Изучение свойств строу-трубок и определение требований к считывающей электронике

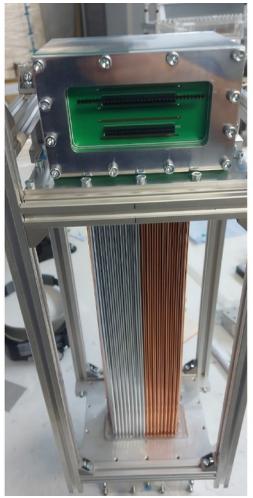
Е.Кузнецова

on behalf of the Straw Tracker Team

ongoing and starting activities

- Mechanics and geometry (not covered here) - ongoing
- **Prototyping - ongoing**
- **Lab and testbeam measurements - ongoing**
  + establishing approaches for:
    - Prototype quality control – initiated
    - Electrical connections - initiated
  - Defining parameters of the readout electronics - ongoing
- **Garfield/LTSpice simulation studies – well developed**
  - Validation with lab/testbeam measurements with the known electronics
  - Prediction of the readout performance for various readout options
  - Prediction for various operation conditions (field, particle momentum, angle)
- **Defining requirements and conceptual design of the readout electronics - ongoing**
  - Stage2 – fast, optional charge measurements
  - Stage1 - ~10 times lower max occupancy, good charge measurements
- **Realistic simulation of the tracker response in SPDroot - initiated**
  - Realistic parametrization based on Garfield/LTSpice – started
  - Implementing realistic noise, finite TDC/ADC, finite dynamic range - scheduled
  - Pattern recognition also with realistic noise – needed…

prototyping



Combined prototype

Straw and wire diameters:

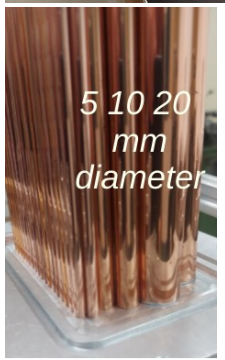
20mm / 30um : SHiP type

10mm / 30um : SPD type

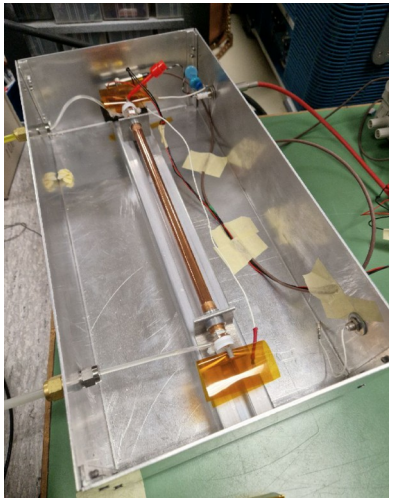
5mm / 20um :

NA62 upgrade (Cu/Au coating)

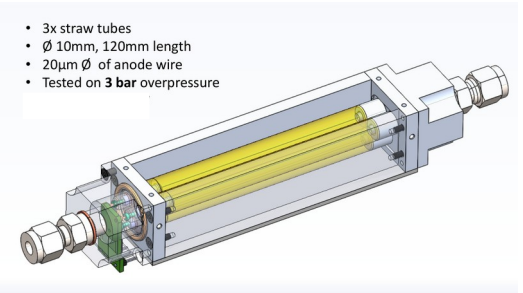
DUNE (Al metallisation)



- Dedicated small size prototype for testbeam measurements and alignment control studies
- Good for x-check with existing measurements (NA62, SHiP)
- Tests of x-talks, impedance measurements etc
- Lessons learned
  - Calibration/termination connector from opposite side
  - ….



Various single straw or small assembly setups



Laboratory tests with sources:

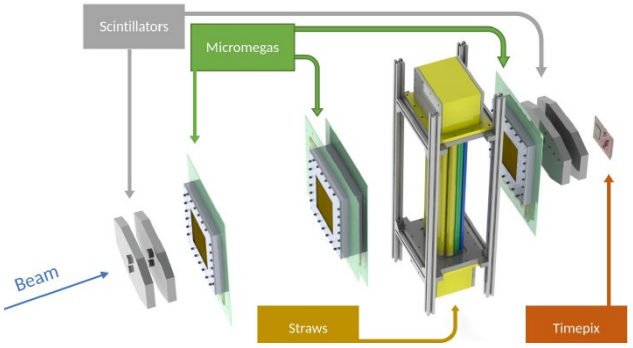
- Gas gain measurements
- Tests with different custom readout
- Tests with different gas mixtures

Further prototypes

- Single straw max length for lab tests
- Assembly with a stereo-angle? Which angle??

