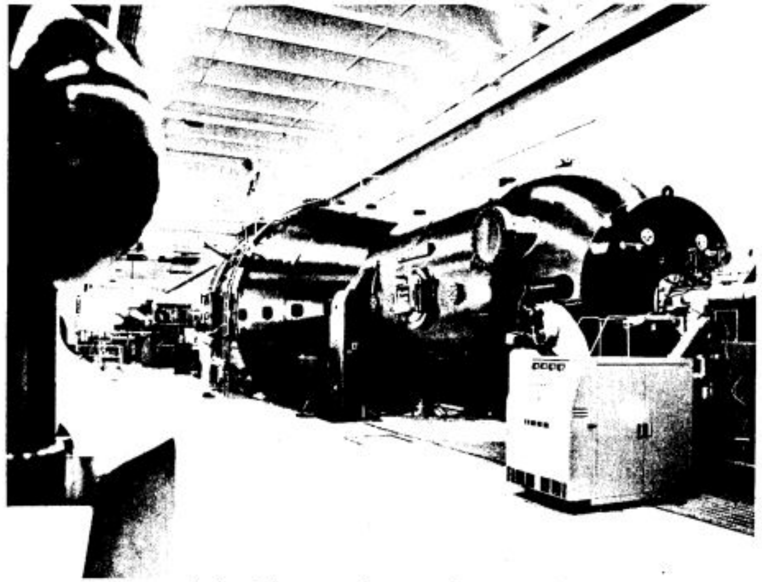
The AGS Conversion Group working on the 200 MeV (Million electron Volts) linear accelerator achieved full design energy of 200 MeV on Wednesday, November 18, at 1:44 a.m. The linac had reached 160.5 MeV during the late hours of November 16-17, surpassing the energy level of all other proton linacs, and, thus, became the most powerful proton linac presently in existence.

As the 200 MeV energy was approached in the early hours of Wednesday morning, many accelerator people came in to lend a hand at achieving the record. Dr. Fred Mills, Chairman of the Accelerator Department was joined by John Blewett, Jules Spiro, Jack Lancaster, and members of the Linac bowling team still wearing their "Sandbagger" shirts.

According to George Wheeler, in charge of the Conversion project, the linac was designed to deliver a beam current in excess of 100 milliamperes at 200 MeV. Earlier studies of the beam current showed that 200 milliamperes was actually attainable. This earlier measurement confirmed that the proper engineering decisions had been made during the early stages of design.

Delicate balancing of variables was necessary to permit acceleration through

World's Highest Energy Van de Graaff Is Dedicated



A view of the two accelerators as they appear today at the Tandem Van de Graaff facility.

The world's highest energy Van de Graaff system which is designed to accelerate hydrogen ions to an energy of 30 MeV (million electron volts) will be dedicated today.

AEC Commissioner Theos J. Thompson will deliver the Dedication Address at 2:30 p.m. in Berkner Hall. Other speakers at the ceremony will be: Denys H. Wilkinson, Director of the Nuclear Physics Laboratory, Oxford, England; D. Allan Bromley, Director of the Arthur W. Wright Nuclear Structure Laboratory, Yale University; and Harvey E. Wegner, Manager of the Tandem Van de Graaff Construction Project.

According to Commissioner Thompson, "Both Brookhaven National Laboratory and the High Voltage Engineering Corporation can be justly proud of the successful design construction, and operation of this accelerator system. The fact that a facility of this complexity, originally estimated to cost $12 million in 1962, has been completed in 1970 at a cost of $12,130,000, is a little short of miraculous. It should be a source of substantial pride not only for the Laboratory, but also for the Atomic En-

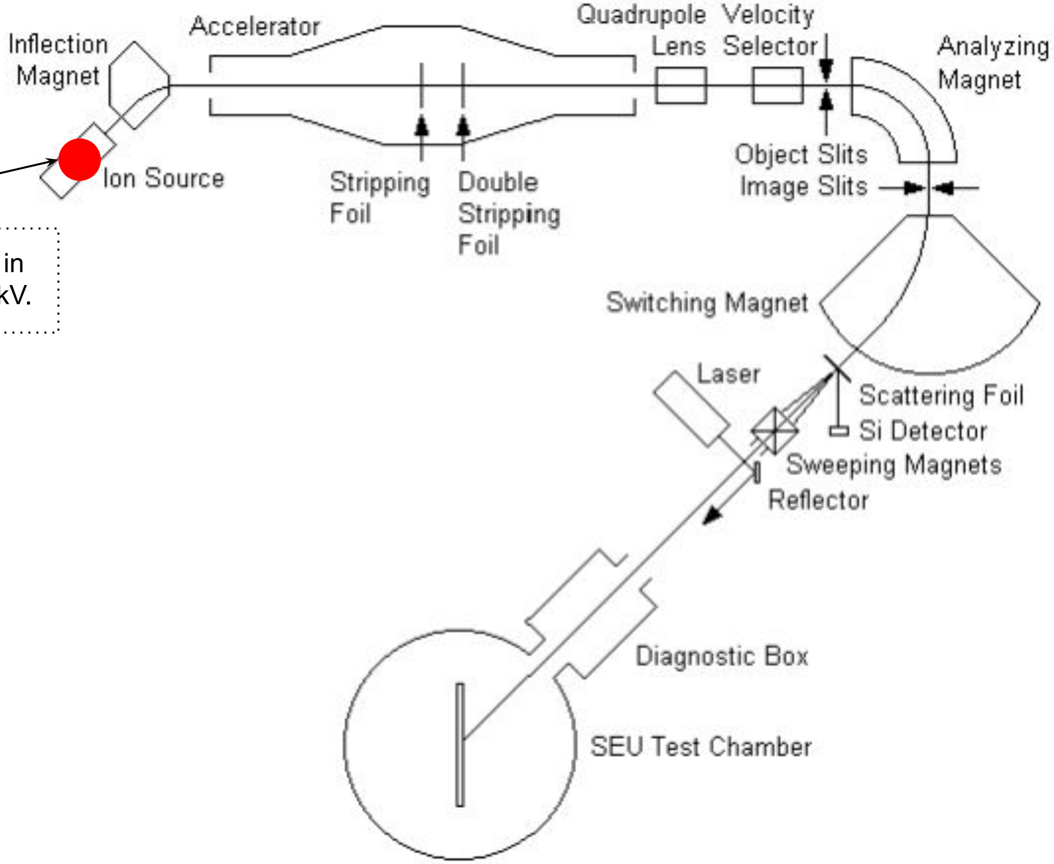
Maurice Goldhaber Wins Bonner Physics Prize

Beam types

Flux can be in the range of 1 particle/cm^2/sec to greater than $1 \cdot 10^6$ particles/cm^2/sec.					In Silicon High LET Summary Low LET Summary How To Use Th	
		Mass	Max Energy		Surface LET	Range
Z	Symbol	AMU	MeV	MeV/AMU	MeV/(mg/cm^2)	Microns
1	^{1}H	1.0079	28.75	28.52	0.0153	4550
2	^{4}He	6.0029	43.2	10.80	0.131	815.0
3	^{7}Li	7.0160	57.2	8.15	0.369	390
5	^{11}B	11.0093	85.5	7.77	1.08	206.13
6	^{12}C	12.0000	99.6	8.30	1.46	180.43
8	^{16}O	15.9994	128	8.00	2.61	137.78
9	^{19}F	18.9954	142	7.48	3.51	118.88
12	^{24}Mg	23.9927	161	6.71	6.01	84.16
14	^{28}Si	28.0855	187	6.66	7.81	77.16
17	^{35}Cl	34.9688	212	6.06	11.5	64.41
20	^{40}Ca	39.9753	221	5.53	15.8	51.89
22	^{48}Ti	47.9479	232	4.84	19.6	47.8
24	^{52}Cr	51.9405	245	4.72	22.3	45.86
26	^{56}Fe	55.9349	259	4.63	25.1	44.24
28	^{58}Ni	57.9353	270	4.66	27.9	44.56
29	^{63}Cu	62.9296	277	4.40	30.1	42.06
32	^{72}Ge	71.9221	273	3.80	35.9	37.94
35	^{81}Br	80.9163	287	3.55	41.3	37.50
41	^{93}Nb	92.9060	300	3.23	47.5	36.32
47	^{107}Ag	106.9051	313	2.93	59.2	32.48
53	^{127}I	126.9045	322	2.54	66.9	32.54
79	^{197}Au	196.9665	337	1.71	84.6	29.21

What does Tandem mean?

How it works



Single charged negative ions are generated in a sputter-type **ion source** operated at -150 kV.

How it works

Preliminary mass selection is performed by an **inflection magnet** operated at -120 kV with resolution of 2.5 %

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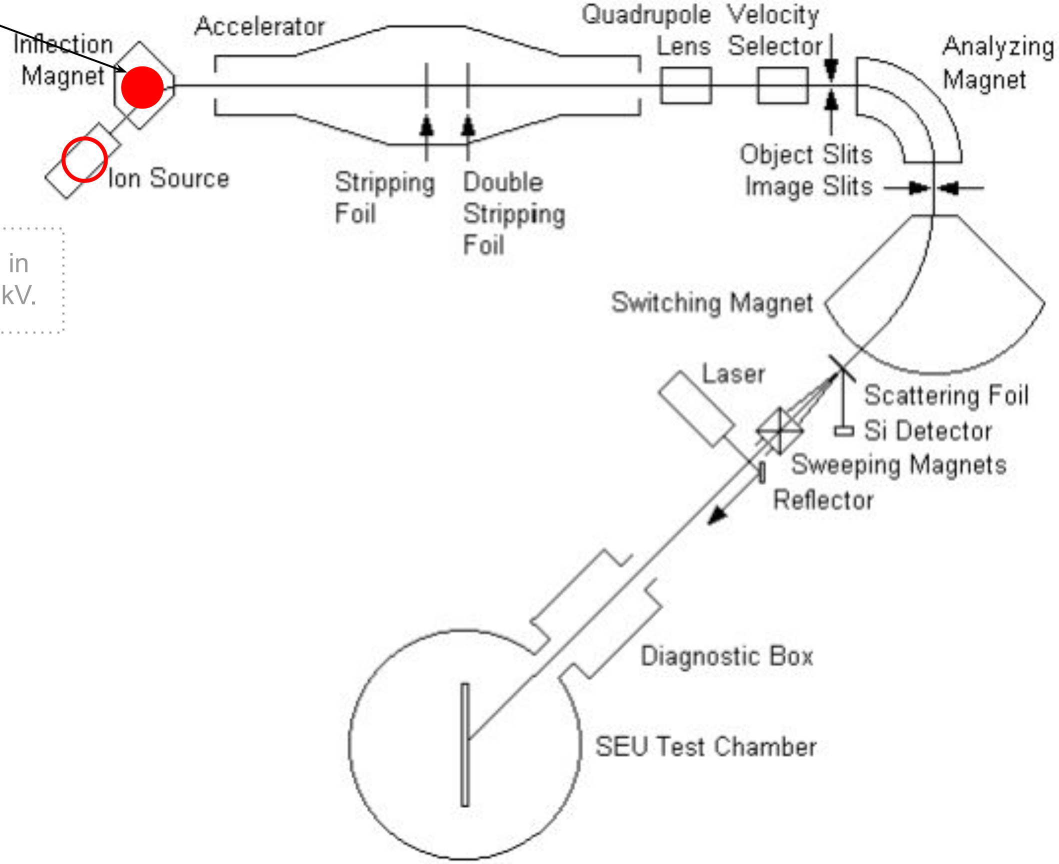

How it works

The negative 150 keV ions are accelerated in an evacuated **acceleration tube** to the positive high voltage terminal operated at voltages 1 to 14.5 MV, gaining energy 1 to 14.5 MeV.

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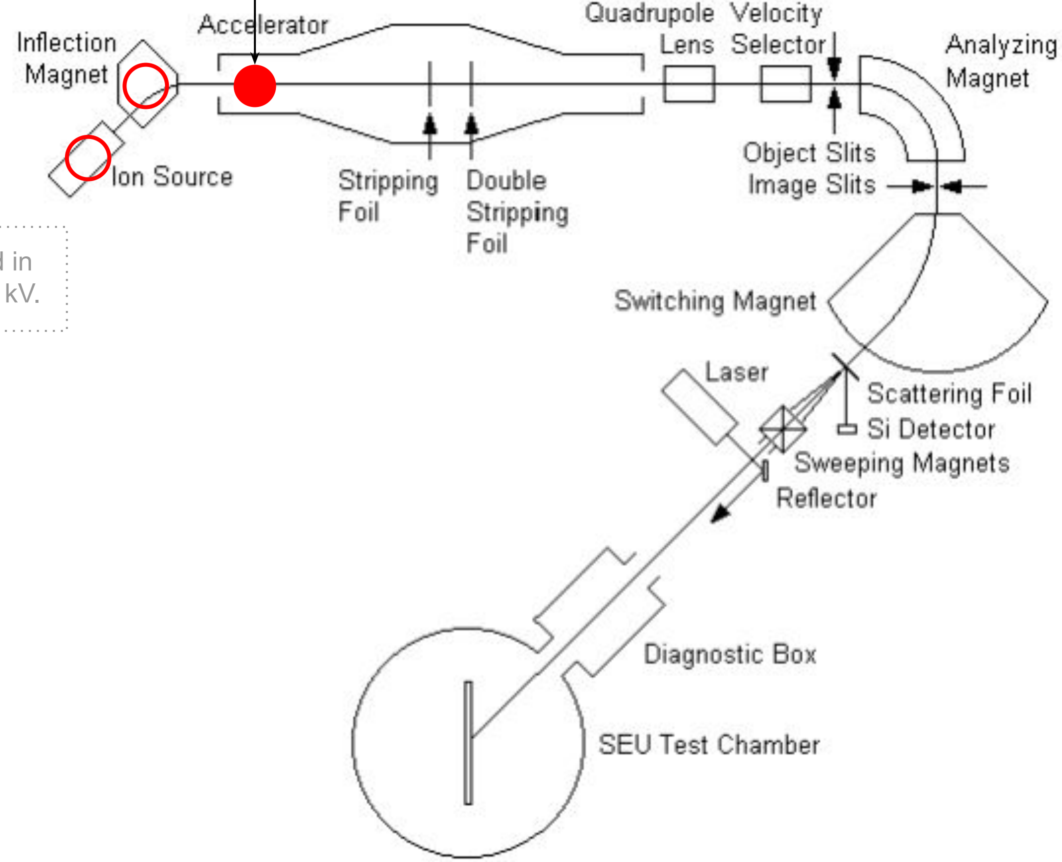

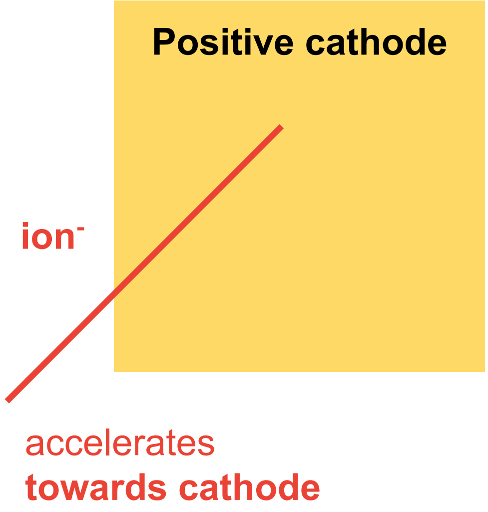

How it works

In the high voltage terminal, single charged negative ions are converted into multiple charged positive ions by passing through a thin carbon **stripping foil**.

The foil strips away several electrons from the ions but it is thin enough to cause a negligible energy loss (<0.05 % of the final energy for the heaviest ions). The multiple charged positive ions are accelerated away from the positive high voltage terminal, gaining energy up to 14.5 MeV/e.

A **second stripping foil** located at 75 % of terminal voltage can be optionally used to achieve higher charge states and higher energy gain in the last stage of acceleration.

