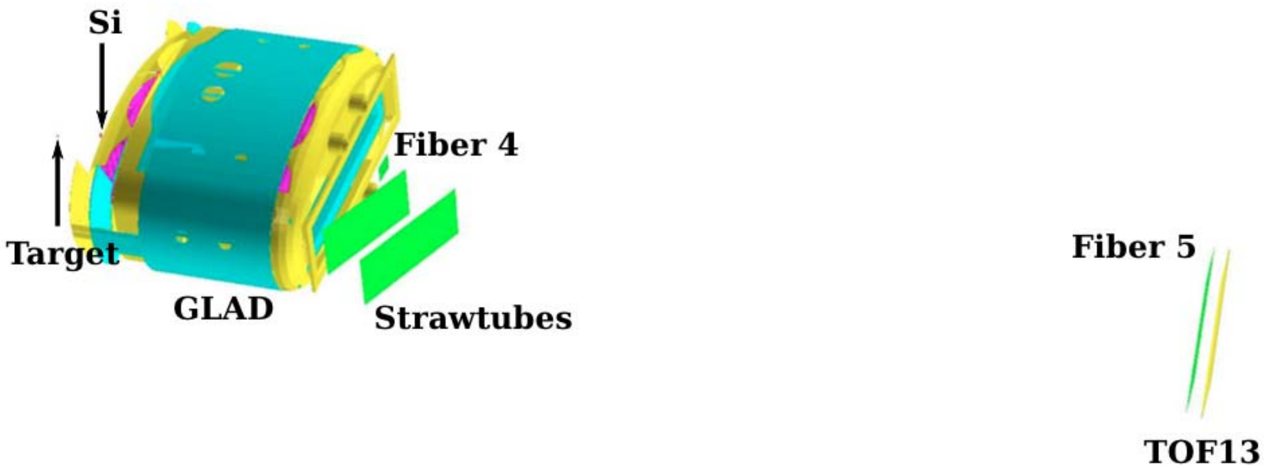
R^{3}B Tracking System



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NUSTAR Annual meeting,

GSI, Darmstadt

02-06, March, 2015,

General Specification

1. Charge of heavy fragments with resolution - $\Delta Z/Z$ – 0.5% (σ);
2. Mass and momentum with a resolution $\Delta A/A$ – $\Delta P/P$ – 10^{-3} (σ);
3. High rate mode - up to 1 MHz;
4. Multi hit capability;
5. Large momentum acceptance of - up to 20%;
6. Detection efficiency of combined system - $\geq$ 85%

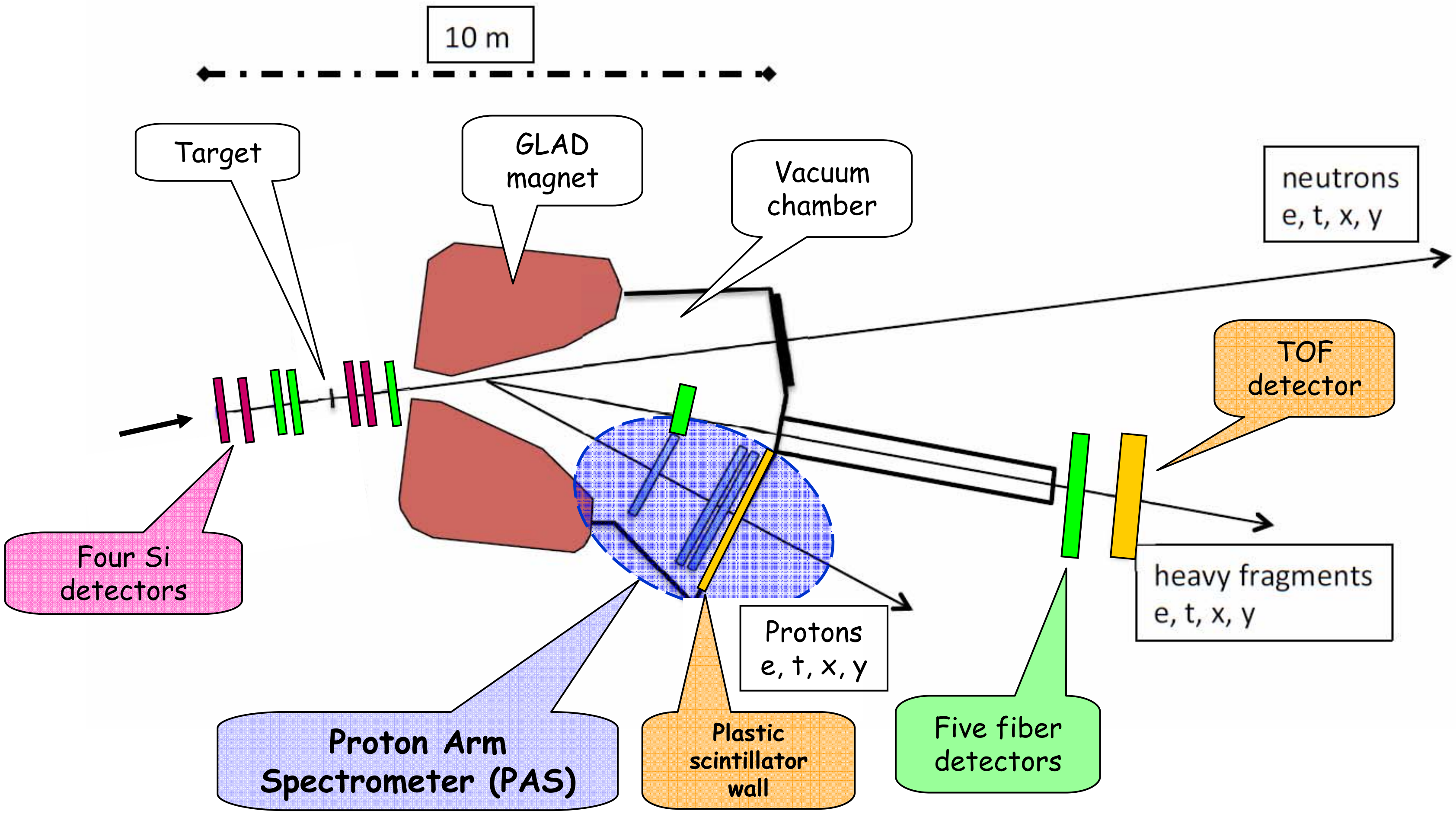
Three main modes of operation

High-resolution mode: tracking of heavy ions
(in this context: Z >50, A >100)