SPS testbeam measurements

setup-23



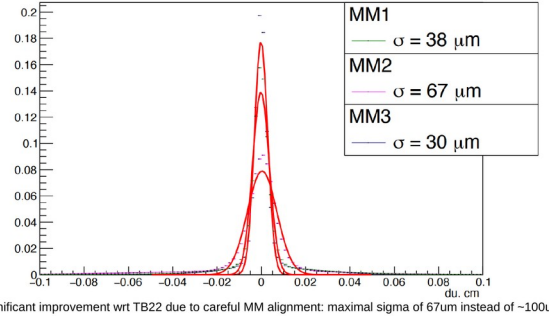
Reference tracking:

- MM detectors (250 um) + Tiger readout (Torino University)
- Timepix4 – 50um x 50um

Under the test: a combined straw tracker prototype with the Tiger and mu2e (VMM3) readouts

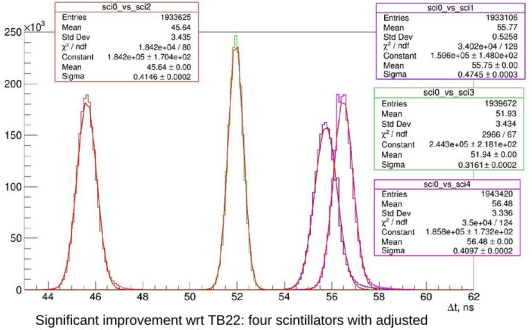
Good data taking with MM+straw and success in integrating the Timepix4

Reference tracking -- residuals



Significant improvement wrt TB22 due to careful MM alignment: maximal sigma of 67um instead of ~100um

Time resolution -- T0



Significant improvement wrt TB22: four scintillators with adjusted thresholds/delays each with sigma ~ 400/1.4 ps wrt ~1ns in 2022

Reference tracking (MM only): **better than 70 um**
work on adding the timepix layer in the analysis is ongoing
Reference time (T0): **better than ~300 ps**

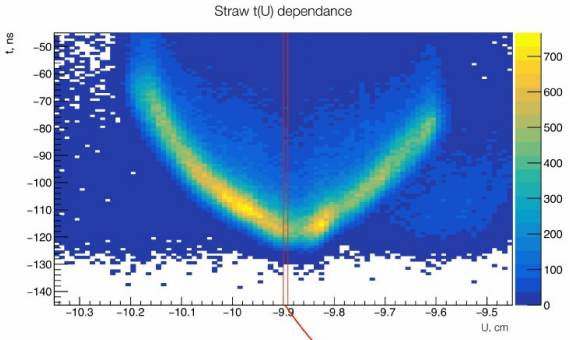
goals

- Precise measurement of the spatial resolution for different readout parameters (gas and electronics gain, thresholds, pressure,…)
- Validation of the simulation results
- Evaluation of the realistic tracker parameters (noise, cross-talks)
- Evaluation of the charge measurements performance (MIP) with the available electronics
  - Direct charge measurements (VMM3, equivalent number of bits~8)
  - Time-over-threshold measurements (Tiger)
- Developing a set of measurements for the prototype quality control

SPS testbeam measurements

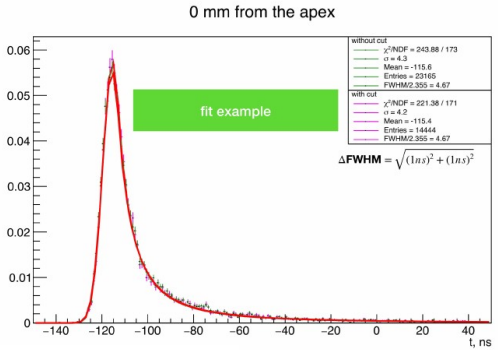
Preliminary results (work in progress)

Andrey



σ_T from the fit associated with Time resolution. The Idea is to obtain the **Spatial** resolution from the **Time** resolution