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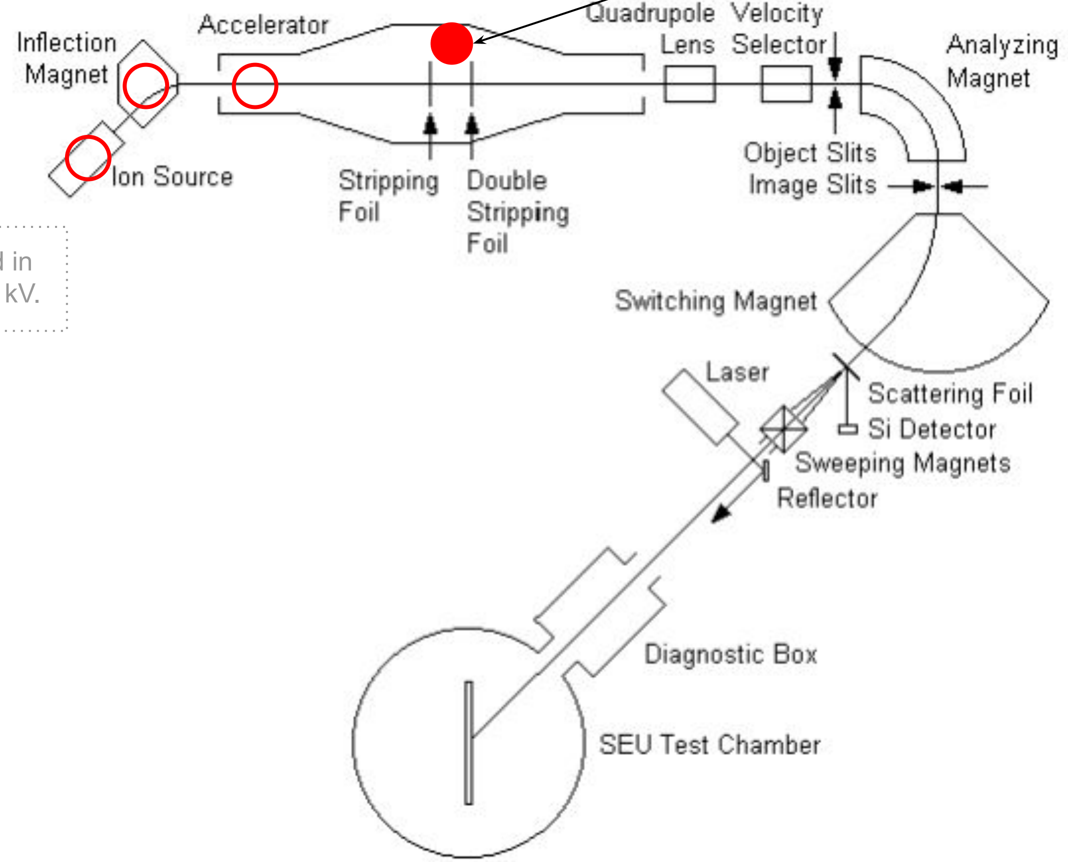

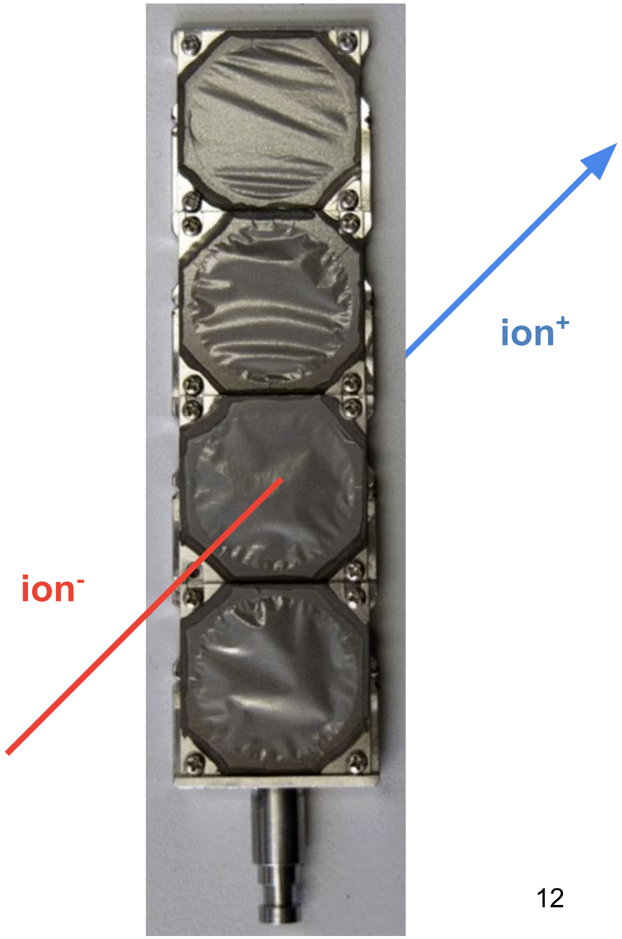

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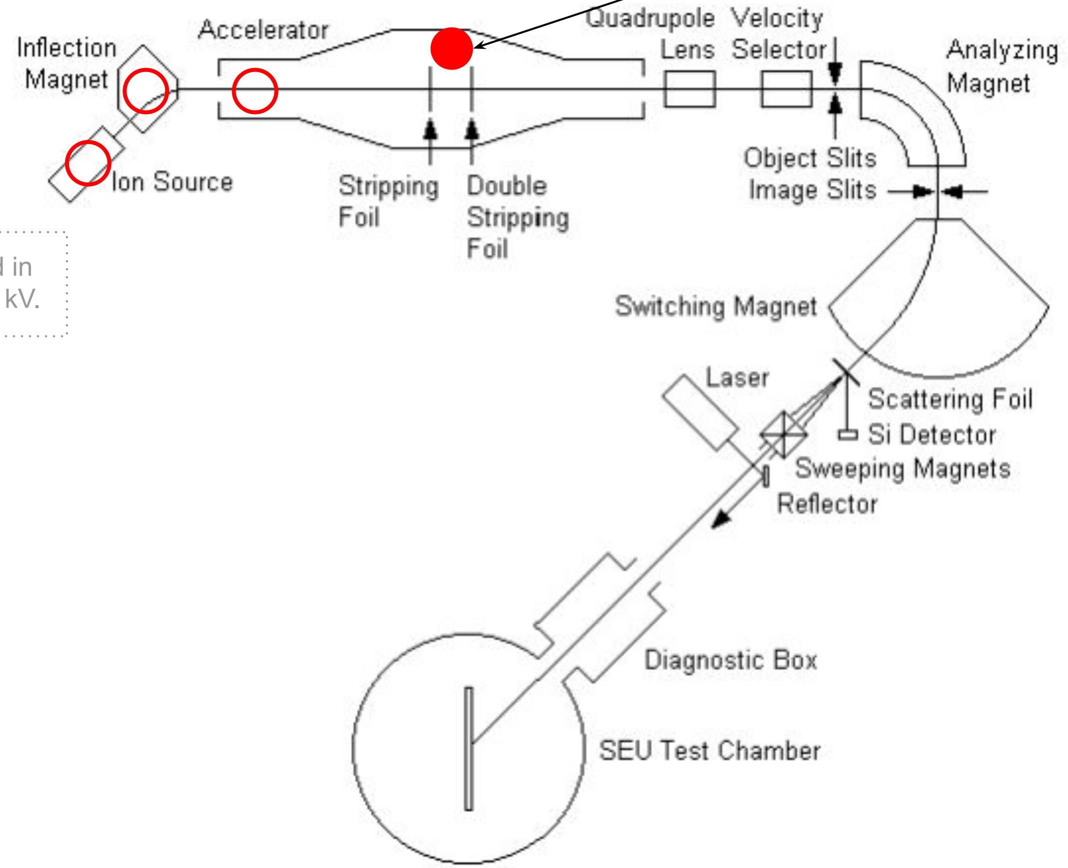

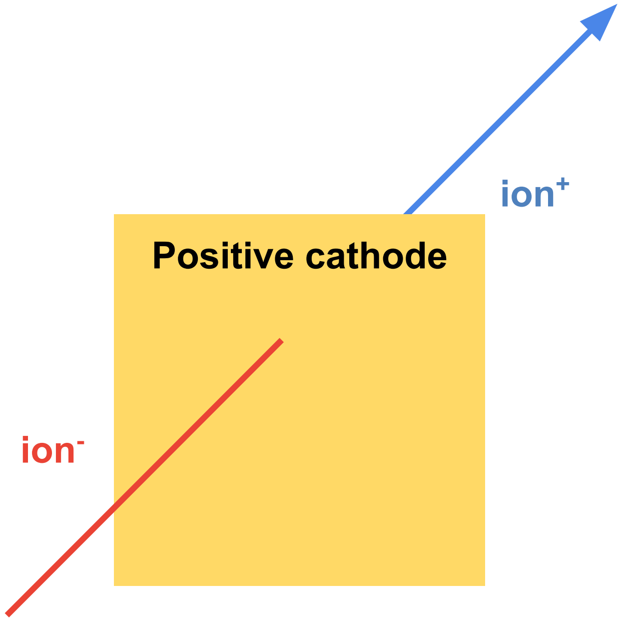

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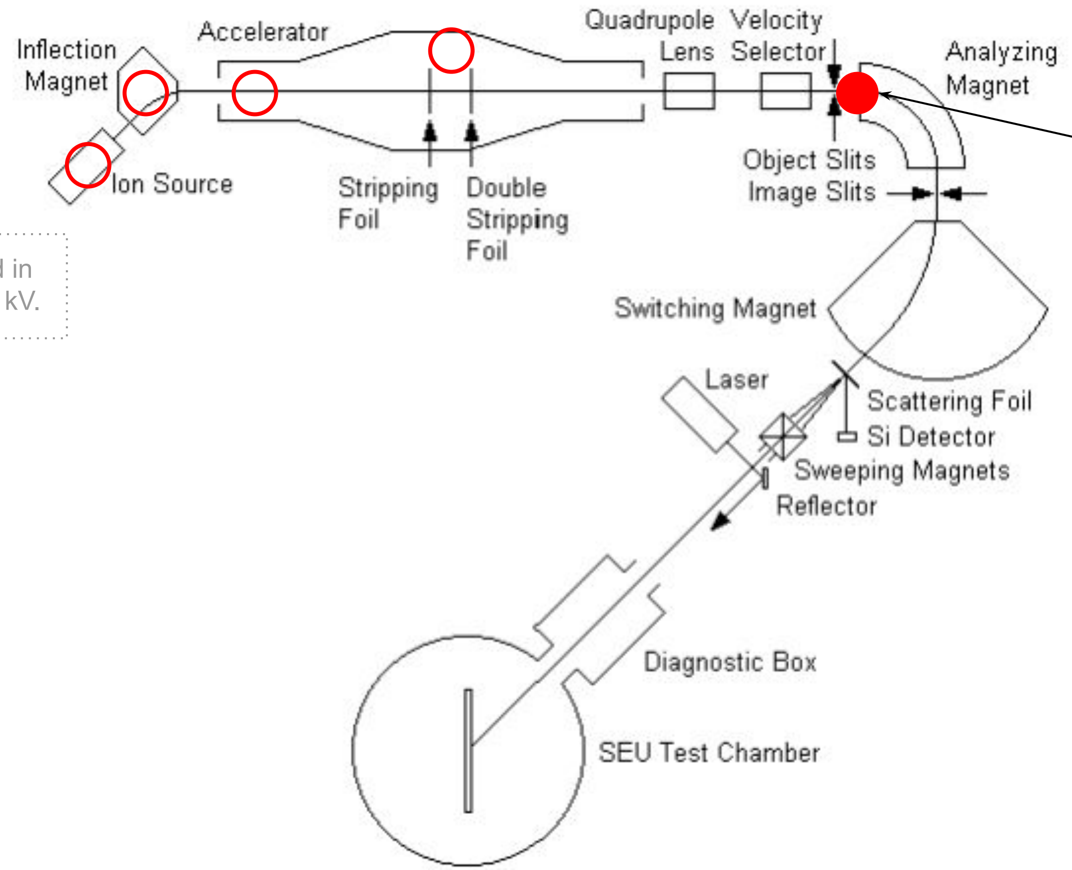

A single charge component is selected by a highly precise double focusing **analyzing magnet** in conjunction with narrow object and image slits according to its magnetic rigidity (momentum divided by charge).

A cross-field electrostatic and magnetic **velocity selector** (Wien filter) is installed in front of the analyzing magnet.

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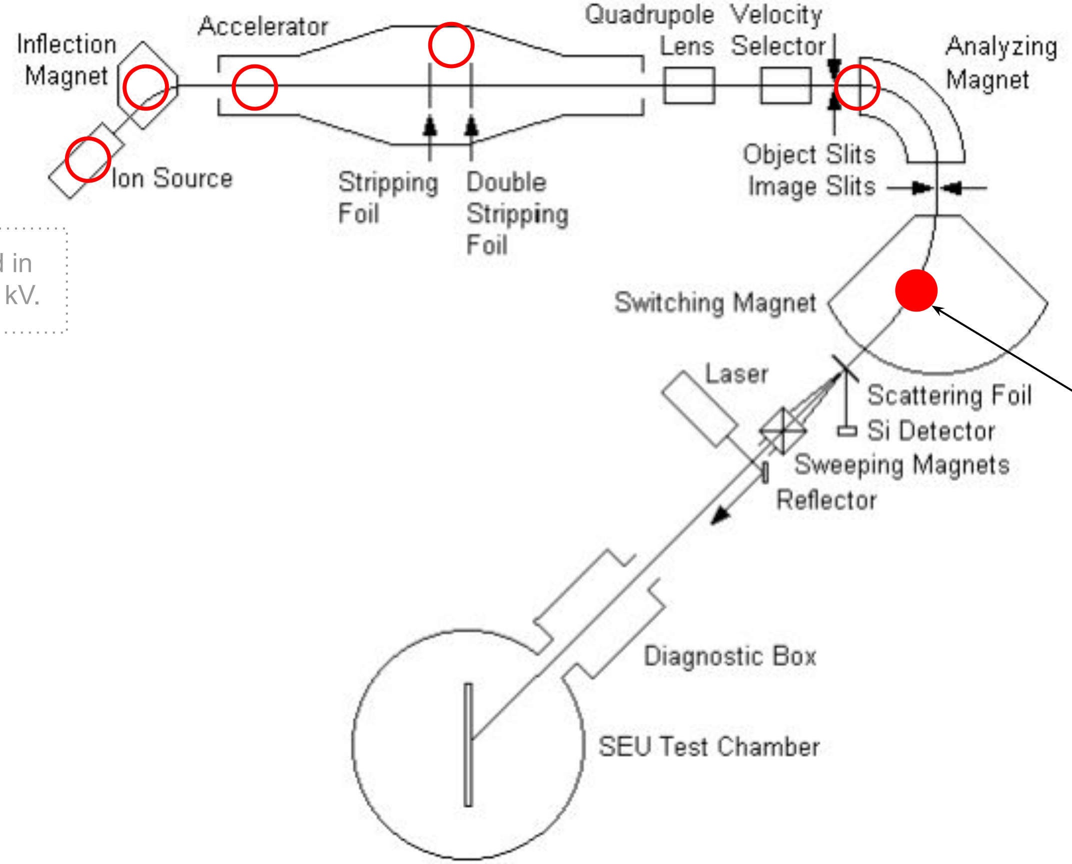

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A cross-field electrostatic and magnetic velocity selector (Wien filter) is installed in front of the analyzing magnet.

The selected beam is deflected by the **switcher magnet** into the 55° east beamline.