High-acceptance and multi-hit mode: tracking of multi-particle (fragment-breakup) decays and in-flight proton evaporation

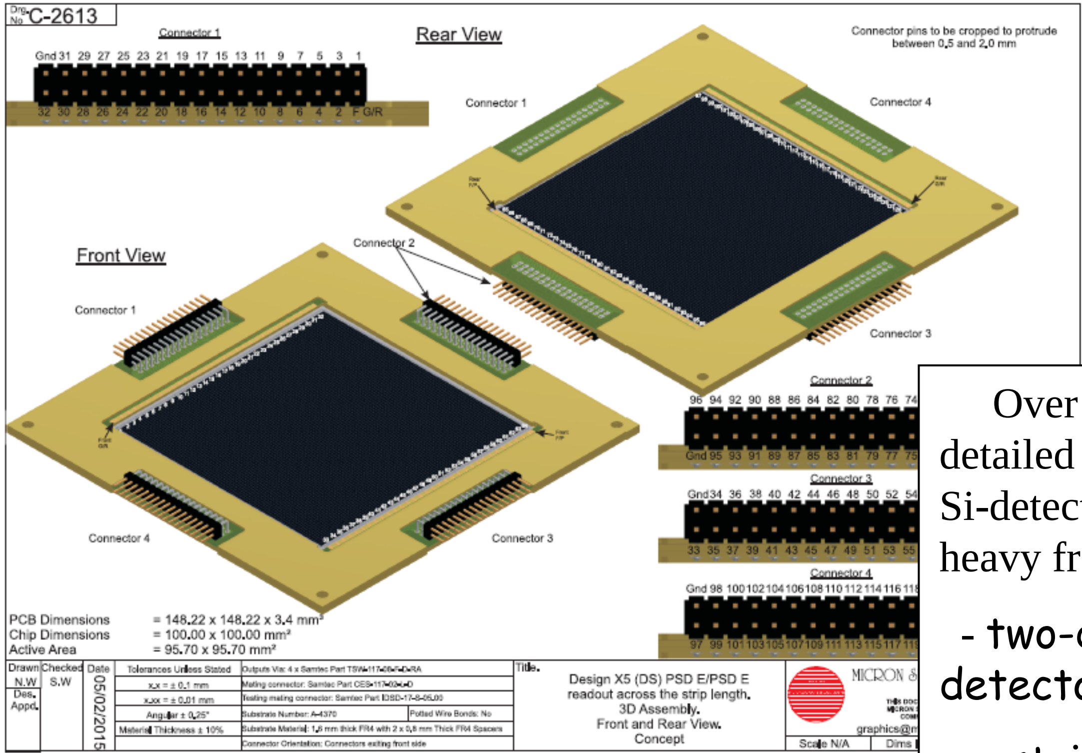
High-rate experiments (□1 MHz): less exotic beams
(exclusive use of plastic scintillator detectors)

R^3B tracking system setup



Si detectors

Status



Preliminary concept of the future 2D PSD Si detector (10x10cm2).

Over the past years we have performed detailed investigations of the use of Si-detectors for the detection of relativistic heavy fragments and protons, including:

- two-dimensional position sensitive detectors (2D PSD);
- strip position sensitive Si detectors;
- Si micro-strip detectors.

Presented below results have been obtained from both α-source and in-beam measurements

Preliminary results and conclusions.

1. Si detectors have to be used for both **energy loss** (charge identification) and **precise position measurements** before and after the target.

2. The nominal configuration is placing two Si-detectors before the target. From the two 2D-position measurements the angle and position on target is determined.

3. The thickness of the detectors **is chosen as the optimal solution** between position resolution, energy loss measurement, energy straggling and angular straggling but also the detector rise time, which defines the rate performance.

4. Since these detectors are placed in the beam line they must introduce **a minimum background** reaction rate and should withstand radiation damage.

5. <u>The first detector</u> is chosen to have a **thickness of 300 μm**, which allows for a clean identification of neighboring charges.

6. <u>The second detector</u> is placed closer to the target has a **thickness of 100 μm** thickness to minimize the contribution of the angular straggling.

7. Si microstrip detector a double-sided detector with a size of **10x10 cm2** and a pitch of about **700 μm** on both sides

Fiber detectors

Status

The tracking system will contain a total of five Fiber Detectors (FD). The fiber detectors will be designed to provide position measurements with very high precision, at various places along the trajectories of the beam and of the beam-like fragments

Technical parameters.