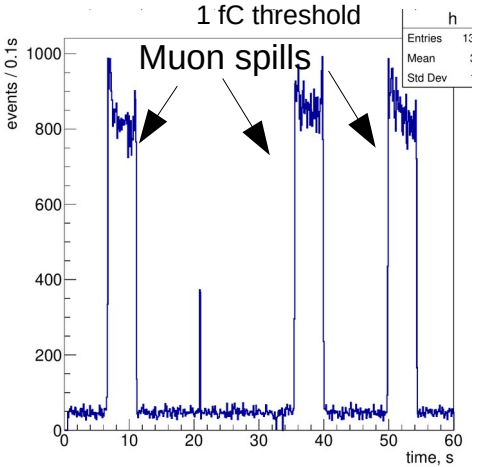
$$\sigma_U = \frac{\sigma_T}{|f'(U)|}$$



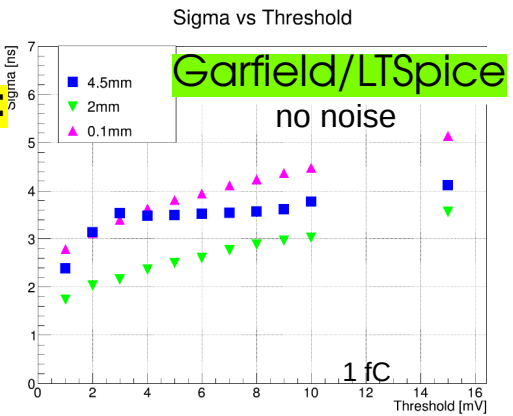
Tiger readout

Noise studies (work in progress)

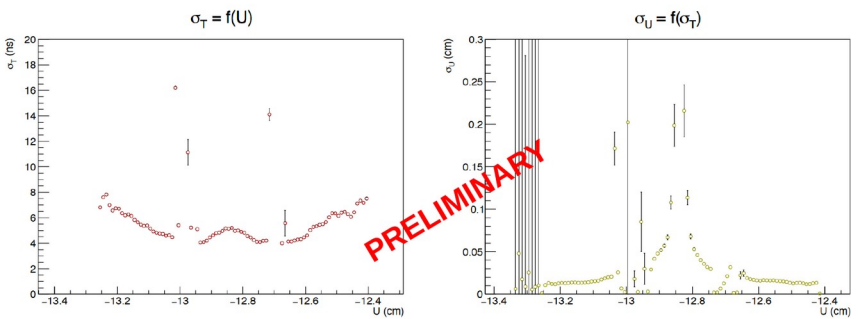
Dima



Assel, Sonja, Vitaly



10mm Straw Resolution



1. The best time 'resolution' is about **4 ns**!
2. The weighted mean of Coordinate resolution distribution is **150 µm**!

Resolution for different thresholds:

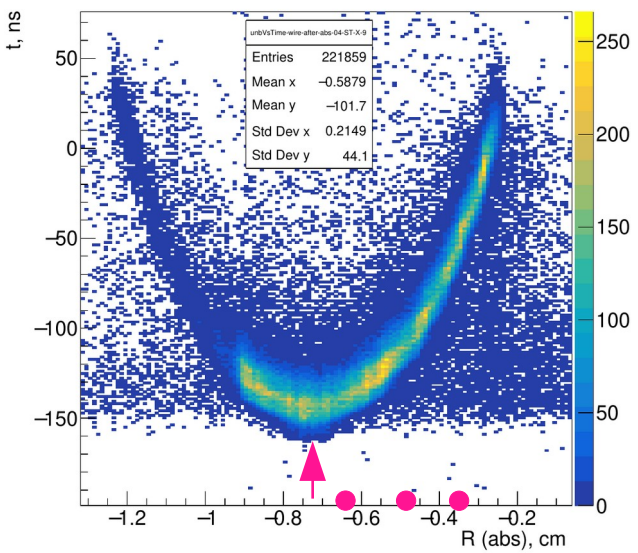
- Resolution vs threshold - data available for VMM3 and Tiger – analysis ongoing
- Evaluation of the expected thresholds for 100 Hz noise - ongoing
- Simulation validation with the testbeam results - ongoing