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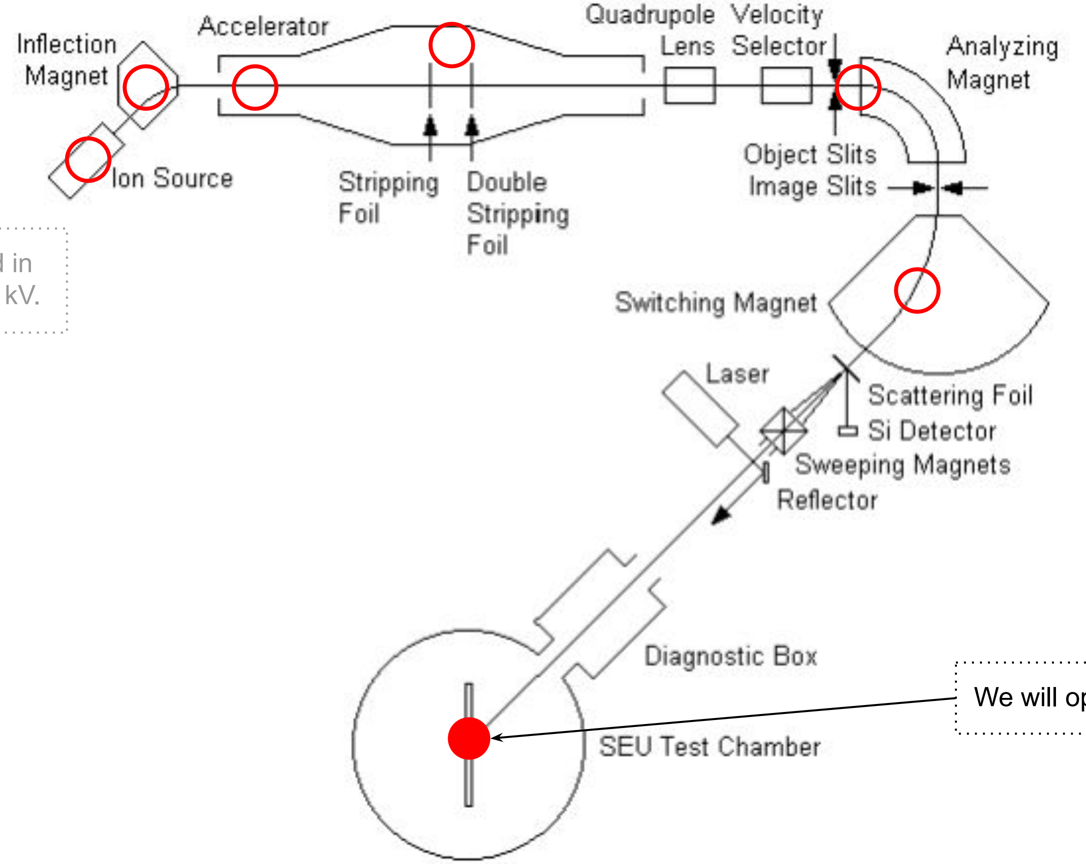

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The selected beam is deflected by the switcher magnet into the 55° east beamline and allowed to traverse a thin multiple scattering gold foil.

We will operate in the SEU (Single Event Upset) Test Chamber.

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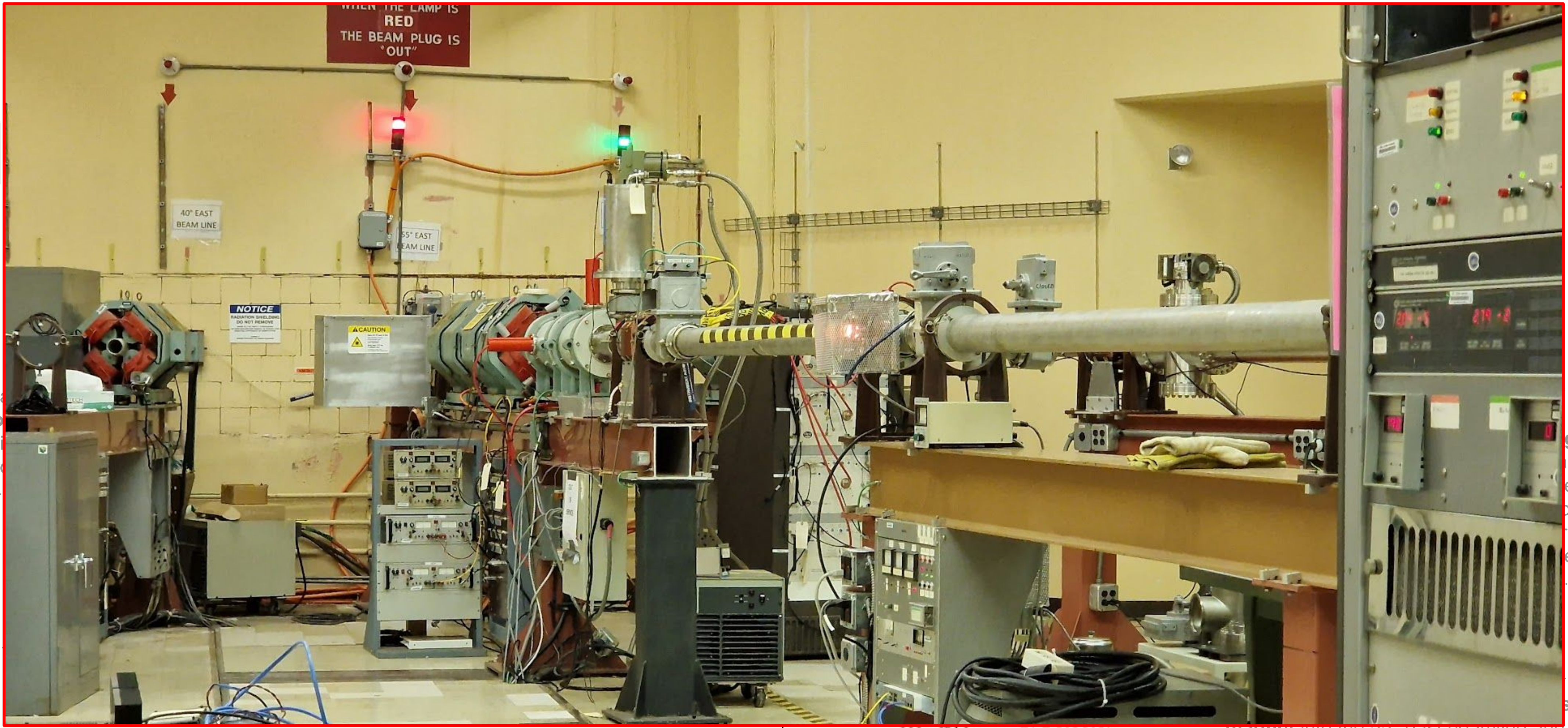

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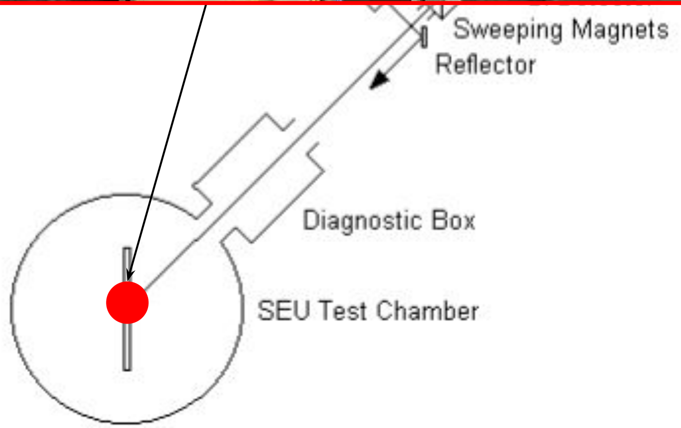
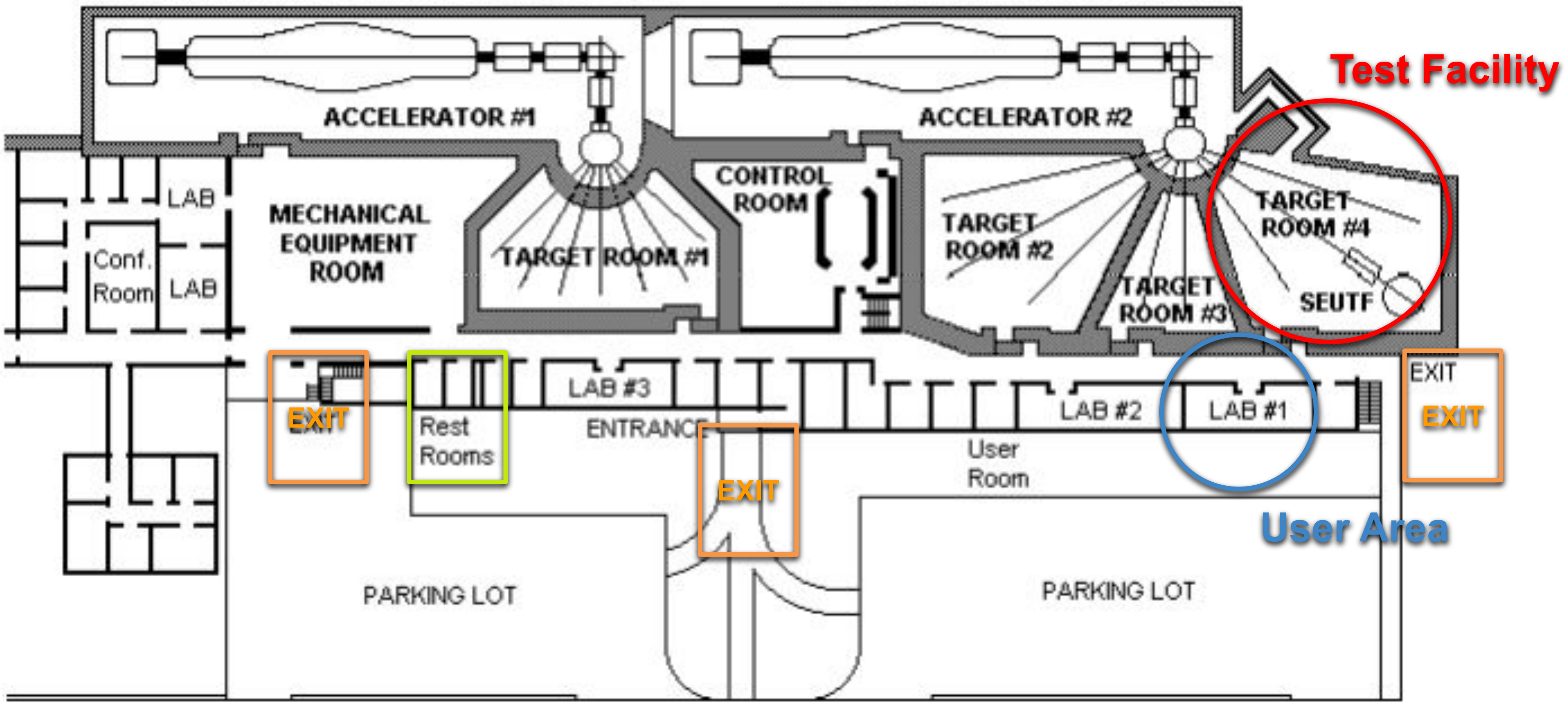


switcher
magnet into the 55° east beamline and allowed to traverse a thin multiple **scattering gold foil** (600 mg/cm² or more).

The test facility

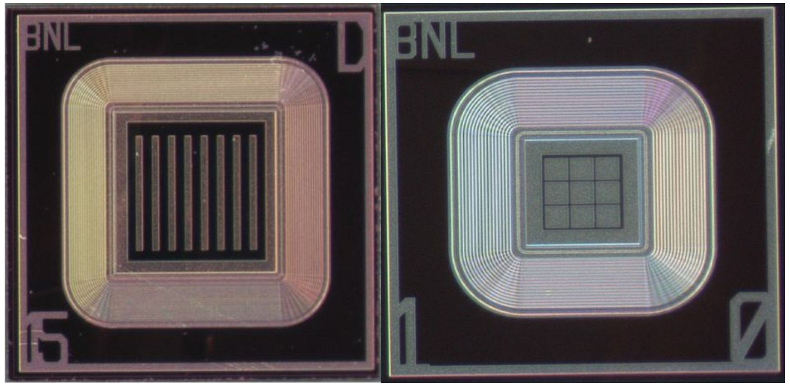


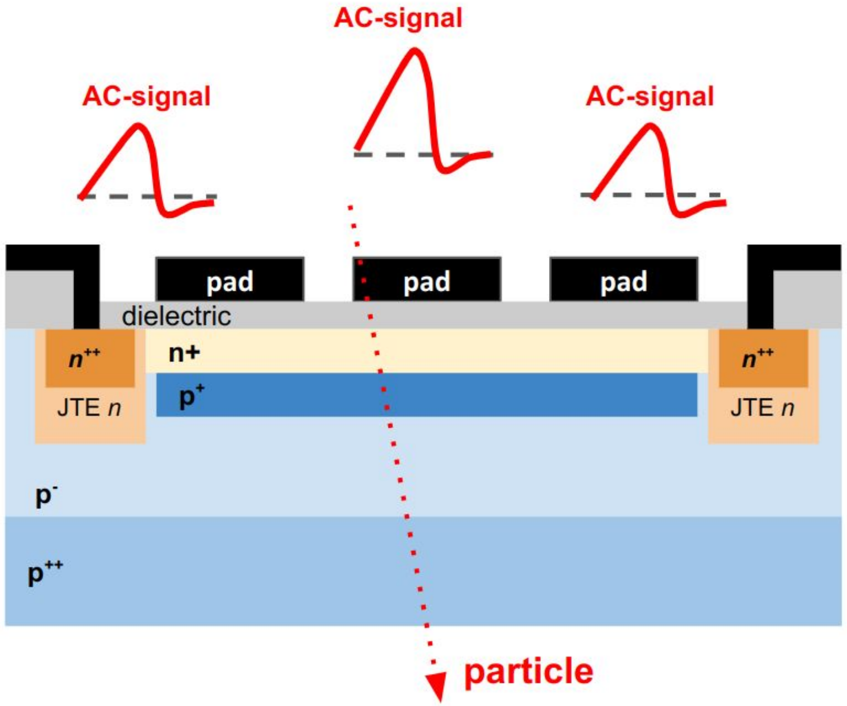
Visualizing Particles

The AC-LGAD silicon sensor

AC-coupled **L**ow **G**ain **A**valanche **D**etector

Silicon detector proposed in 2015

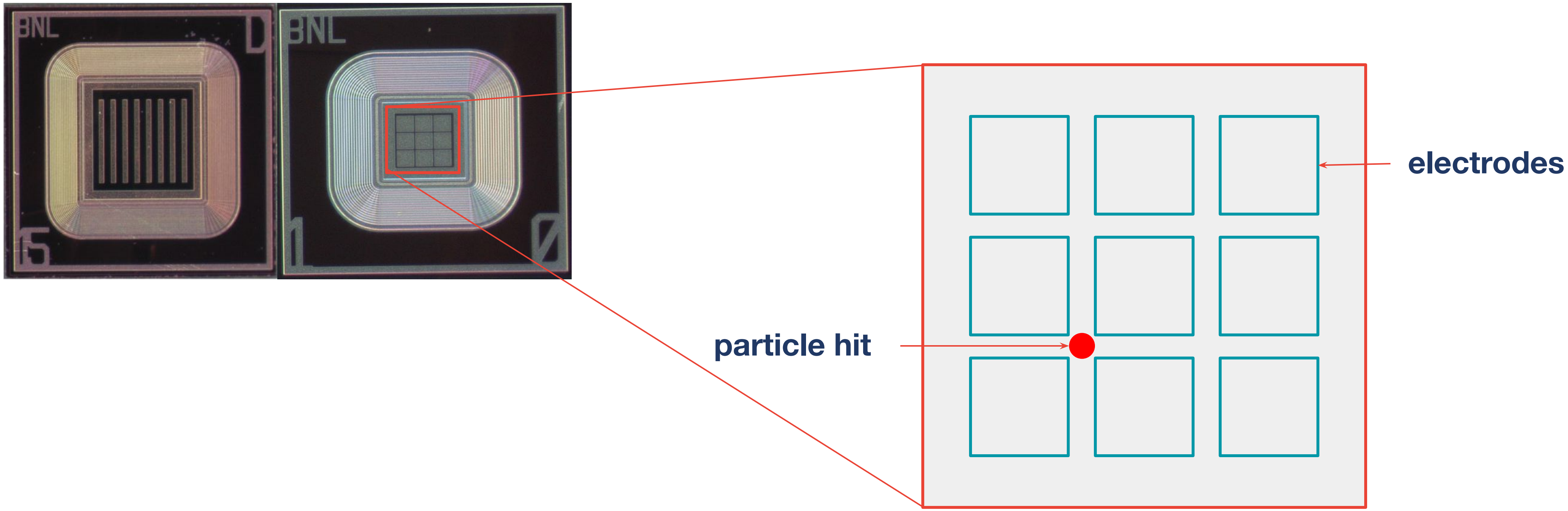




The AC-LGAD silicon sensor

Excellent time resolution (LGAD-like) thanks to **internal gain**

Excellent space resolution thanks to **Signal Sharing**



Shared signal seen by pads

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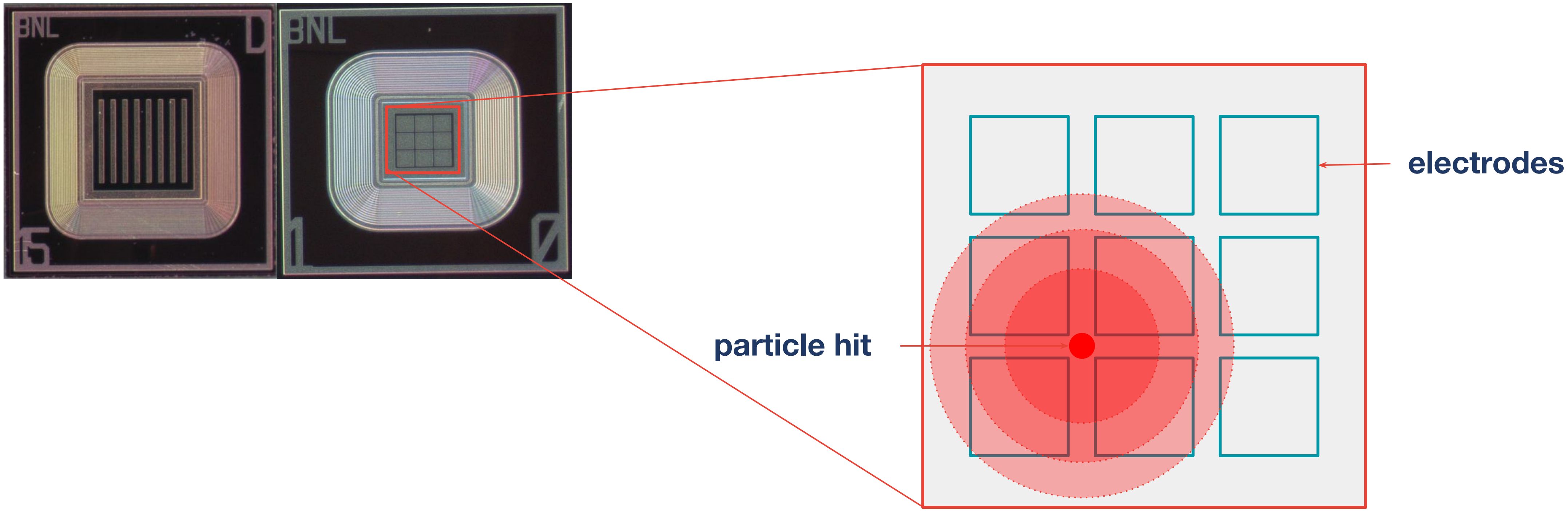