1. The plastic has a peak emission of light with a wavelength of 450 nm (blue) and a long attenuation length (>4.0 m).

2. The profile of the fibers will be squared with a size of **200×200 μm2**.

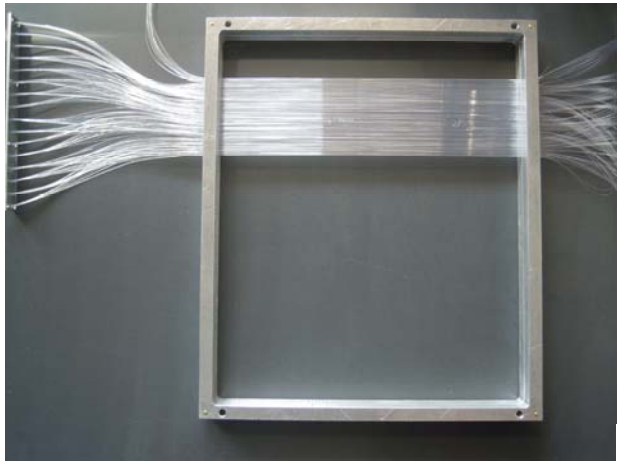
3. Total detection **efficiency of 90%** for one detector.

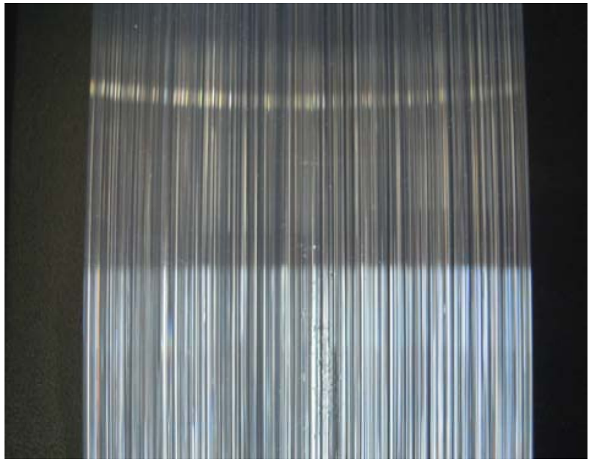
4. The 200 μm will give a position resolution of **σ = 57.7μm** across the fiber.

5. **FD1** (X,Y), **FD2** (X,Y) and **FD3** (X,Y) are placed around of target and have an active area of 10.24×10.24 cm2. These the small fiber detectors will be used instead of the Si for the very high rate runs.

6. **FD4** (X) is placed after GLAD magnet in vacuum volume. The width of the detector will be 40.96 cm.

7. **FD5** (X,Y) - the large fiber detector:
   - active area **120×80 cm2**;
   - consist of four layers of 200×200 μm2 fibers;
   - a position resolution of **σx = 58.3μm** and **σy = 462μm**;
   - is placed directly in front of the TOF-wall.



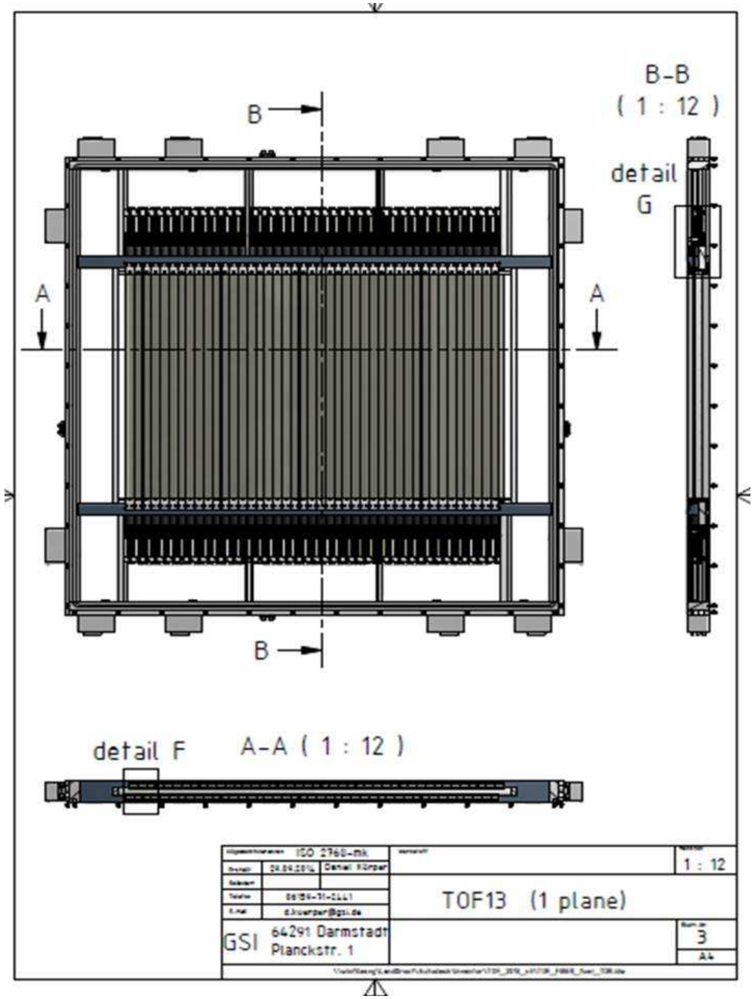


A picture of the frame with fibers for the prototype. The bundling of the fibers can be seen on the left. The right side is a close up of the fibers.

The FEBEX digitizer is build around a flash-ADC and runs at a sampling rate of 50 MHz. <u>The results from the prototype show that this rate will be sufficient to distinguish true signals from background.</u>

Time-of-flight plastic scintillator wall

Status



Front, top and side view of the TOF13 detector, that has been used as a prototype in our investigations.

Preliminary results and conclusions.

1. The active area of TOF detector should have dimensions of **120×80cm^2** (width and height).

2. We have made choice of scintillators with the dimensions:
- 800x27x**5** mm3 for lighter beams;
- 800x27x**3** mm3 for the heavier ions.

3. In principle, two layers of plastic scintillators behind each other, shifted by half the width **would be sufficient** for a full geometrical coverage of the fragment trajectories.