SPS testbeam measurements

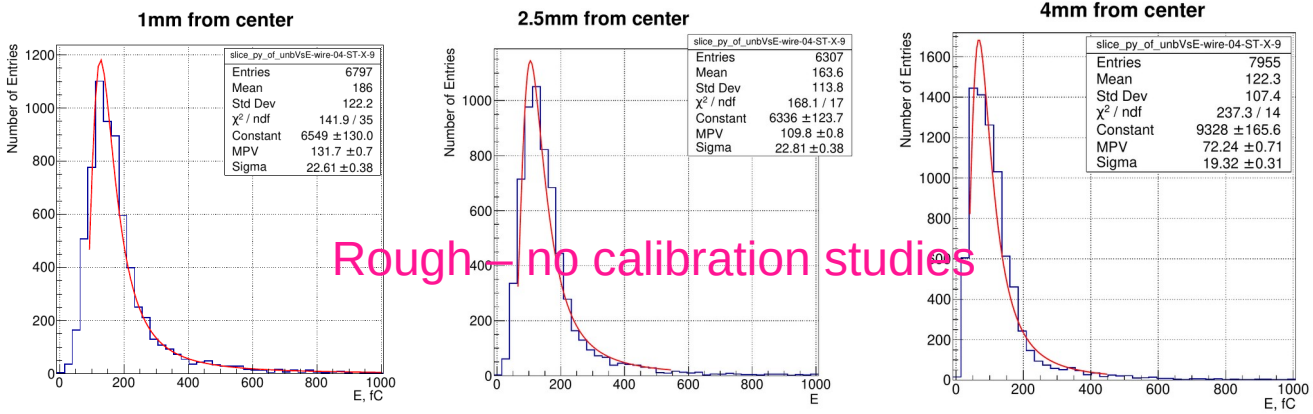
Preliminary results (work in progress)

Dima

Mu2e: 3mV/fC, **25ns** peak time, 5mV thr



Mu2e: 0.5mV/fC, **200ns** peak time, 5mV thr



Rough – no calibration studies

Rough selection, quick estimate:
MPV: 12.0-13.5 fC/mm – 10% deviation
sigma/MPV: 27-17 %

More dedicated analysis is expected soon (Artem)

Rough x-check: Ar at 18 degC and 1 bara: rho ~ 1.7 e-3 g/cm3
MIP SP[MeVcm2/g] = dE/dx/rho ~ O(1) MeV/1.7e-3/cm ~ keV/cm
Charge uncertainty (w/o electronics):

$$\left(\frac{\sigma_Q}{Q}\right)^2 = \left(\frac{\sigma_{n_0}}{n_0}\right)^2 + \frac{1}{n_0}\left(\frac{\sigma_{A_{typical}}}{A_{typical}}\right)^2$$

Prim charge — Gain fluct (Polya)

Ionization — Fano — par from Polya, F, b<1 (F, b~0.5)

$$\frac{\sigma_Q}{Q} = \sqrt{\frac{W(F+b)}{E}}$$

E - energy loss

Largest rel error: sqrt(2*26 eV/1keV) = sqrt (5)*0.1 = 0.22
If b=0.5, F(Ar)=0.2 => 0.13

BUT: no electronics, no non-uniformities
BUT: the larger energy loss, the less fluctuations

Garfield/LTSpice

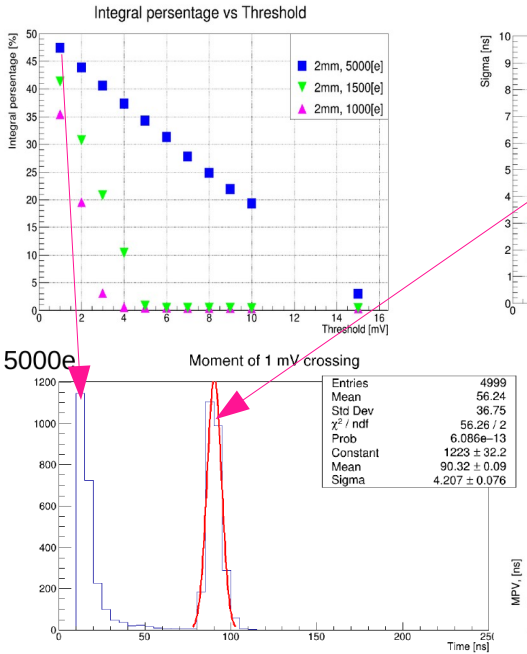
- Garfield – some fixes is needed (gain)
  - communication with the developers
  - X-checks with lab measurements
- LTSpice
  - Models of VMM3, Tiger
  - Validation with TB data
- Accounting for noise
- Next steps:

  => input to SPDroot (together with digitization, dynamic range etc)