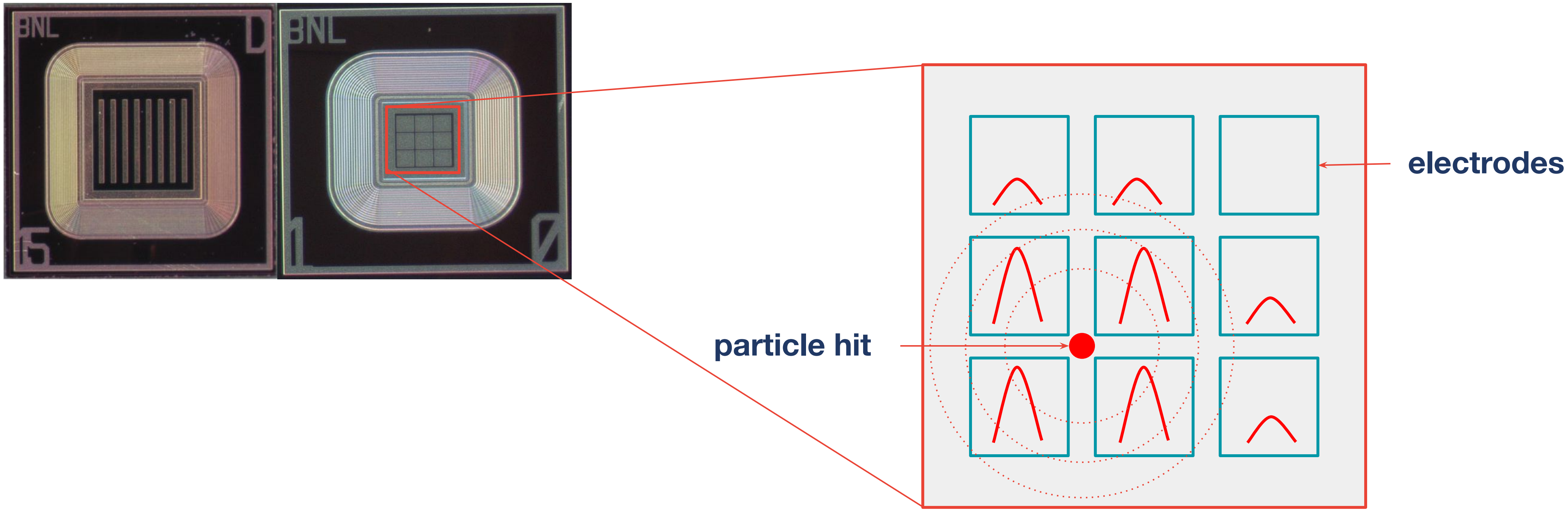
Shared signal seen by pads

The AC-LGAD silicon sensor

Signal **shared among multiple pads** (pixels/strips)

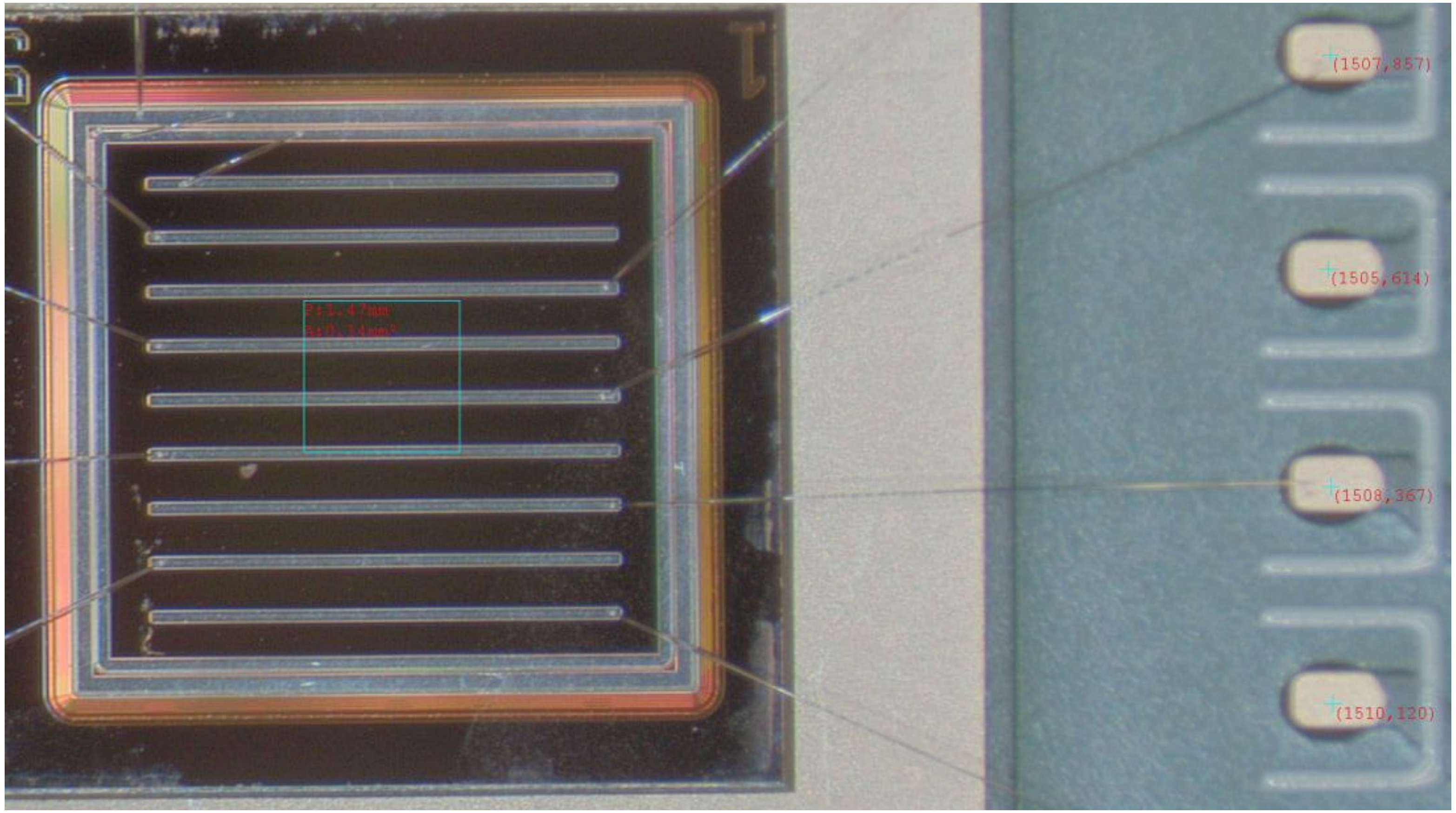
Pad response **proportional to distance** to interaction

Allows for **high spatial resolution** with low granularity



Shared signal seen by pads

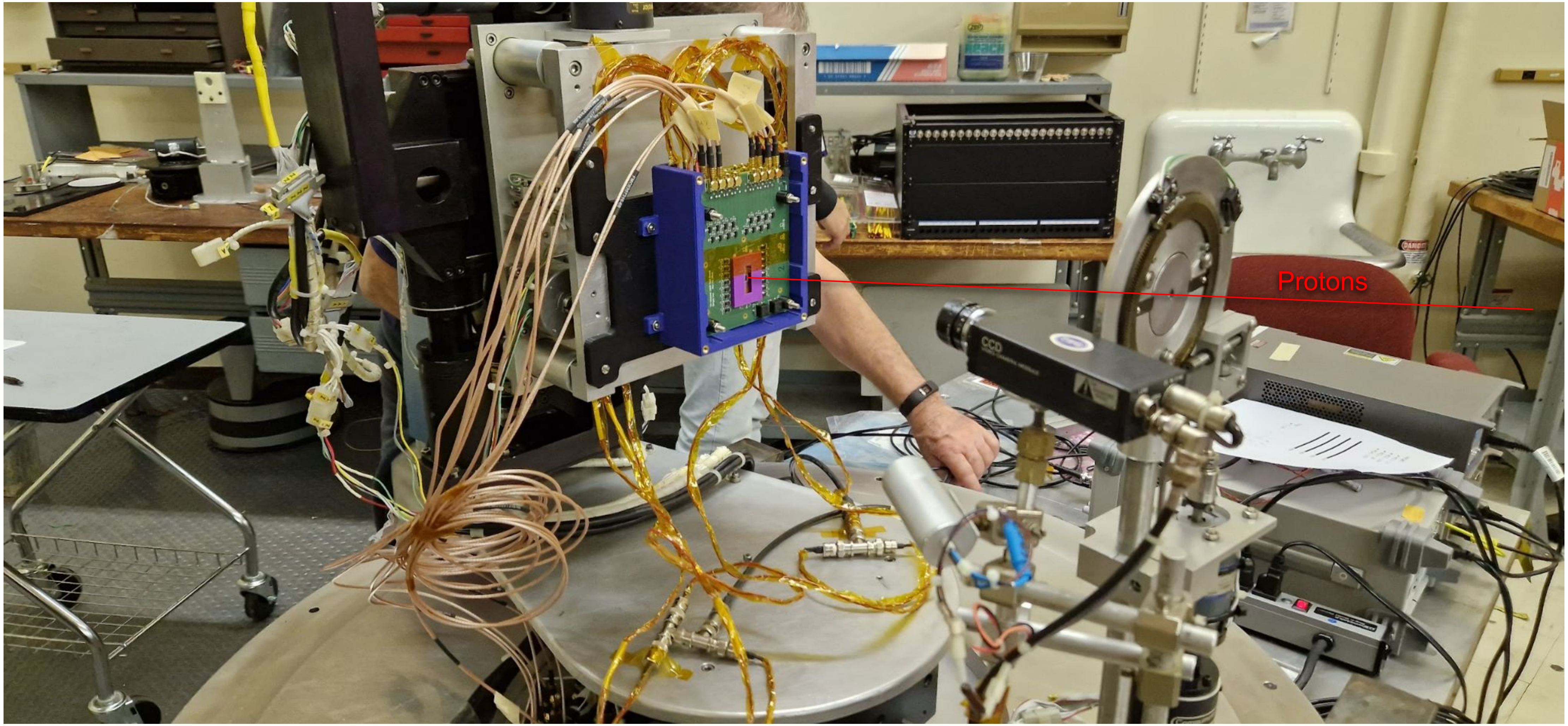
The detector we will use



DUT: Strip AC-LGAD

- **Total active area: 5x5 mm^2**
- Divided in 9 strips (8 read out)
- Strip pitch 500 um
- Designed and fabricated @**BNL**
- Each channel readout via dedicated **2-stage amplification**
- Signals acquired via **8-channels oscilloscope**

AC-LGAD at the Tandem accelerator



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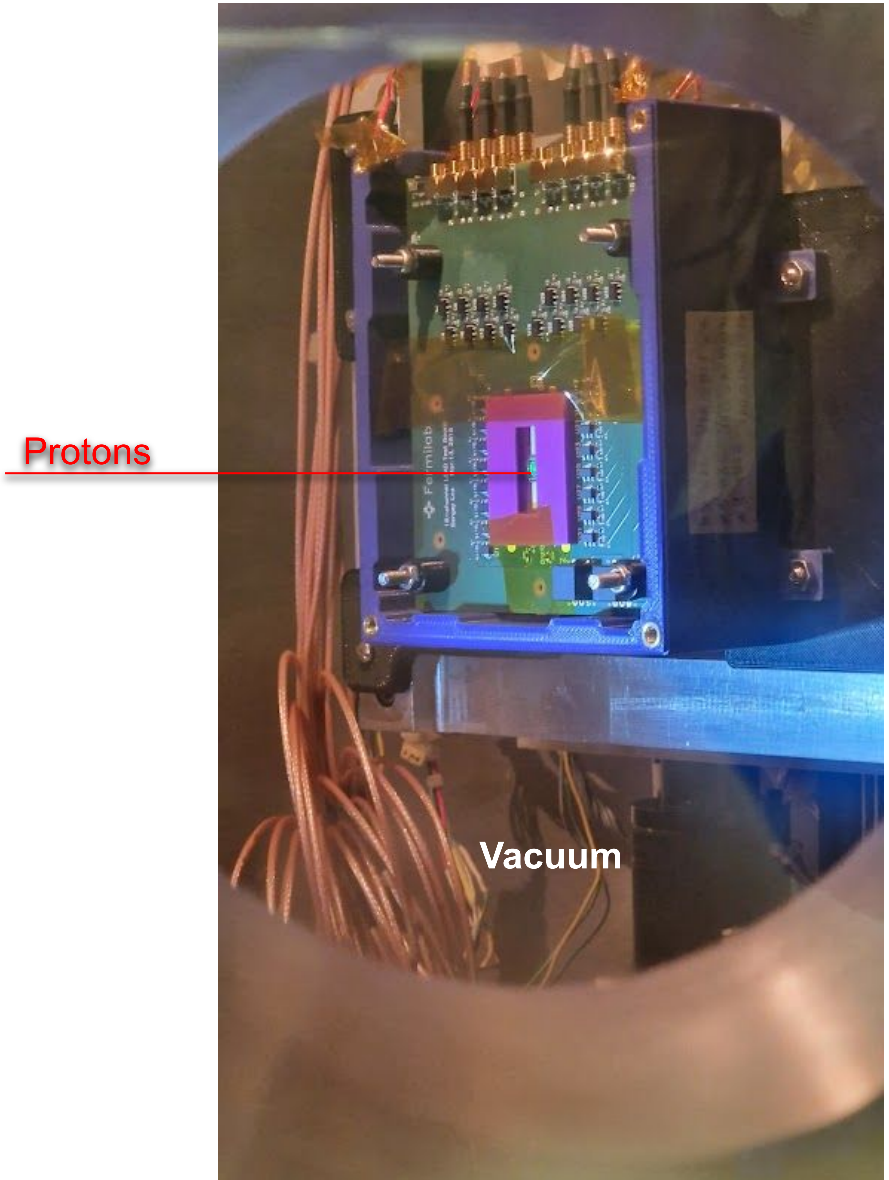
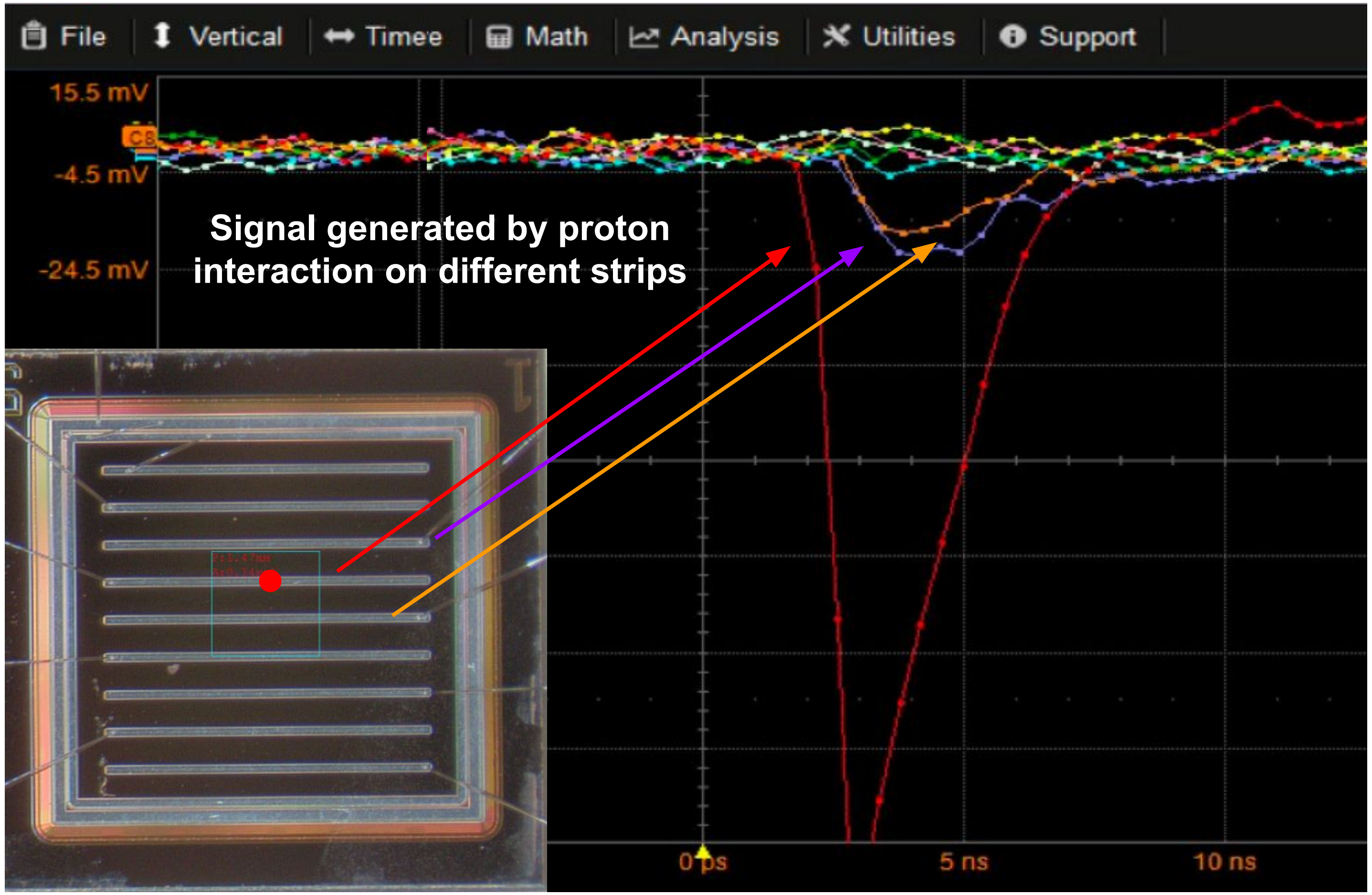