4. The signals are split in a **time** and **energy** branch.

- The signals of the time branch are recorded by a time-to-digital converter (TDC). The time signals are also used to produce, together with time signals of other detectors, a **high level trigger signal** for the read-out.

- The main contributions to the energy-loss and, thus, nuclear-charge resolution are coming from the number of detected photoelectrons and energy-loss straggling.

5. We are planning to build a new ToF detector with superior time and energy resolution at beam rates up to 1 MHz:

- Even at **1000 kHz** one could reach a time resolution for the whole detector of **23 ps,** which is rather close to the design goal.

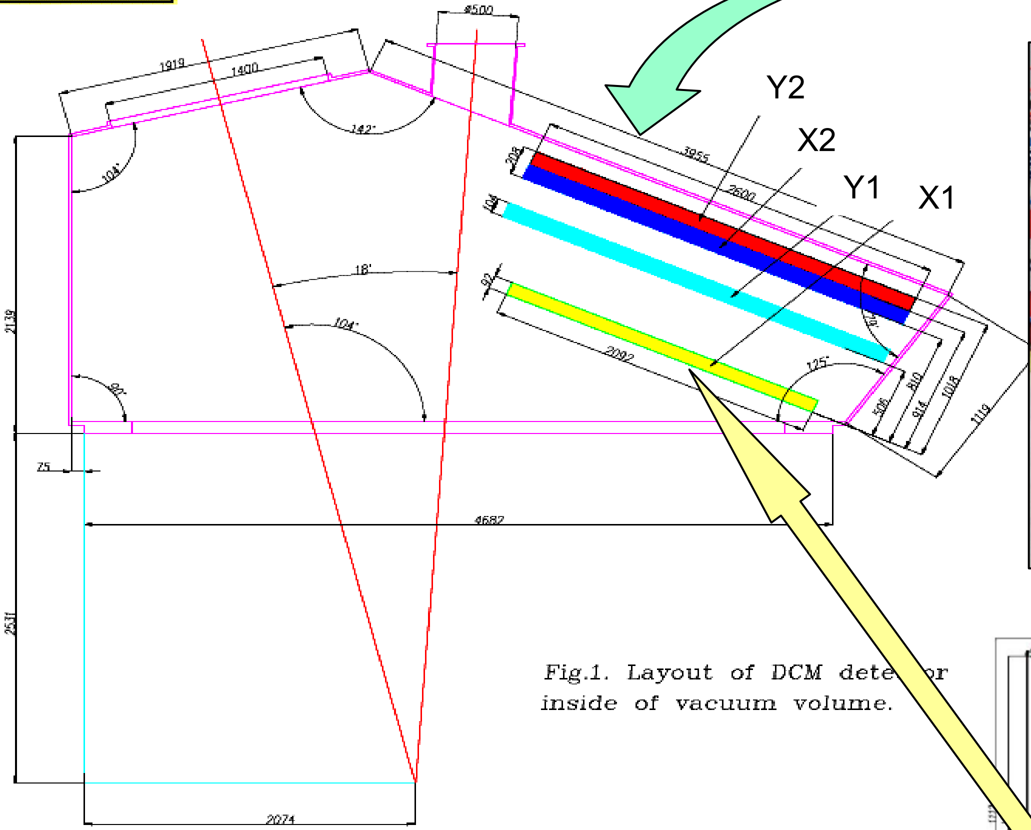
- Aim for TOF detector - **an energy resolution of σ(E)<1%.** The variation in scintillator thickness along one paddle contributes of course to the energy resolution.

- We see that up to about **300 kHz** counting rate the **shift is about 1% or less**. Only at higher rates the shift becomes larger than 1% which is not acceptable.

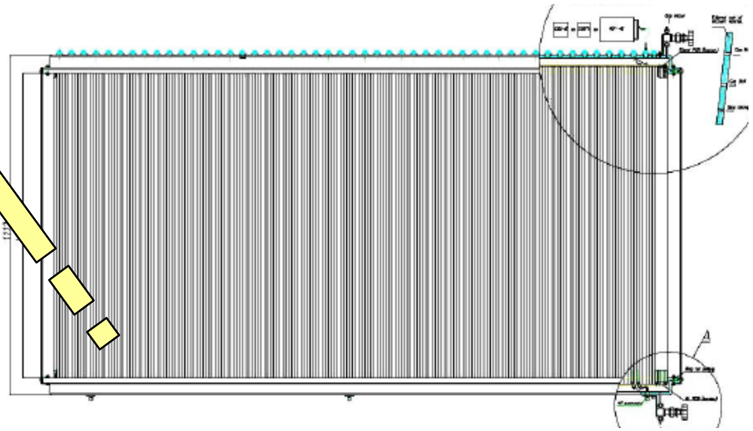
Proton Arm Spectrometer (PAS)

Status

Proton Arm Spectrometer layout



Layout of the drift chamber planes X1 (yellow), Y1 (light blue), X2 (blue and Y2 (red) inside the vacuum chamber behind the GLAD magnet.



General view of first STW (X1 – coordinate)

Overview of the four Straw Tube Wall (STW)

STW station	Outside dimensions [mm]	Aperture [mm^2]	Straw tube material	Straw diameter, mm	Number of straws (max)	Number of preamplifiers	Number of high voltage inputs
X1	2092×1112×92	2000×1000	Kapton (wall thickness - 60mkm)	10	610	39	3×2=6
Y1	2611×1092×104	2500×1000	Aluminum (wall thickness - 300mkm)	10	310	20	3×2=6
X2	2592×1112×104	2500×1000	Aluminum (wall thickness - 300mkm)	10	760	48	3×3=9
Y2	2611×1092×104	2500×1000	Aluminum (wall thickness - 300mkm)	10	310	20	3×2=6
				Totally	**1990**	**127**	**27**

Kapton tubes. First plane measures the X1 coordinate introducing minimal straggling.