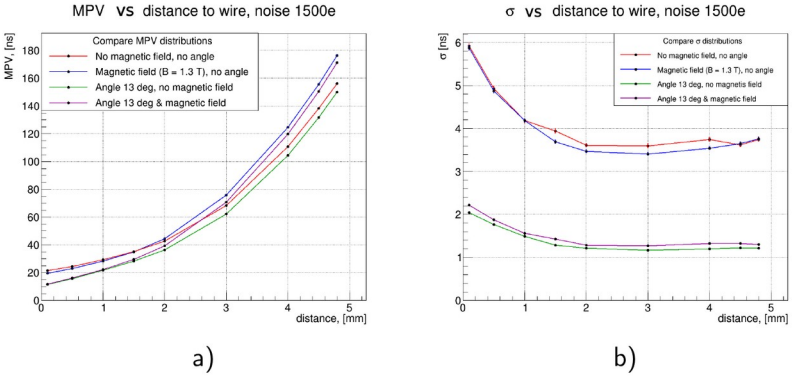
  => ready for modelling custom readout (further development)

Noise studies, VMM3

Assel, Sonja, Vitaly



Response parametrization, VMM3



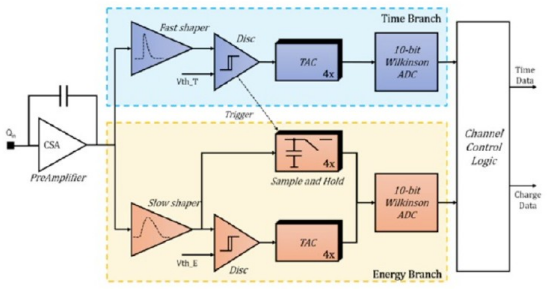
a) b)

Рис. 13: (a) Зависимость MPV (ns) и (b) σ (ns) временных распределений от расстояния между треком и анодой проволокой.

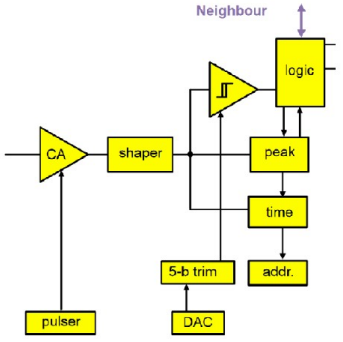
Readout electronics concept

"Existing" ASICs

TIGER Architecture



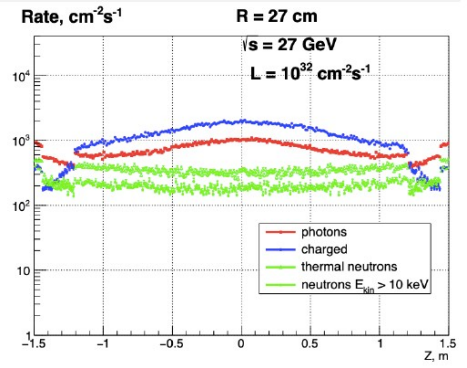
VMM3 Architecture



	VMM3	TIGER
Number of channels	64	64
Clock frequency	10…80 MHz	160…200 MHz
Input capacitance	<300 pF	<100 pF
Dynamic range	Linearity within ±2% up to 2 pC	50 fC
Gain	0.5, 1, 3, 6, 9, 12, 16 mV/fC	12 mV/fC
ENC (energy branch)	<3000	<1500
TDC binning	~1 ns	50 ps
Maximum event rate	140 kHz/ch	60 kHz/ch
Consumption	15 mW/ch	12 mW/ch

Our requirements

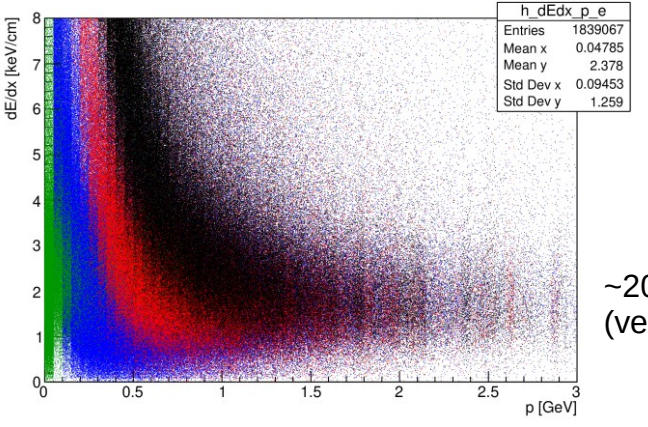
Andrey Gridin



Minor update still expected
Stage2 : > 200kHz
Stage1 : factor ~0.1

dE/dx vs p

Ruslan Akhunzyanov



~200 fC/cm
(very roughly)

Readout electronics concept

Other (non-SPD) developments

Dune:
- triggerless
- identical requirements for time resolution
- similar requirements to charge measurements
- significantly lower bandwidth (<kHz)

Torino (post-Tiger):
- triggerless
- charge measurements adopted for MWPC/straws
- worse time resolution

Other options:
- Time-Over-Threshold for charge measurements?