The day of the Test-Beam

Monday Oct 16th
Tuesday Oct 17th

8:00 Bus to BNL
We will meet at Danfords

8:30 Safety course - Tandem Van de Graaff
Meeting in front of the Tandem Van de Graaff building (901A).
Everyone will receive a short safety course on how to work safely in the facility.

9:00 Tour of Tandem

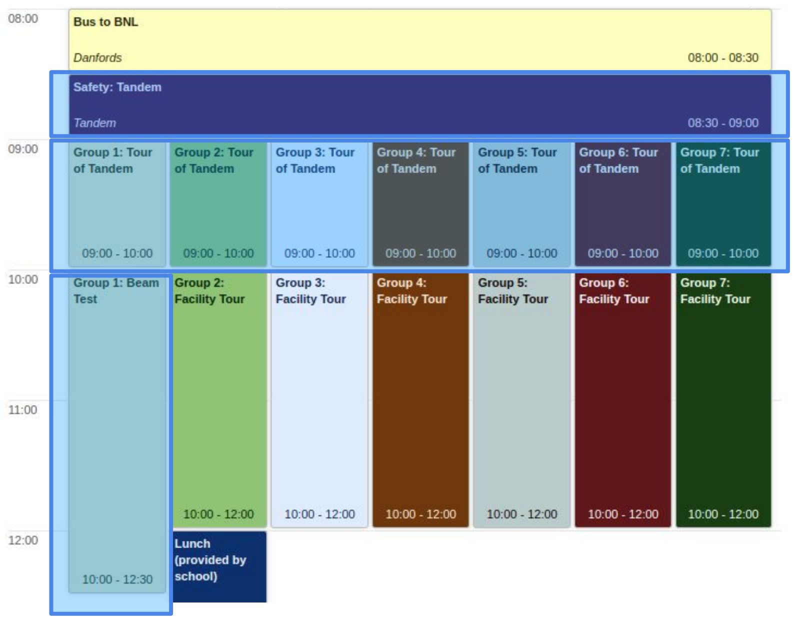
10:00 Calibration procedure and start of data taking (Group 1)

13:00 Data taking (Groups 2 and 3)

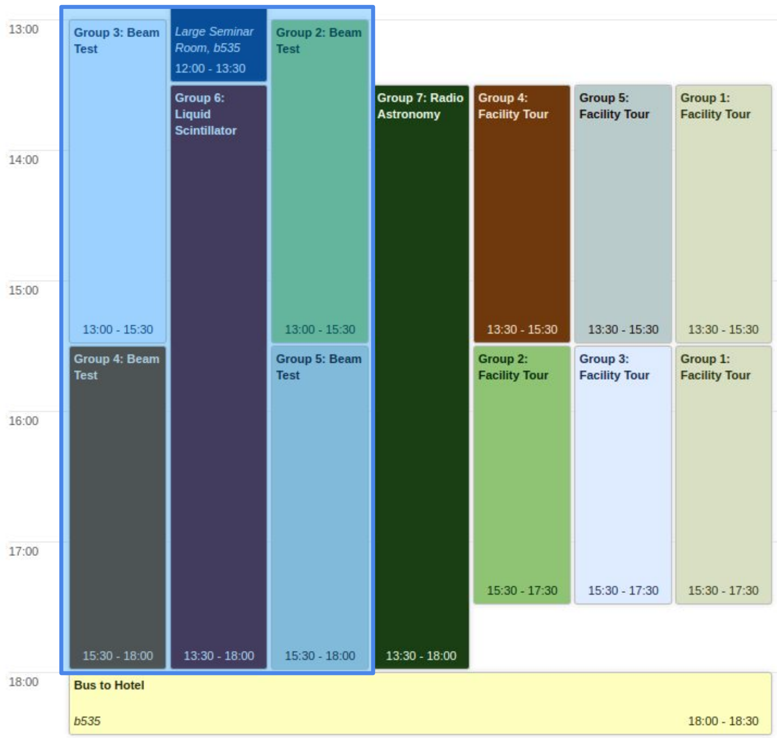
15:30 Data taking (Groups 4 and 5)

13:30 Data taking (Groups 6 and 7)

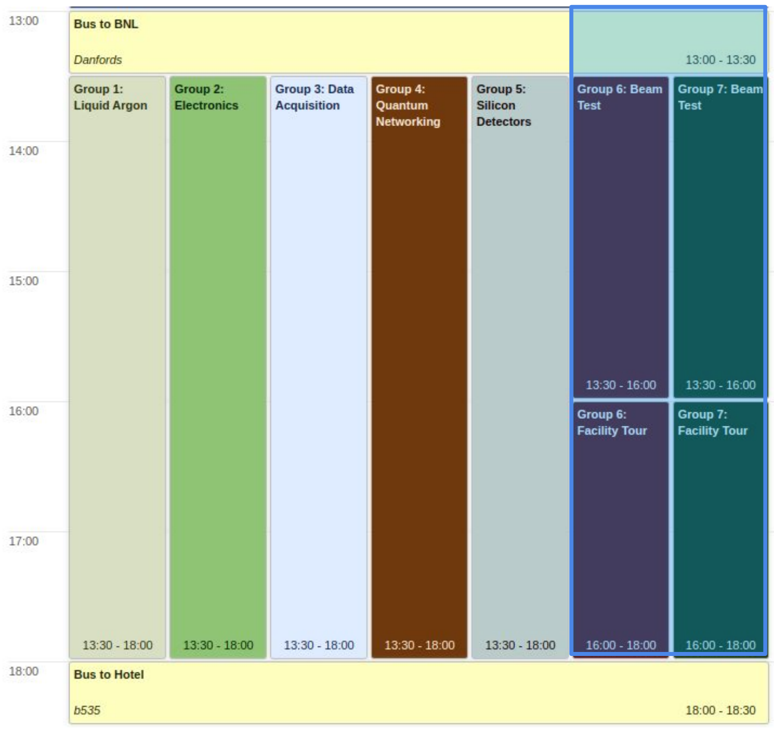
Monday 16th - Morning



Monday 16th - Afternoon



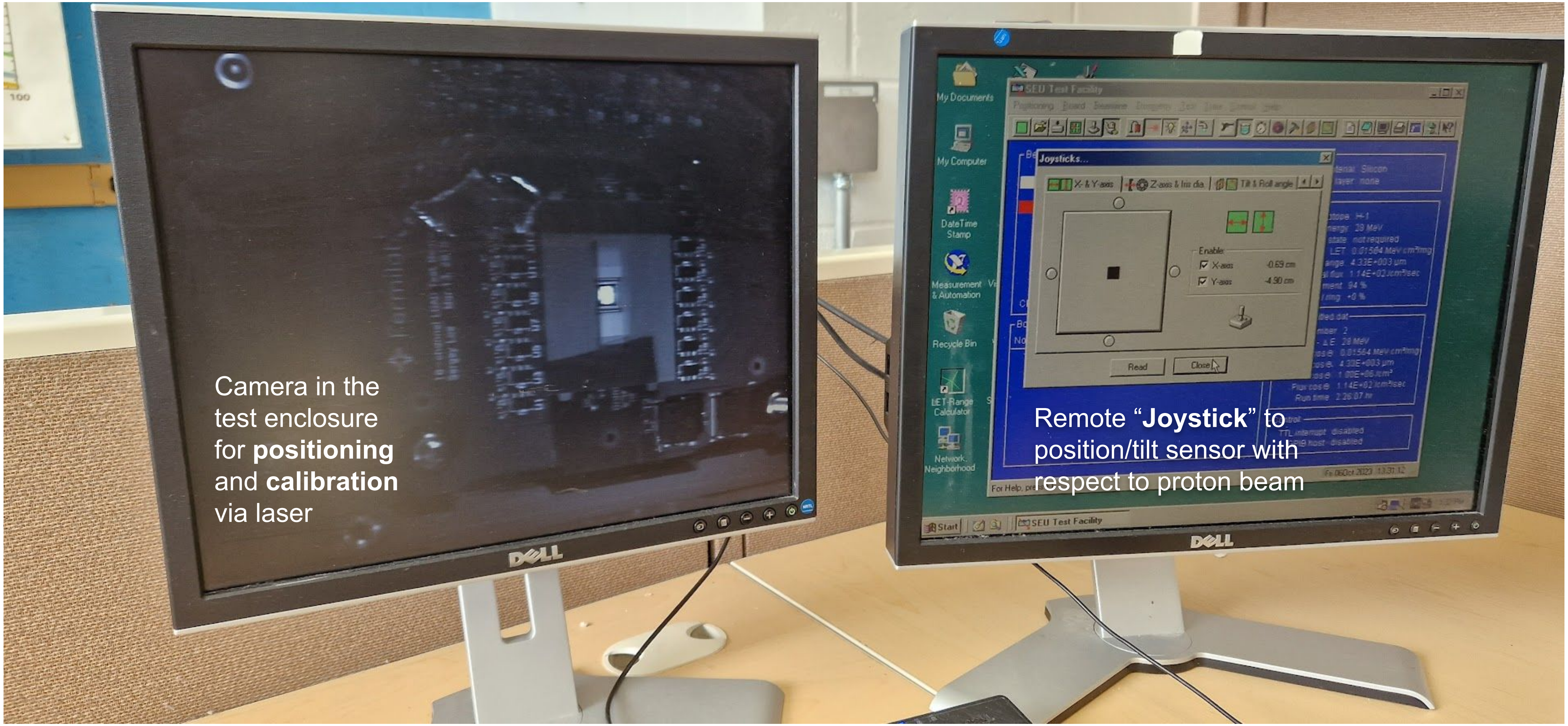
Tuesday 17th - Afternoon



Data taking procedure - User Area

Data taking procedure - Analysis Area

Data taking procedure



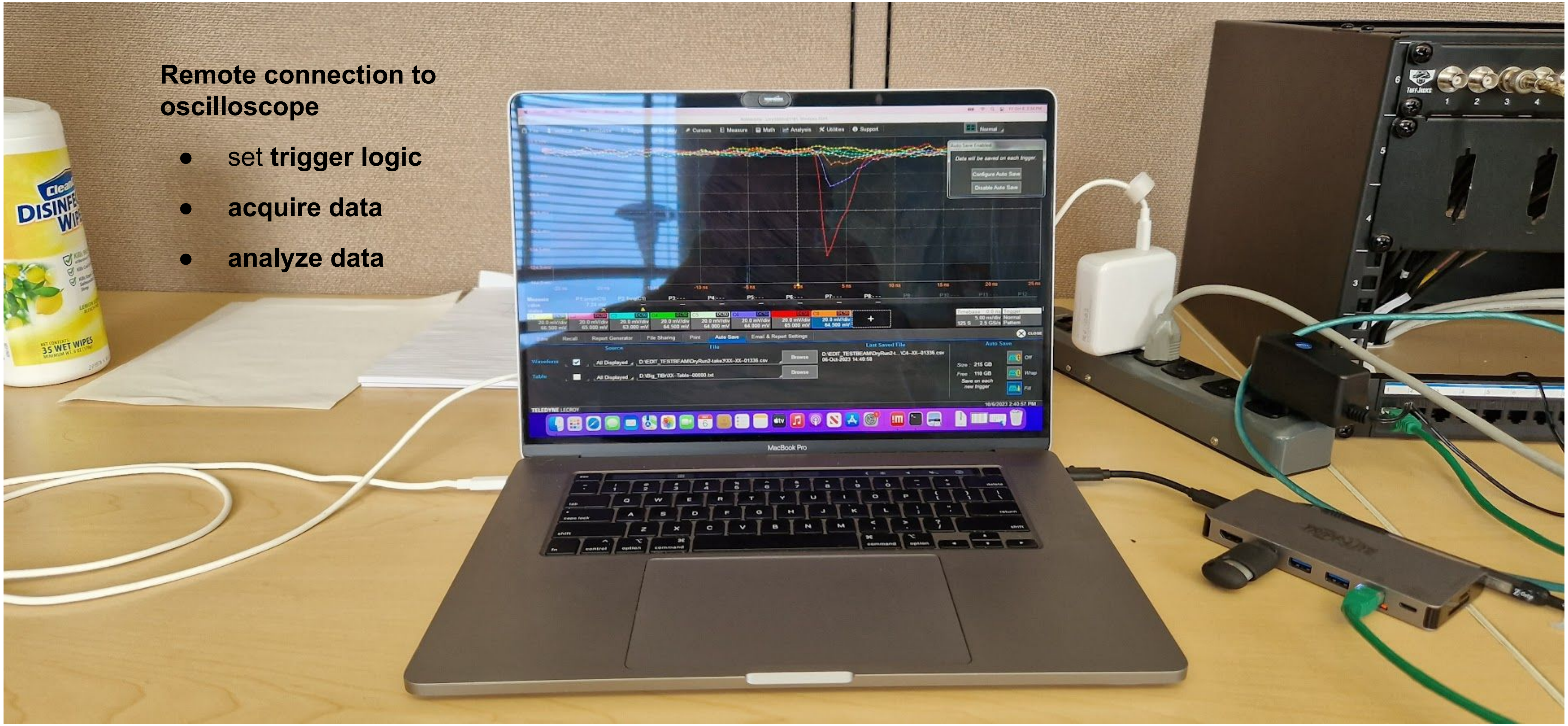
Camera in the test enclosure for **positioning** and **calibration** via laser