Aluminum tubes. Although the angular straggling introduced by these tubes is significantly higher compared to the thin Kapton tubes their contribution in the dispersive angular measurement is negligible since they are placed at the end of the track.

Straw Tube Description

Figure 5.11.: Schematic drawing of a straw tube wound with two Kapton ribbons and an intermediate aluminized layer.

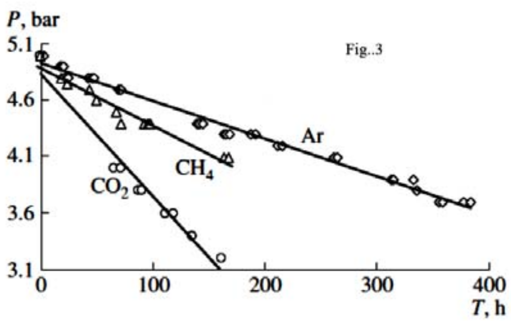


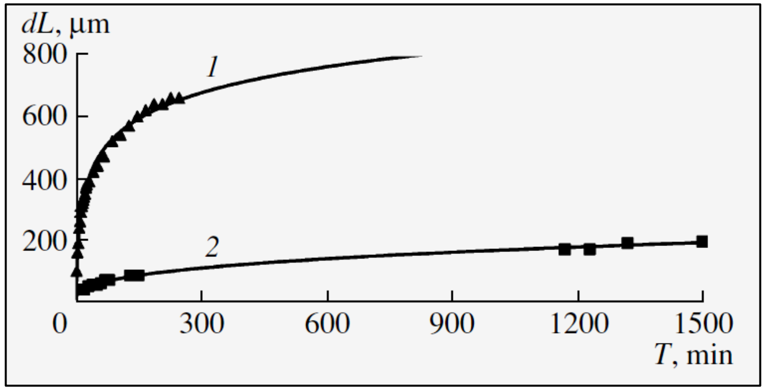
Figure 5.12.: Time dependence of the pressure of the straw-tube-filling gaseous mixture.

We are going to use the overpressure straw technology that has been developed by Juelich (Peter Wintz group) for different experiments (COSY, PANDA etc.).

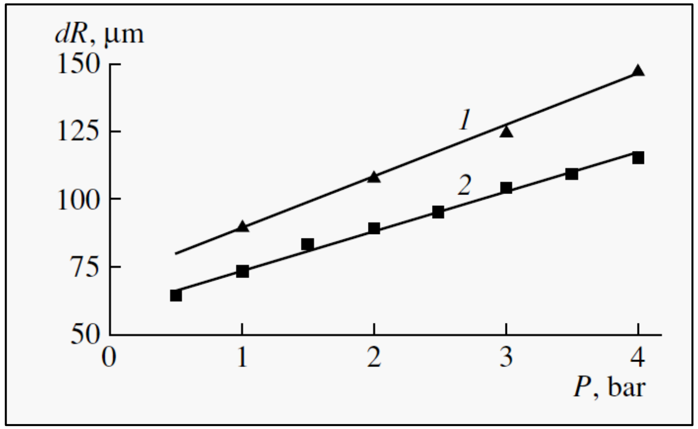
Who will be producer of straw itself (LAMINA or Dubna) still open.

The first STW (X1 plane) uses the high-pressure thin-wall straw tubes designed at JINR (Joint Institute for Nuclear Research, Dubna)

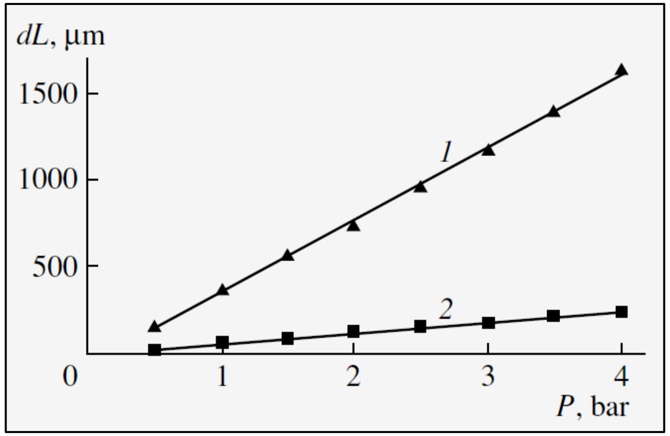
Straw tube mechanical properties



Time instability of the length of the straw tube at fixed pressures of (1) 4Bar and (2) 1Bar.



Radius of straw tubes as a function of differential pressure of the tube-filling gaseous mixture: (1) ordinary straw tube and (2) straw tube strengthened with carbon filaments



Elongation of a 1.55-m-long straw tube as a function of the differential pressure of the gaseous mixture: (1) without and (2) with strengthened walls of the straw tube.

Significant changes of the straw outside dimensions under influence of the gas overpressure have to be taken into account during production technology.

Radiation lengths. Detector material budget.