Though no direct match, the experience of the ongoing R&Ds is useful

Possible solution:

Alexandr Solin

Параметры быстрого, временного канала		
Время формирования быстрого канала, нс	6÷10	
Разрешение временного канала, нс	1	
Регулировка порога дискриминатора, фК	0.5÷15	
ENC (r.m.s.), e Cd=60 пФ	<1000	
Временное окно TAC, нс	500÷5000	
Параметры медленного, амплитудного канала		
Коэффициент преобразования медленного канала, мВ/фК	straw	micromegas
	1/3	3/6/9
Время формирования медленного канала, нс	straw	micromegas
	75/150	75/150/250
Ширина сигнала по основанию, нс	300/600	300/600/1000
Порядок формирователя	4	
Разрядность АЦП, бит	10	
ENC (r.m.s.), e Cd=60 пФ	<1000	

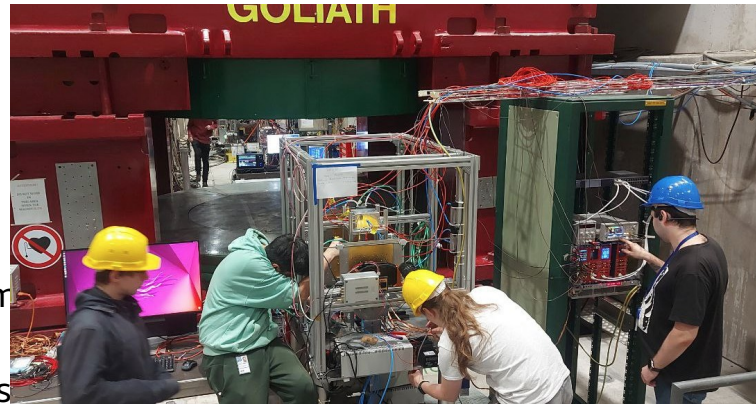
Параметры детектора	
Диапазон входных зарядов, фК	+/-(0÷1000)
Емкость straw детектора, пФ	20÷100
Загрузка на канал, кГц	150
Режим работы	Бестриггерный

Model exists
- can be used in Garfield/LTSpice

Expected to be designed by April next year

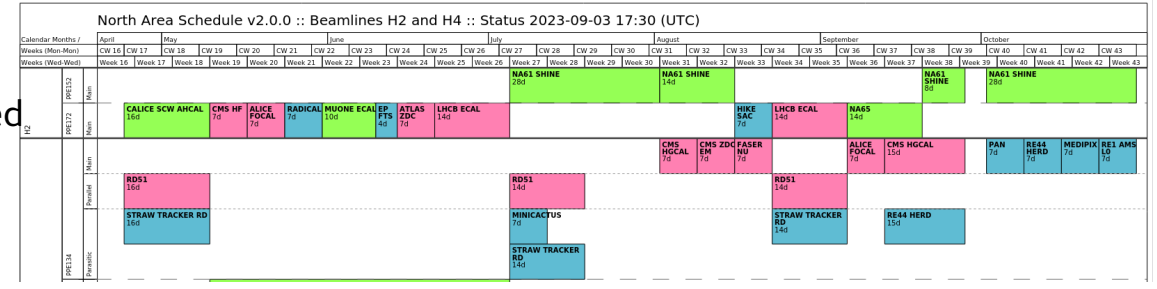
Summary

Complimentary studies are ongoing:
- lab and testbeam measurements
- Garfield/LTSpice simulation
- development of the readout concept



Advanced test setup is developed, combining up to three independent DAQ systems synchronized for offline merging and providing the good reference time (~300 ps) and spatial (better than 70 um even without the timepix layer) resolutions.

A significant part of the measurements is done during the scheduled SPS test beam periods (3x2 week of intense muon beam) – including the possibility to use dedicated electronics (VMM3, Tiger, Timepix4). Extra-time at the beam dump gives possibility for debugging + slow remote data taking



Measurements dedicated to PID (E(h)<GeV) are considered to be done next year with the PS beam. Possibility to use synchrocyclotron beam at PNPI is also considered.

Lack of experienced manpower!
But a lot of experience is being gained by young colleagues involved in R&D

Understanding the influence of the measured expected straw+readout performance on the track/charge reconstruction requires support with simulation studies