Remote “**Joystick**” to position/tilt sensor with respect to proton beam

Data taking procedure

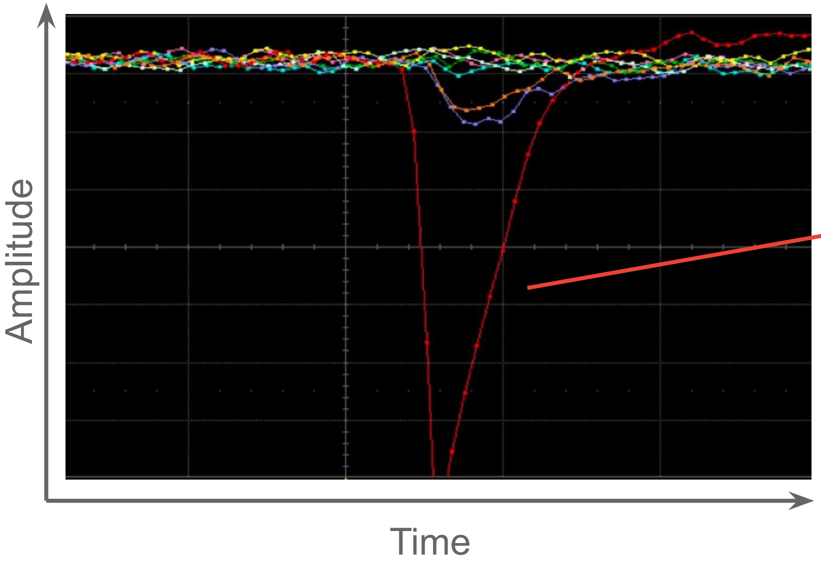
Remote connection to oscilloscope

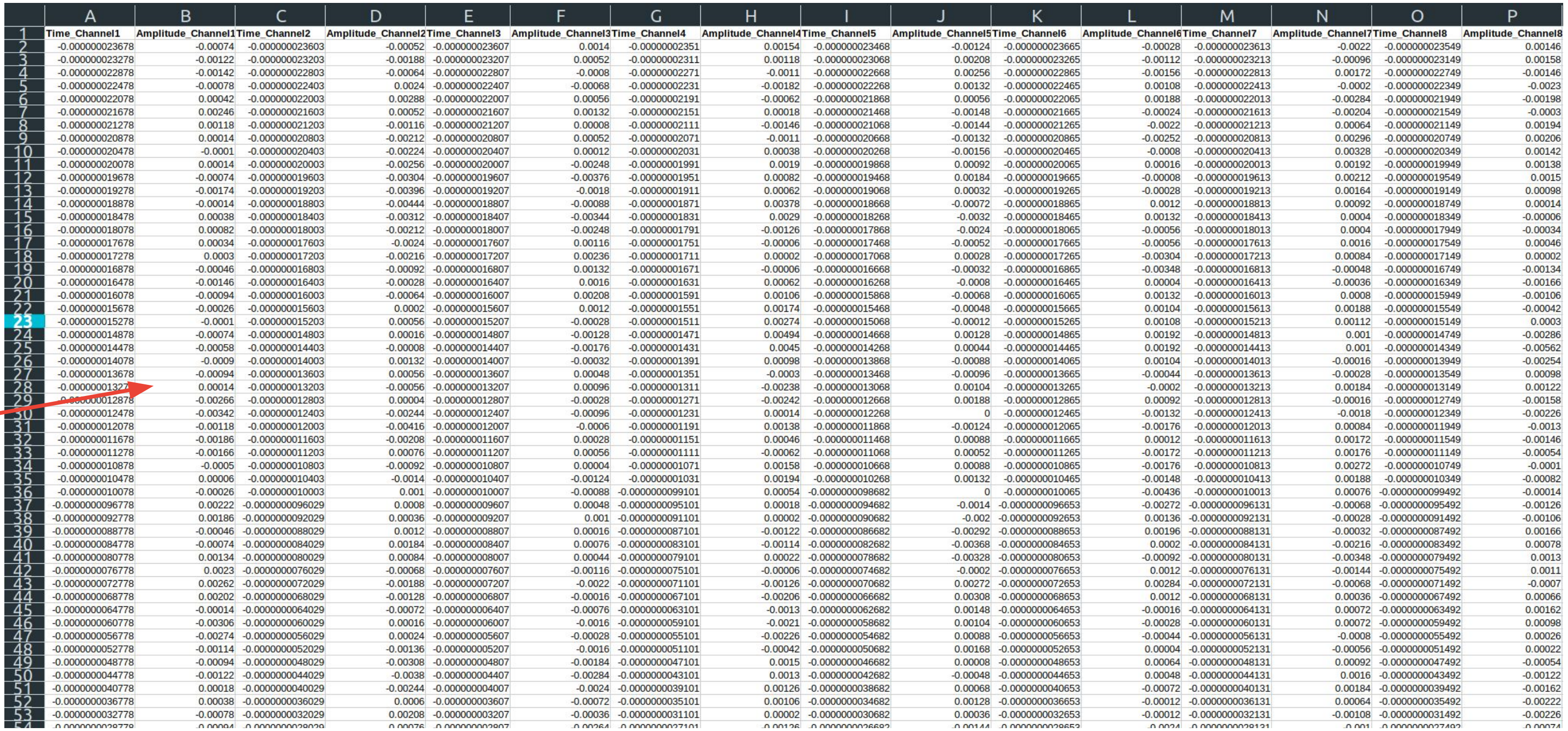
- set **trigger logic**
- **acquire data**
- **analyze data**



Analysis software

Signals will be saved in .csv (**comma separated value**) databases (one per event)





	Time_Channel1	Amplitude_Channel1	Time_Channel2	Amplitude_Channel2	Time_Channel3	Amplitude_Channel3	Time_Channel4	Amplitude_Channel4	Time_Channel5	Amplitude_Channel5	Time_Channel6	Amplitude_Channel6	Time_Channel7	Amplitude_Channel7	Time_Channel8	Amplitude_Channel8
2	-0.000000023678	-0.00074	-0.000000023603	-0.00052	-0.000000023607	0.0014	-0.00000002351	0.00154	-0.000000023468	-0.00124	-0.000000023665	-0.00028	-0.000000023613	-0.0022	-0.000000023549	0.00146
3	-0.000000023278	-0.00122	-0.000000023203	-0.00188	-0.000000023207	0.00052	-0.00000002311	0.00118	-0.000000023068	0.00208	-0.000000023265	-0.00112	-0.000000023213	-0.00096	-0.000000023149	0.00158
4	-0.000000022878	-0.00142	-0.000000022803	-0.00064	-0.000000022807	-0.0008	-0.00000002271	-0.0011	-0.000000022668	0.00256	-0.000000022865	-0.00156	-0.000000022813	0.00172	-0.000000022749	-0.00146
5	-0.000000022478	-0.00078	-0.000000022403	0.0024	-0.000000022407	-0.00068	-0.00000002231	-0.00182	-0.000000022268	0.00132	-0.000000022465	0.00108	-0.000000022413	-0.0002	-0.000000022349	-0.0023
6	-0.000000022078	0.00042	-0.000000022003	0.00288	-0.000000022007	0.00056	-0.00000002191	-0.00062	-0.000000021868	0.00056	-0.000000022065	0.00188	-0.000000022013	-0.00284	-0.000000021949	-0.00198
7	-0.000000021678	0.00246	-0.000000021603	0.00052	-0.000000021607	0.00132	-0.00000002151	0.00018	-0.000000021468	-0.00148	-0.000000021665	-0.00024	-0.000000021613	-0.00204	-0.000000021549	-0.0003
8	-0.000000021278	0.00118	-0.000000021203	-0.00116	-0.000000021207	0.00008	-0.00000002111	-0.00146	-0.000000021068	-0.00144	-0.000000021265	-0.0022	-0.000000021213	0.00064	-0.000000021149	0.00194
9	-0.000000020878	0.00014	-0.000000020803	-0.00212	-0.000000020807	0.00052	-0.00000002071	-0.0011	-0.000000020668	-0.00132	-0.000000020865	-0.00252	-0.000000020813	0.00296	-0.000000020749	0.00206
10	-0.000000020478	-0.0001	-0.000000020403	-0.00224	-0.000000020407	0.00012	-0.00000002031	0.00038	-0.000000020268	-0.00156	-0.000000020465	-0.0008	-0.000000020413	0.00328	-0.000000020349	0.00142
11	-0.000000020078	0.00014	-0.000000020003	-0.00256	-0.000000020007	-0.00248	-0.00000001991	0.0019	-0.000000019868	0.00092	-0.000000020065	0.00016	-0.000000020013	0.00192	-0.000000019949	0.00138
12	-0.000000019678	-0.00074	-0.000000019603	-0.00304	-0.000000019607	-0.00376	-0.00000001951	0.00082	-0.000000019468	0.00184	-0.000000019665	-0.00008	-0.000000019613	0.00212	-0.000000019549	0.0015
13	-0.000000019278	-0.00174	-0.000000019203	-0.00396	-0.000000019207	-0.0018	-0.00000001911	0.00062	-0.000000019068	0.00032	-0.000000019265	-0.00028	-0.000000019213	0.00164	-0.000000019149	0.00098
14	-0.000000018878	-0.00014	-0.000000018803	-0.00444	-0.000000018807	-0.00088	-0.00000001871	0.00378	-0.000000018668	-0.00072	-0.000000018865	0.0012	-0.000000018813	0.00092	-0.000000018749	0.00014
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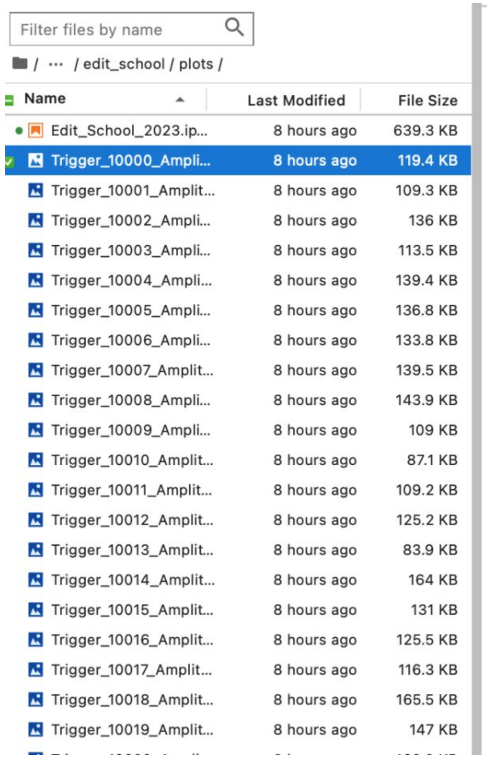
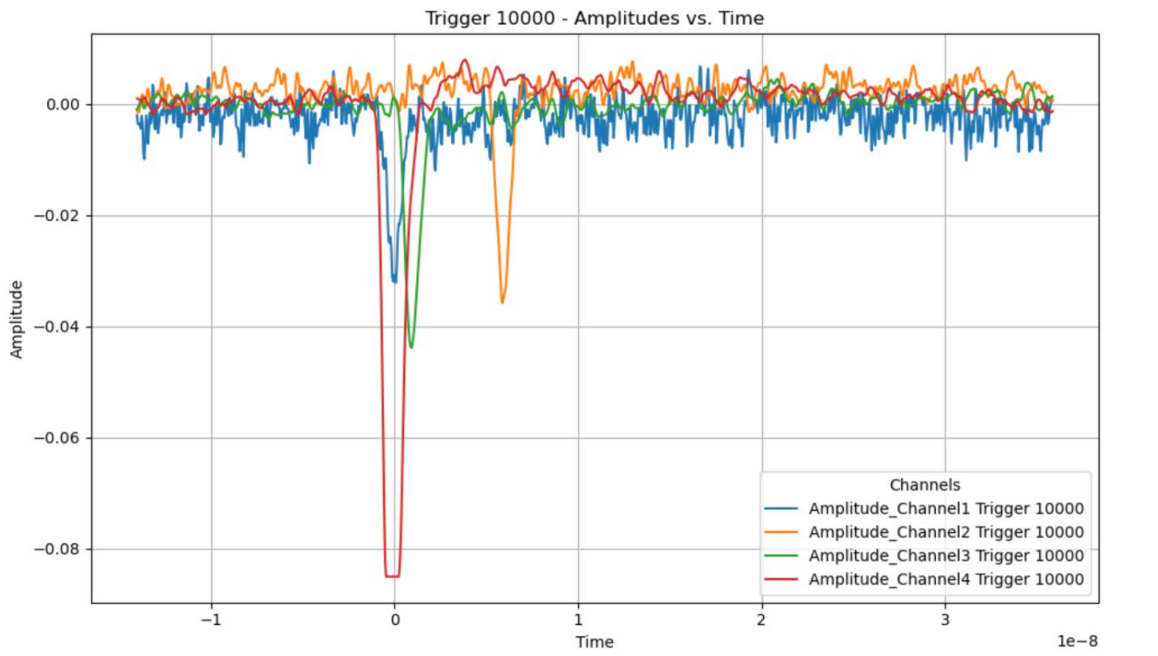
17	-0.000000017678	0.00034	-0.000000017603	-0.0024	-0.000000017607	0.00116	-0.00000001751	-0.00006	-0.000000017468	-0.00052	-0.000000017665	-0.00056	-0.000000017613	0.0016	-0.000000017549	0.00046
18	-0.000000017278	0.0003	-0.000000017203	-0.00216	-0.000000017207	0.00236	-0.00000001711	0.00002	-0.000000017068	0.00028	-0.000000017265	-0.00304	-0.000000017213	0.00084	-0.000000017149	0.00002
19	-0.000000016878	-0.00046	-0.000000016803	-0.00092	-0.000000016807	0.00132	-0.00000001671	-0.00006	-0.000000016668	-0.00032	-0.000000016865	-0.00348	-0.000000016813	-0.00048	-0.000000016749	-0.00134
20	-0.000000016478	-0.00146	-0.000000016403	-0.00028	-0.000000016407	0.0016	-0.00000001631	0.00062	-0.000000016268	-0.0008	-0.000000016465	0.00004	-0.000000016413	-0.00036	-0.000000016349	-0.00166
21	-0.000000016078	-0.00094	-0.000000016003	-0.00064	-0.000000016007	0.00208	-0.00000001591	0.00106	-0.000000015868	-0.00068	-0.000000016065	0.00132	-0.000000016013	0.0008	-0.000000015949	-0.00106
22	-0.000000015678	-0.00026	-0.000000015603	0.0002	-0.000000015607	0.0012	-0.00000001551	0.00174	-0.000000015468	-0.00048	-0.000000015665	0.00104	-0.000000015613	0.00188	-0.000000015549	-0.00042
23	-0.000000015278	-0.0001	-0.000000015203	0.00056	-0.000000015207	-0.00028	-0.00000001511	0.00274	-0.000000015068	-0.00012	-0.000000015265	0.00108	-0.000000015213	0.00112	-0.000000015149	0.0003
24	-0.000000014878	-0.00074	-0.000000014803	0.00016	-0.000000014807	-0.00128	-0.00000001471	0.00494	-0.000000014668	0.00128	-0.000000014865	0.00192	-0.000000014813	0.001	-0.000000014749	-0.00286
25	-0.000000014478	-0.00058	-0.000000014403	-0.00008	-0.000000014407	-0.00176	-0.00000001431	0.0045	-0.000000014268	0.00044	-0.000000014465	0.00192	-0.000000014413	0.001	-0.000000014349	-0.00562
26	-0.000000014078	-0.0009	-0.000000014003	0.00132	-0.000000014007	-0.00032	-0.00000001391	0.00098	-0.000000013868	-0.00088	-0.000000014065	0.00104	-0.000000014013	-0.00016	-0.000000013949	-0.00254
27	-0.000000013678	-0.00094	-0.000000013603	0.00056	-0.000000013607	0.00048	-0.00000001351	-0.0003	-0.000000013468	-0.00096	-0.000000013665	-0.00044	-0.000000013613	-0.00028	-0.000000013549	0.00098
28	[illegible]	0.00014	-0.000000013203	-0.00056	-0.000000013207	0.00096	-0.00000001311	-0.00238	-0.000000013068	0.00104	-0.000000013265	-0.0002	-0.000000013213	0.00184	-0.000000013149	0.00122
29	-0.000000012878	-0.00266	-0.000000012803	0.00004	-0.000000012807	-0.00028	-0.00000001271	-0.00242	-0.000000012668	0.00188	-0.000000012865	0.00092	-0.000000012813	-0.00016	-0.000000012749	-0.00158
30	-0.000000012478	-0.00342	-0.000000012403	-0.00244	-0.000000012407	-0.00096	-0.00000001231	0.00014	-0.000000012268	0	-0.000000012465	-0.00132	-0.000000012413	-0.0018	-0.000000012349	-0.00226
31	-0.000000012078	-0.00118	-0.000000012003	-0.00416	-0.000000012007	-0.0006	-0.00000001191	0.00138	-0.000000011868	-0.00124	-0.000000012065	-0.00176	-0.000000012013	0.00084	-0.000000011949	-0.0013
32	-0.000000011678	-0.00186	-0.000000011603	-0.00208	-0.000000011607	0.00028	-0.00000001151	0.00046	-0.000000011468	0.00088	-0.000000011665	0.00012	-0.000000011613	0.00172	-0.000000011549	-0.00146
33	-0.000000011278	-0.00166	-0.000000011203	0.00076	-0.000000011207	0.00056	-0.00000001111	-0.00062	-0.000000011068	0.00052	-0.000000011265	-0.00172	-0.000000011213	0.00176	-0.000000011149	-0.00054
34	-0.000000010878	-0.0005	-0.000000010803	-0.00092	-0.000000010807	0.00004	-0.00000001071	0.00158	-0.000000010668	0.00088	-0.000000010865	-0.00176	-0.000000010813	0.00272	-0.000000010749	-0.0001
35	-0.000000010478	0.00006	-0.000000010403	-0.0014	-0.000000010407	-0.00124	-0.00000001031	0.00194	-0.000000010268	0.00132	-0.000000010465	-0.00148	-0.000000010413	0.00188	-0.000000010349	-0.00082
36	-0.000000010078	-0.00026	-0.000000010003	0.001	-0.000000010007	-0.00088	-0.0000000099101	0.00054	-0.0000000098682	0	-0.000000010065	-0.00436	-0.000000010013	0.00076	-0.0000000099492	-0.00014
37	-0.0000000096778	0.00222	-0.0000000096029	0.0008	-0.000000009607	0.00048	-0.0000000095101	0.00018	-0.0000000094682	-0.0014	-0.0000000096653	-0.00272	-0.0000000096131	-0.00068	-0.0000000095492	-0.00126
38	-0.0000000092778	0.00186	-0.0000000092029	0.00036	-0.000000009207	0.001	-0.0000000091101	0.00002	-0.0000000090682	-0.002	-0.0000000092653	0.00136	-0.0000000092131	-0.00028	-0.0000000091492	-0.00106
39	-0.0000000088778	-0.00046	-0.0000000088029	0.0012	-0.000000008807	0.00016	-0.0000000087101	-0.00122	-0.0000000086682	-0.00292	-0.0000000088653	0.00196	-0.0000000088131	-0.00032	-0.0000000087492	0.00166
40	-0.0000000084778	-0.00074	-0.0000000084029	0.00184	-0.000000008407	0.00076	-0.0000000083101	-0.00114	-0.0000000082682	-0.00368	-0.0000000084653	0.0002	-0.0000000084131	-0.00216	-0.0000000083492	0.00078
41	-0.0000000080778	0.00134	-0.0000000080029	0.00084	-0.000000008007	0.00044	-0.0000000079101	0.00022	-0.0000000078682	-0.00328	-0.0000000080653	-0.00092	-0.0000000080131	-0.00348	-0.0000000079492	0.0013
42	-0.0000000076778	0.0023	-0.0000000076029	-0.00068	-0.000000007607	-0.00116	-0.0000000075101	-0.00006	-0.0000000074682	-0.0002	-0.0000000076653	0.0012	-0.0000000076131	-0.00144	-0.0000000075492	0.0011
43	-0.0000000072778	0.00262	-0.0000000072029	-0.00188	-0.000000007207	-0.0022	-0.0000000071101	-0.00126	-0.0000000070682	0.00272	-0.0000000072653	0.00284	-0.0000000072131	-0.00068	-0.0000000071492	-0.0007
44	-0.0000000068778	0.00202	-0.0000000068029	-0.00128	-0.000000006807	-0.00016	-0.0000000067101	-0.00206	-0.0000000066682	0.00308	-0.0000000068653	0.0012	-0.0000000068131	0.00036	-0.0000000067492	0.00066
45	-0.0000000064778	-0.00014	-0.0000000064029	-0.00072	-0.000000006407	-0.00076	-0.0000000063101	-0.0013	-0.0000000062682	0.00148	-0.0000000064653	-0.00016	-0.0000000064131	0.00072	-0.0000000063492	0.00162
46	-0.0000000060778	-0.00306	-0.0000000060029	0.00016	-0.000000006007	-0.0016	-0.0000000059101	-0.0021	-0.0000000058682	0.00104	-0.0000000060653	-0.00028	-0.0000000060131	0.00072	-0.0000000059492	0.00098
47	-0.0000000056778	-0.00274	-0.0000000056029	0.00024	-0.000000005607	-0.00028	-0.0000000055101	-0.00226	-0.0000000054682	0.00088	-0.0000000056653	-0.00044	-0.0000000056131	-0.0008	-0.0000000055492	0.00026
48	-0.0000000052778	-0.00114	-0.0000000052029	-0.00136	-0.000000005207	-0.0016	-0.0000000051101	-0.00042	-0.0000000050682	0.00168	-0.0000000052653	0.00004	-0.0000000052131	-0.00056	-0.0000000051492	0.00022
49	-0.0000000048778	-0.00094	-0.0000000048029	-0.00308	-0.000000004807	-0.00184	-0.0000000047101	0.0015	-0.0000000046682	0.00008	-0.0000000048653	0.00064	-0.0000000048131	0.00092	-0.0000000047492	-0.00054
50	-0.0000000044778	-0.00122	-0.0000000044029	-0.0038	-0.000000004407	-0.00284	-0.0000000043101	0.0013	-0.0000000042682	-0.00048	-0.0000000044653	0.00048	-0.0000000044131	0.0016	-0.0000000043492	-0.00122
51	-0.0000000040778	0.00018	-0.0000000040029	-0.00244	-0.000000004007	-0.0024	-0.0000000039101	0.00126	-0.0000000038682	0.00068	-0.0000000040653	-0.00072	-0.0000000040131	0.00184	-0.0000000039492	-0.00162
52	-0.0000000036778	0.00038	-0.0000000036029	0.0006	-0.000000003607	-0.00072	-0.0000000035101	0.00106	-0.0000000034682	0.00128	-0.0000000036653	-0.00012	-0.0000000036131	0.00064	-0.0000000035492	-0.00222
53	-0.0000000032778	-0.00078	-0.0000000032029	0.00208	-0.000000003207	-0.00036	-0.0000000031101	0.00002	-0.0000000030682	0.00036	-0.0000000032653	-0.00012	-0.0000000032131	-0.00108	-0.0000000031492	-0.00226