Element	Particle type	dE/dX_0 [MeV/mm]	X_0 [mm]	X/X_0
Straw tube material	Proton	0.315	8.19×10^{2}	1.46×10^{-4}
	α- particles	2.560	101	1.19×10^{-3}
	Li ions	8.594	30.1	3.99×10^{-3}
	B ions	33.284	7.76	1.55×10^{-2}
Anode wire	Proton	2.565	101	1.79×10^{-4}
Gas mixture $Ar\text{-}CO_2\text{-}CF_4$ (at 1 Bar)	Proton	4.613×10^{-3}	5.6×10^{4}	2.48×10^{-4}

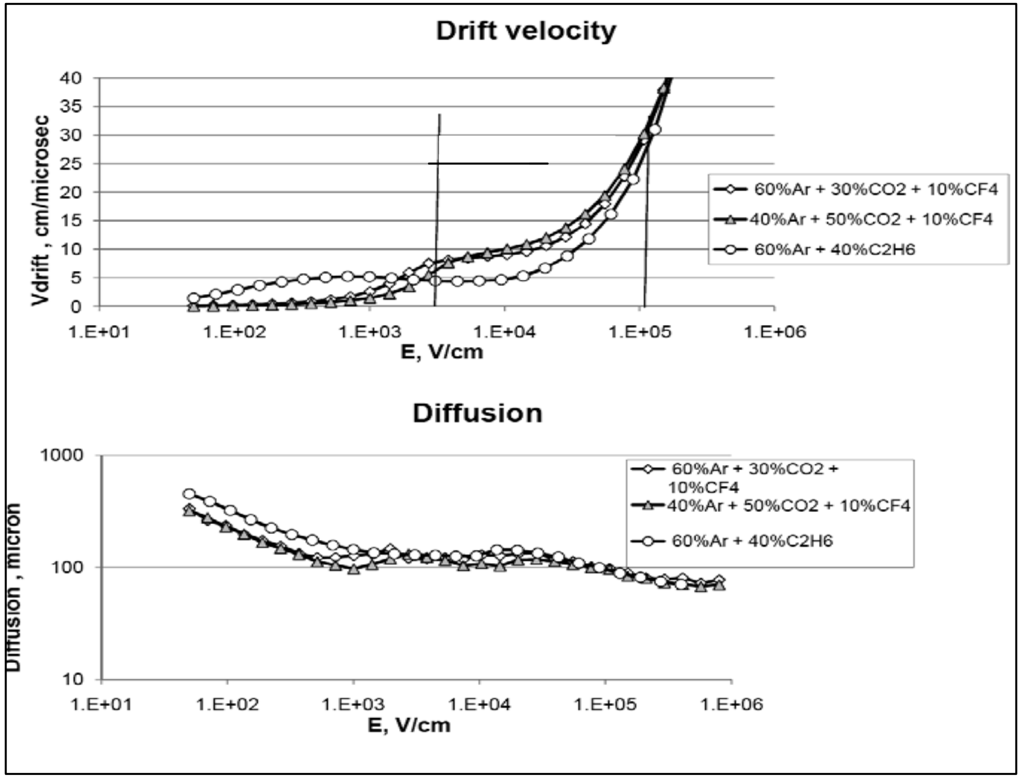
Total X/X_0 of one straw [%]	*Proton*	0.057 [%]
Total X/X_0 of STW(X1) [%]		**0.172 [%]**

Mean thickness in radiation lengths of the different straw tube components for the protons, α- particles, Li and B ions with the energy of 700 MeV for one straw tube and for STW.

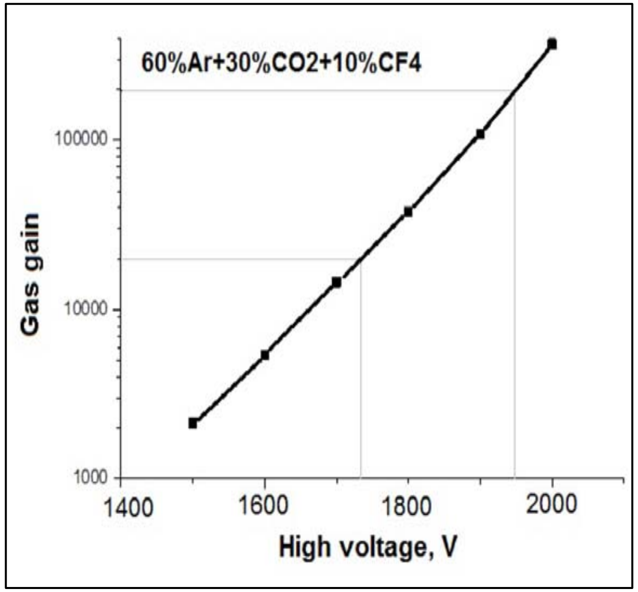
The STW material contributes no more than 0.2% of the total radiation length

It was evaluated by using SRIM@2011 program.

Garfield simulation of drift velocities, diffusions and gas gain behavior for different gas mixtures



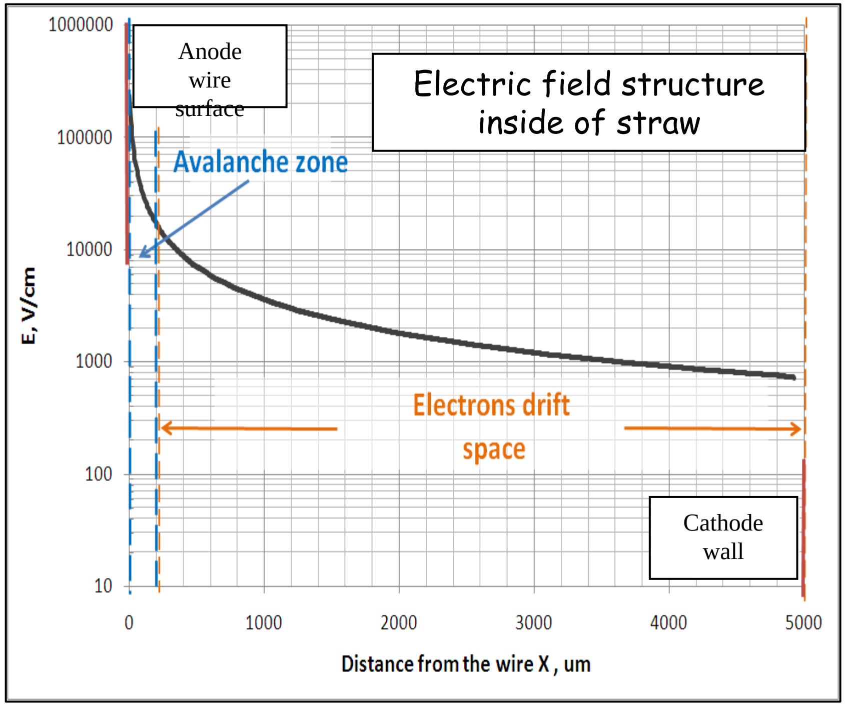
Drift velocities and diffusion coefficients via the field tension for the gas mixtures intended to use in detector.