Analysis software

We will provide a simple **analysis software** in Python3 to extrapolate **important parameters** of acquired signals (max amplitude, fwhm, etc.)

Data will be stored in **Pandas DataFrame** containers and plotted using the **Matplotlib package** (instructions will be provided)





Many thanks to:

Ashley Jammel Brooks [Indiana U.]
Emily Duden [Brandeis U.]
Aaron Petersen [Brandeis U.]

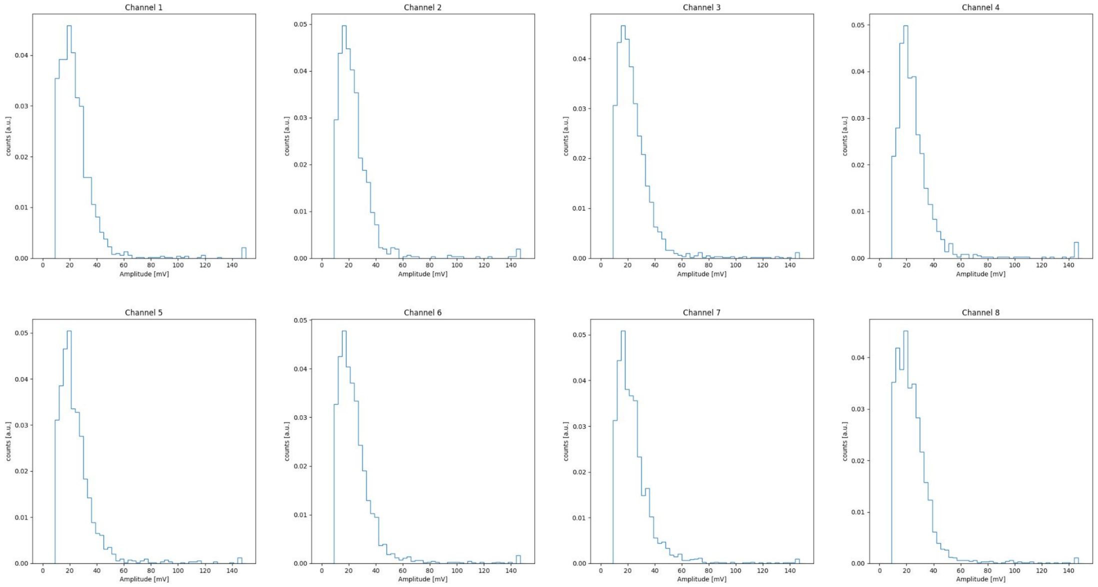
for their work on the analysis code.

Analysis code, instructions, and a sample dataset are available at:

https://github.com/GDamen/EDIT2023-TestBeam

Analysis software

Extrapolated parameters will be saved in
results.csv
ready for you to analyze



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Amp1[mV]	Amp2[mV]	Amp3[mV]	Amp4[mV]	Amp5[mV]	Amp6[mV]	Amp7[mV]	Amp8[mV]	FWHM1[ns]	FWHM2[ns]	FWHM3[ns]	FWHM4[ns]	FWHM5[ns]	FWHM6[ns]	FWHM7[ns]	FWHM8[ns]
2			21.04					18.78			2					2
3								36.7								1.6
4				64.18								1.6				
5	39.3					36.08			2					2		
6		28.96								2						
7	19.5			19.42	36.8	10.52			2			2	1.6	2.4		
8	41.42		16.28						2		2.4					
9	13.42		29.72		11.6	82.28	22.16		2.8		1.6		1.6	2	2	
10	15.5		37.84				31.96	12.22	2		2				2	2
11	28.3						42.28		2						2	
12		26.56								2						
13		32.12						33.3		1.6						1.6
14							11.76	60.42							2.4	1.6
15								29.7								1.6
16			11.04			28.16	16.48				2.4			2	2	
17						53.6	92.32							2.4	2.4	
18								35.98								2
19					38.04								1.6			
20	24.02		40.48			31.52	13.96		2		2			2	2.4	
21					29.32	36.32							2	1.6		
22					42.52								1.6			
23					44.72								2			
24				15.06	115.28	95.6	10.6					2	2	2	2.8	
25		15.72								2						
26	28.98								2							
27	30.82			10.46	33.48				1.6			2.4	2			
28								13.74								2
29			19.6								2.4					
30	38.02		15.32		18.8				1.6		2		1.6			
31		18.12								2						
32				23.7		28.72	11.96					1.6		2	1.6	
33							25.52								2	
34	35.94			27.02		10.2	67.88	19.02	2.4			2		1.6	2	2.4
35					14.24								2			
36		24.4								1.6						
37			34.24								2					
38	20.22								1.6							
39				35.66	58.24	12.08						1.6	2	2		
40	21.5		10.84			56.32	23.24		2		2.4			1.6	1.6	
41					34.04								1.6			
42		32.2								2						
43	14.78		36.16				14.2	24.98	2.4		1.6				2.4	1.6
44							33.76								2	
45					23.52	18.28							2	2.4		
46	31.42		26				22.84		2		2				1.6	
47								26.66								1.6
48	27.94							26.34	2							2
49			17.96				24.24				2.4				2	
50					14.6								2			
51							16.04	21.5							1.6	1.6
52		24.84					34.6			2					2	
53		25.52					22.08	14.9		2					1.6	1.6

Final goals

- **Operate the accelerator commands** to focus the beam on the silicon sensor
- Interact with Tandem Van de Graaff operators in the control room
- Evaluate **optimal data-taking strategy** (time and amplitude window size, trigger logic and thresholds, etc…) based on the physics of interest:

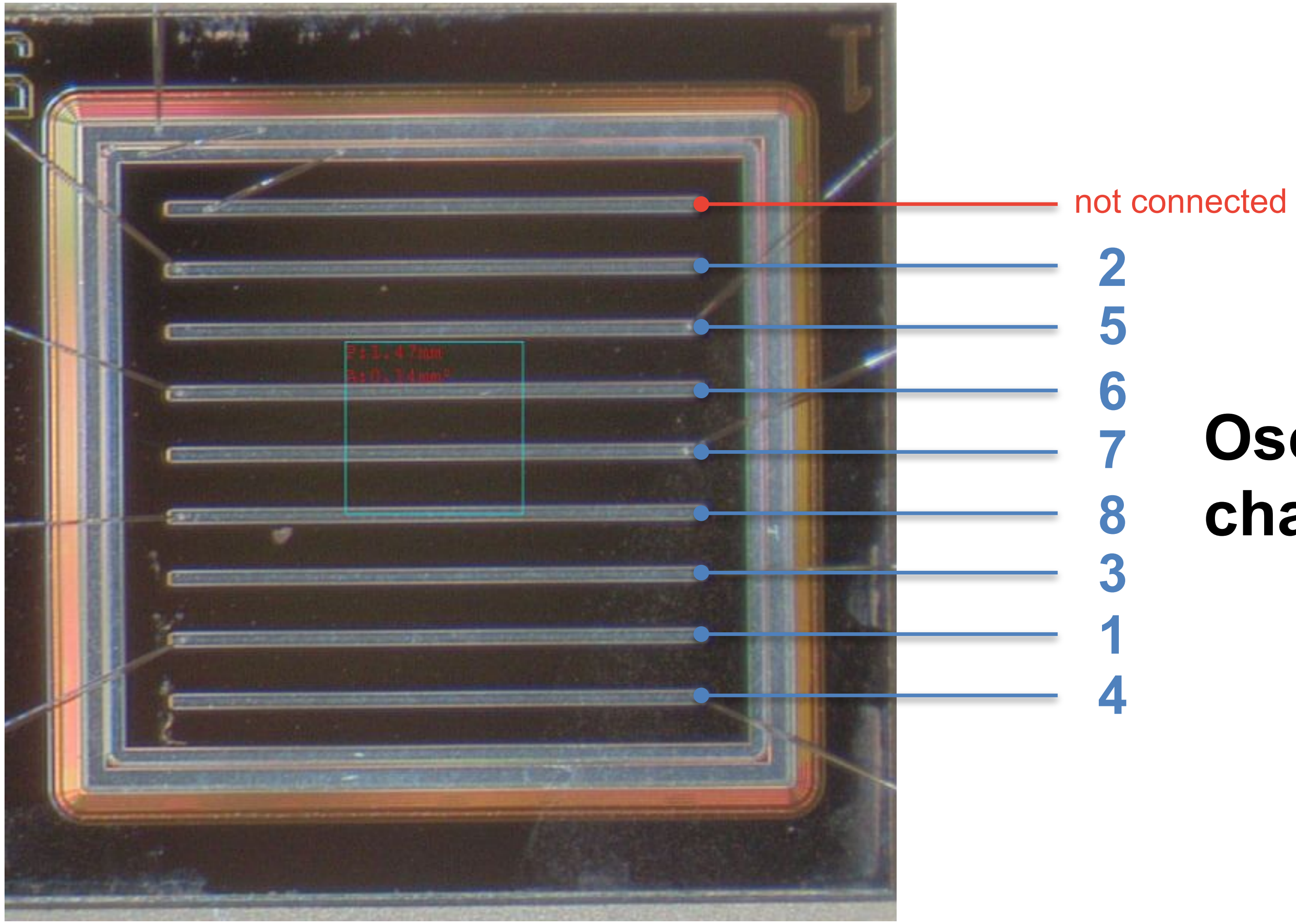
    - Measure **signal noise**
    - Measure **signal amplitude**
    - Measure **signal FWHM**
    - Measure **signal slew-rate**

If you want a challenge…

- Extrapolate **shape of the proton beam**
- Extrapolate **percentage of shared signal** on neighbouring strips

Instructions

Sensor connectivity map



Oscilloscope channels

Setting up triggering scheme

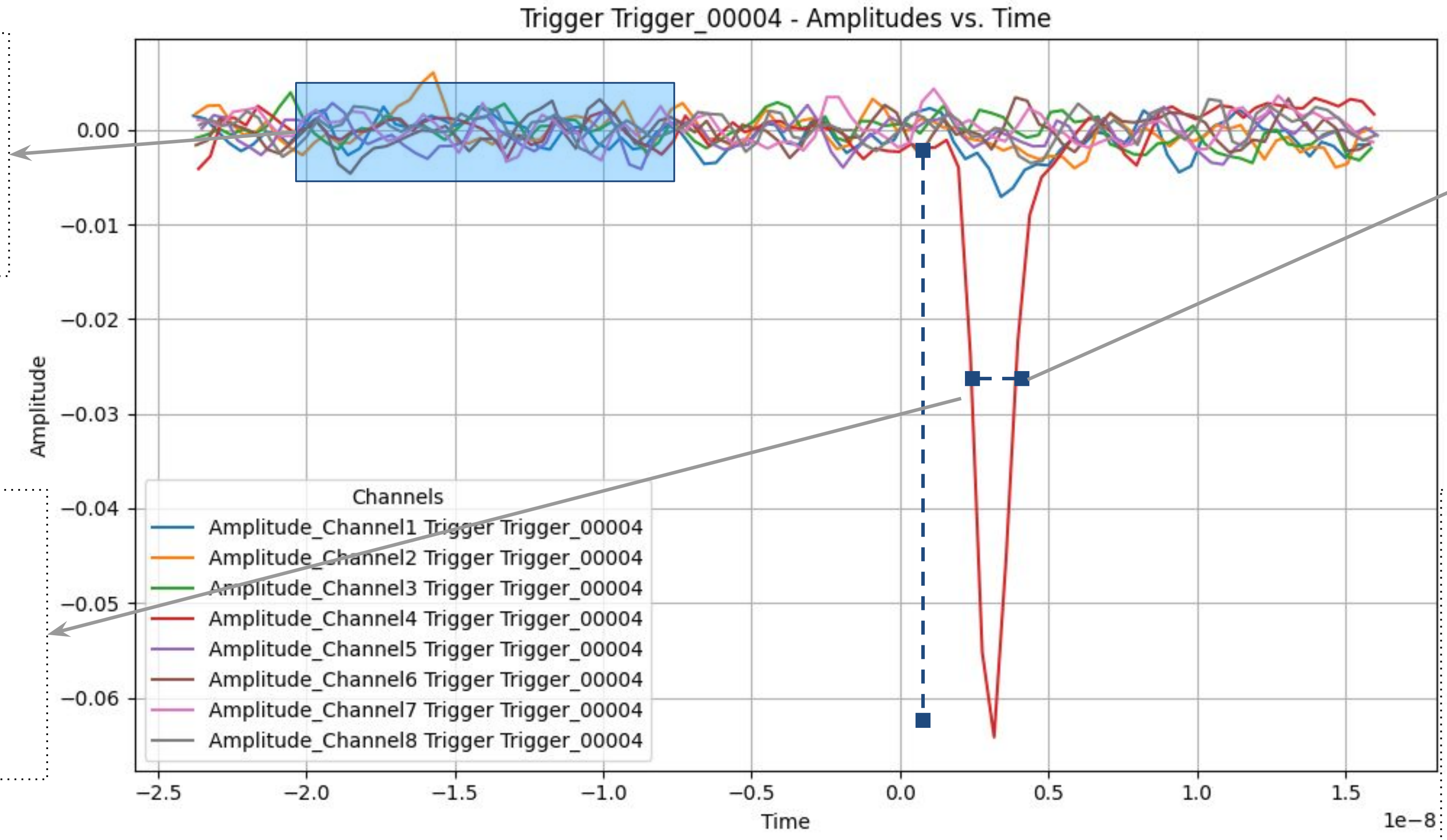
Important parameters to reconstruct

Noise [V]

Standard deviation of amplitude in baseline

Signal Amplitude [V]

Height of the signal peak with respect to baseline, in absolute value



Signal FWHM [s]

The full width of the signal computed at 50% of the peak amplitude

Signal Slew Rate [V/s]

Slope of the rising edge of the signal computed as

$(V^{90\%} - V^{10\%}) / (t^{90\%} - t^{10\%})$

Structure of the Trigger_xxx.csv datasets

Each trigger represents the interaction of a particle with the sensor

Each Trigger_XXX.csv file contains info for all 8 channels

Waveform representation for each channel is store in two columns:

Time_ChannelN
[time coordinate]

Amplitude_ChannelN
[amplitude coordinate]

	A	B	C	D	E	F	G	H
1	Time_Channel1	Amplitude_Channel1	Time_Channel2	Amplitude_Channel2	Time_Channel3	Amplitude_Channel3	Time_Channel4	Amplitude_Channel4
2	-0.000000023489	-0.00182	-0.000000023414	-0.0002	-0.000000023418	-0.00232	-0.000000023721	-0.00006
3	-0.000000023089	-0.00038	-0.000000023014	-0.00304	-0.000000023018	-0.00212	-0.000000023321	-0.00046
4	-0.000000022689	-0.00058	-0.000000022614	-0.00392	-0.000000022618	-0.00104	-0.000000022921	-0.00058
5	-0.000000022289	-0.00086	-0.000000022214	-0.0022	-0.000000022218	0.0004	-0.000000022521	0.00122
6	-0.000000021889	-0.00042	-0.000000021814	0.00068	-0.000000021818	0.00008	-0.000000022121	0.00006
7	-0.000000021489	-0.00174	-0.000000021414	0.00112	-0.000000021418	-0.00184	-0.000000021721	-0.00094
8	-0.000000021089	-0.00118	-0.000000021014	-0.0002	-0.000000021018	-0.00104	-0.000000021321	-0.00146
9	-0.000000020689	0.00098	-0.000000020614	0	-0.000000020618	0.00028	-0.000000020921	-0.0027
10	-0.000000020289	0.00058	-0.000000020214	0.00076	-0.000000020218	0.0014	-0.000000020521	-0.00254
11	-0.000000019889	-0.0023	-0.000000019814	0.0006	-0.000000019818	0.0014	-0.000000020121	-0.00082
12	-0.000000019489	-0.00154	-0.000000019414	-0.00076	-0.000000019418	0.00044	-0.000000019721	-0.0007
13	-0.000000019089	0.00054	-0.000000019014	-0.00004	-0.000000019018	0.00024	-0.000000019321	0.00042
14	-0.000000018689	0.00242	-0.000000018614	0.00236	-0.000000018618	0.0006	-0.000000018921	0.00146
15	-0.000000018289	0.0015	-0.000000018214	0.00244	-0.000000018218	0.00244	-0.000000018521	-0.00154
16	-0.000000017889	0.0001	-0.000000017814	0.001	-0.000000017818	0.00176	-0.000000018121	-0.00478
17	-0.000000017489	0.00094	-0.000000017414	0.00028	-0.000000017418	-0.0012	-0.000000017721	-0.00258
18	-0.000000017089	-0.00082	-0.000000017014	0.00076	-0.000000017018	-0.0008	-0.000000017321	-0.00082
19	-0.000000016689	-0.00246	-0.000000016614	0.0024	-0.000000016618	0.00084	-0.000000016921	0.00146
20	-0.000000016289	-0.00302	-0.000000016214	0.00016	-0.000000016218	0.00036	-0.000000016521	0.00234
21	-0.000000015889	-0.00014	-0.000000015814	-0.00076	-0.000000015818	0.00012	-0.000000016121	0.00058
22	-0.000000015489	0.00054	-0.000000015414	-0.00164	-0.000000015418	0.00028	-0.000000015721	-0.00346
23	-0.000000015089	-0.00078	-0.000000015014	-0.00188	-0.000000015018	0.0014	-0.000000015321	-0.00522
24	-0.000000014689	0.00058	-0.000000014614	-0.00196	-0.000000014618	0.00168	-0.000000014921	-0.00266
25	-0.000000014289	0.0011	-0.000000014214	-0.00284	-0.000000014218	0.00088	-0.000000014521	0.00134
26	-0.000000013889	0.00046	-0.000000013814	-0.00292	-0.000000013818	-0.00092	-0.000000014121	0.0011
27	-0.000000013489	-0.0001	-0.000000013414	-0.00308	-0.000000013418	-0.0008	-0.000000013721	0.00002
28	-0.000000013089	-0.00034	-0.000000013014	-0.002	-0.000000013018	0.00052	-0.000000013321	-0.00014
29	-0.000000012689	-0.0005	-0.000000012614	0.00008	-0.000000012618	0.0002	-0.000000012921	-0.00162
30	-0.000000012289	-0.00246	-0.000000012214	0.00084	-0.000000012218	-0.00048	-0.000000012521	-0.00114
31	-0.000000011889	-0.00338	-0.000000011814	0.00016	-0.000000011818	-0.00128	-0.000000012121	0.00174
32	-0.000000011489	-0.00186	-0.000000011414	-0.00004	-0.000000011418	-0.00236	-0.000000011721	0.00138
33	-0.000000011089	-0.00118	-0.000000011014	0.00072	-0.000000011018	-0.00188	-0.000000011321	0.00066
34	-0.000000010689	-0.00066	-0.000000010614	-0.0016	-0.000000010618	0.00052	-0.000000010921	0.00138
35	-0.000000010289	0.00094	-0.000000010214	-0.00092	-0.000000010218	0.00148	-0.000000010521	-0.00046
36	-0.000000009889	0.00254	-0.0000000098141	0.00208	-0.0000000098182	-0.00084	-0.000000010121	-0.00042
37	-0.000000009489	0.00178	-0.0000000094141	0.0012	-0.0000000094182	-0.001	-0.0000000097214	-0.00038
38	-0.000000009089	0.00118	-0.0000000090141	0.00132	-0.0000000090182	-0.00056	-0.0000000093214	-0.00042
39	-0.000000008689	-0.00138	-0.0000000086141	0.00328	-0.0000000086182	-0.00064	-0.0000000089214	-0.0015

How to use Pandas DataFrame

library to use Pandas DataFrame

```
import pandas as pd
```

your group number

```
input_path = 'pandas_df/' + test_name + '/'
```

trigger file we want to open

```
trigger_number = 5
```

loading DataFrame from you the Trigger file we want to read

```
df_signals =
read_csv(f{input_path}Trigger_0000{trigger_number}.csv')
```

loading the content of the Amplitude Channel 1 and 2 columns of Trigger_00005.csv

```
amps1 = df_signals['Amplitude_Channel1']
amps2 = df_signals['Amplitude_Channel2']
```

name of the columns used in our new DataFrame

```
columnnames=["Amp1[mV]", "Amp2[mV]"]
```

create a new DataFrame

```
df_results = pd.DataFrame(columns = columnnames, dtype = 'float64')
```

set the content of the row [trigger_number] of columns Amp1[mV] and Amp2[mV]

```
df_results[‘Amp1[mV]’].loc[trigger_number] = max(amps1)
df_results[‘Amp2[mV]’].loc[trigger_number] = max(amps2)
```

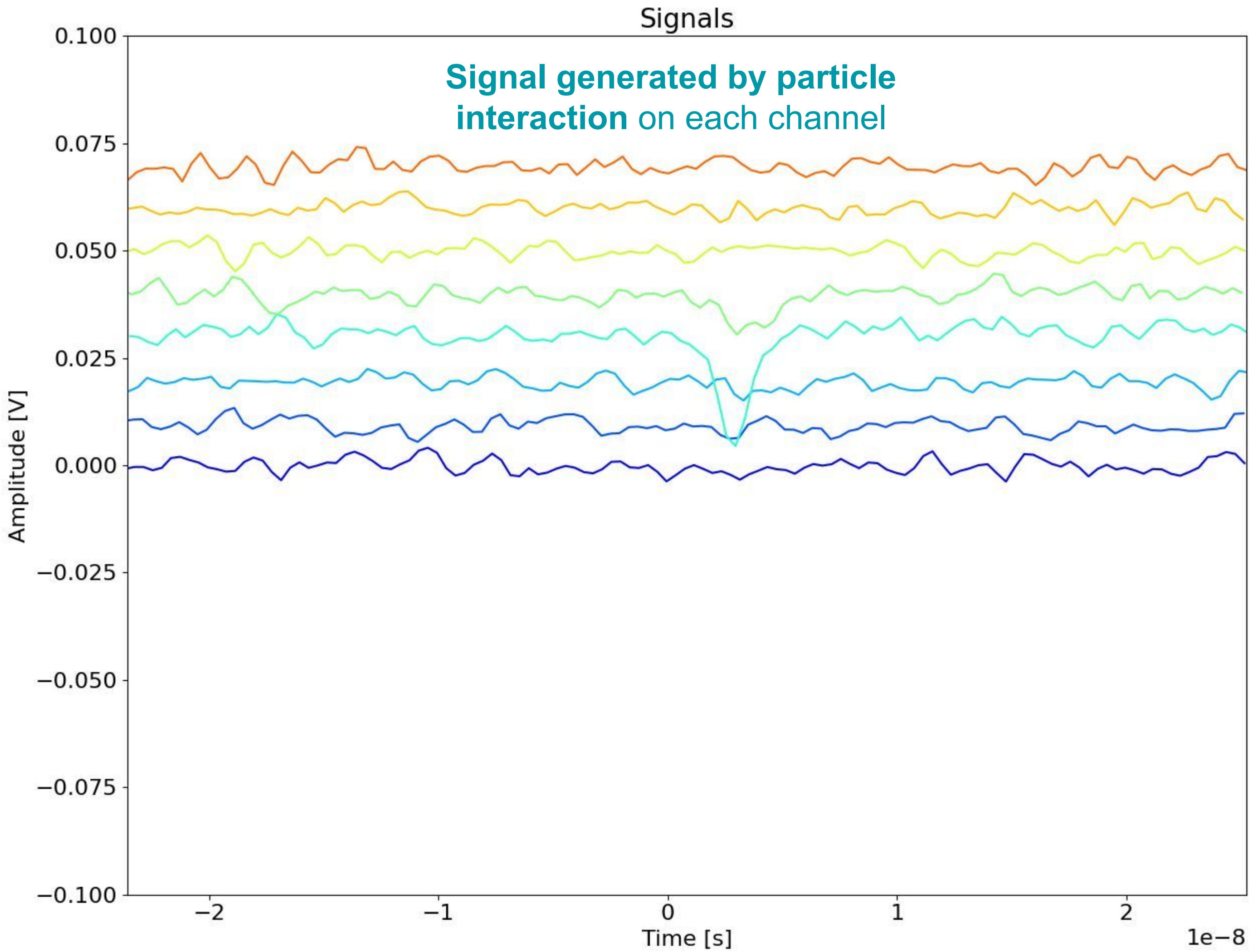
save DataFrame to file

```
df_results.to_csv(os.path.join(input_path, 'results.csv'),
index=True, index_label='Trigger', encoding='utf-8')
```

How to plot using matplotlib

	`import re`
library to read Pandas DataFrames	`import pandas as pd`
library to plot	`import matplotlib.pyplot as plt`
	`general_path = '/Users/omega/EDIT2023/'`
your group number	`test_name = 'group-0'`
	`output_path = general_path + 'pandas_df/' + test_name + '/'`
loading DataFrame from your ‘results.csv’ file	`df_results = pd.read_csv(os.path.join(output_path, 'results.csv'))`
number of bins of your histogram	`binning = 50`
create your canvas	`fig, axs = plt.subplots(1, 1)`
put the content of the column ‘Amp1[mV]’ from the DataFrame into an histogram	`axs[0, 0].hist(df_results['Amp1[mV]'].dropna(), bins=binning, range = [0, 150], histtype='step', density=True)`
set plot title	`axs[0,0].set_title('Channel 1')`
set label of x axis	`axs[0,0].set_xlabel('Amplitude [mV]')`
set label of y axis	`axs[0,0].set_ylabel('counts [a.u.]')`
show the plot	`plt.show()`

The GUI



Reconstructed position of particle interaction based on relative signal amplitude