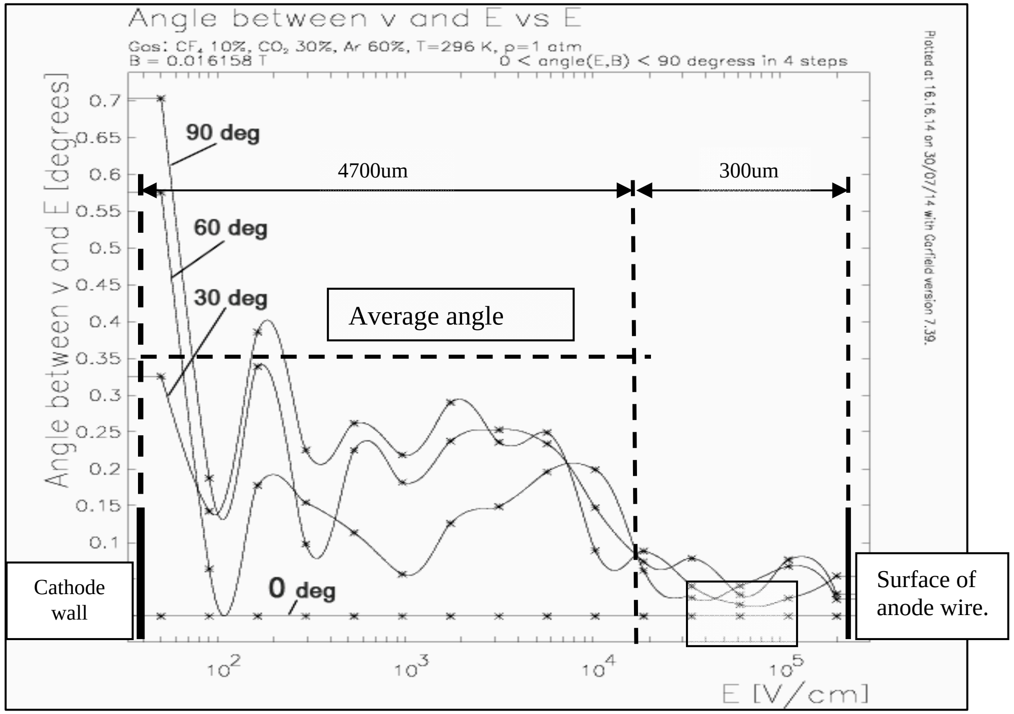


Simulated gas gain versus high voltage

The optimal choice of the working gas mixture is yet to be determined.

Influence of magnetic field on the PAS operation.

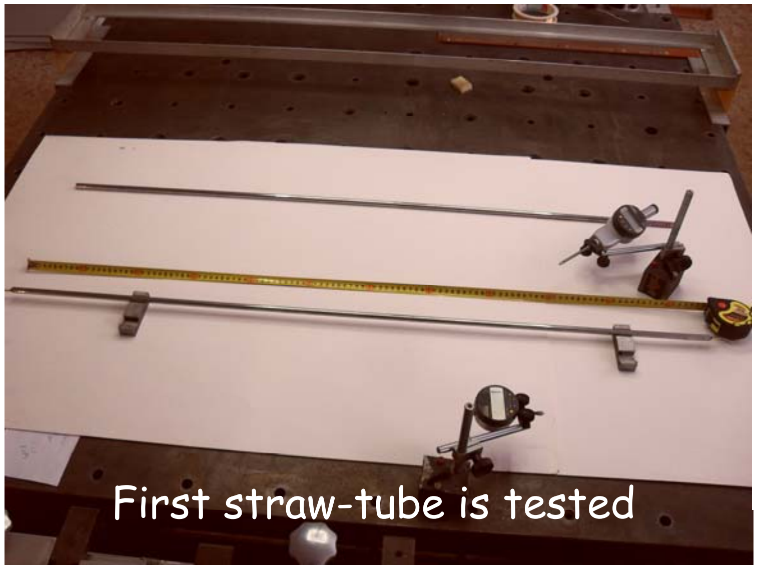




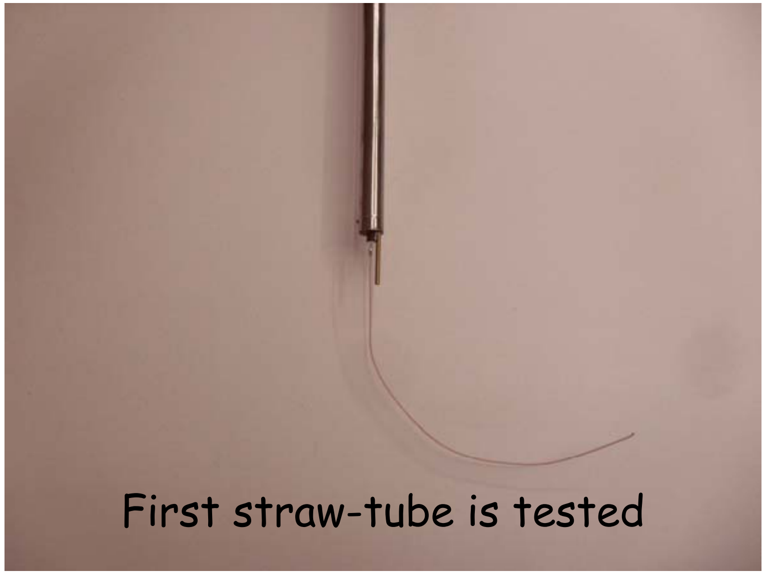
The path lengths of the electrons moving from its particle track to anode wire in crossed electric and magnetic **fields is increased in compared with the case of the lack of a magnetic field**. This causes changes in space/time (X-T) base relation and, consequently, can cause errors in determining of the particle coordinates in the detector.

Average angle between the velocity vector and the vector of the electric drift field is about 0.35^0. This corresponds to an error in the determination of particle coordinates – it **does not exceed of a few microns**.

Influence of the magnetic field on the straw operation parameters can be ignored completely.



First straw-tube is tested



First straw-tube is tested

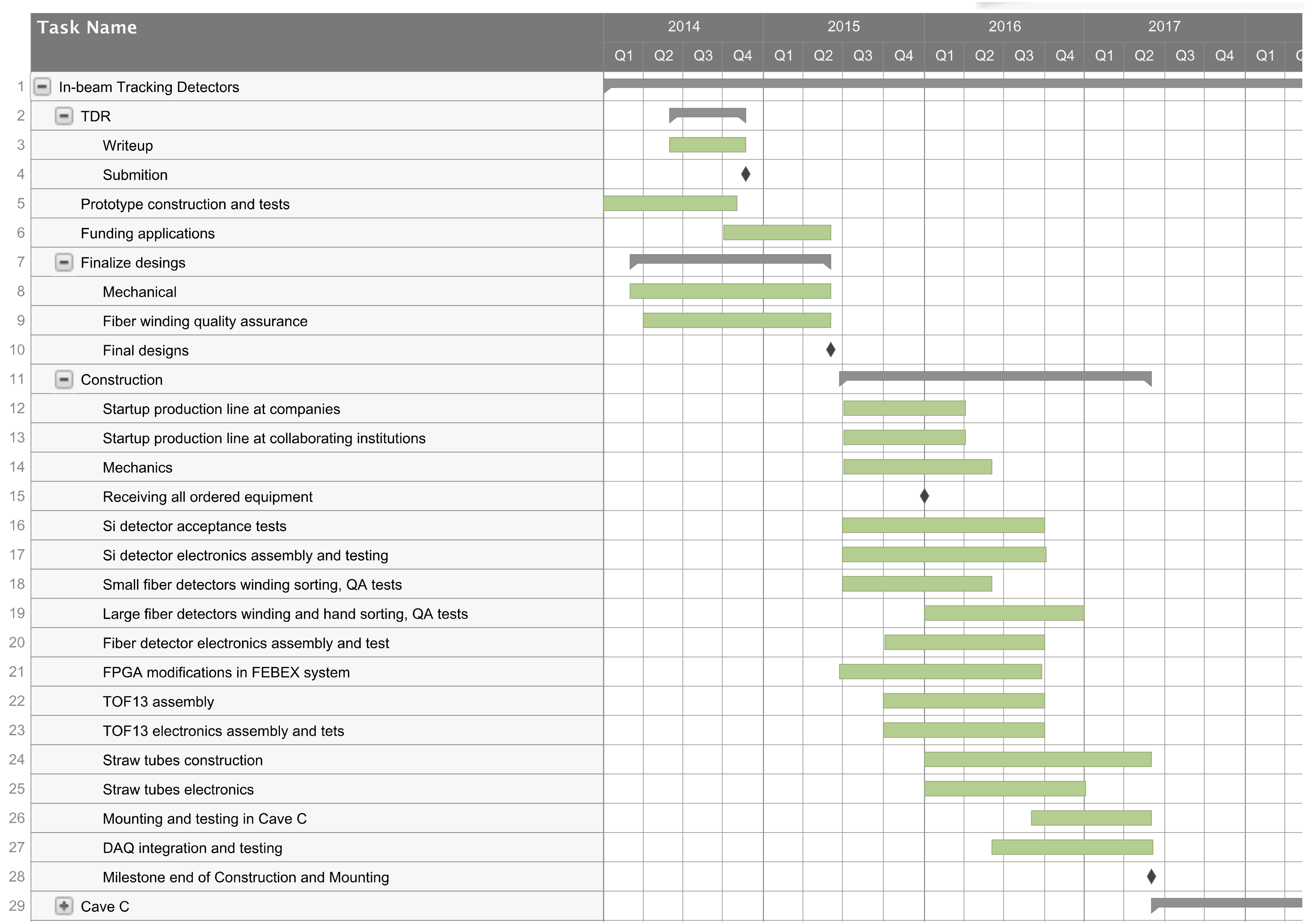
Subsystems

- Readout
- High voltage
- Low voltage
- Gas system
- Cabling

Proton Arm Spectrometer

	PAS parameters	Value
1	Geometrical acceptance	of ±80 mrad (gap of the dipole magnet)
2	Detector active area	up to 1000×2500 mm
3	Granularity (tube diameter)	10 mm
4	Space resolution	≤ 200 μm
5	Angle resolution	≤ 0.2 mrad
6	Gas mixture overpressure	1 Bar
7	Efficiency	≥ 95%
8	Total count rate for single tube	≥ $1x10^5$ s^{-1}.
9	Operation area	vacuum

Time Schedule Table and Milestones



Thank you for your attention