Novosibirsk State University
*THE REAL SCIENCE

Development of compact TPC for future Super Charm-Tau Factory detector

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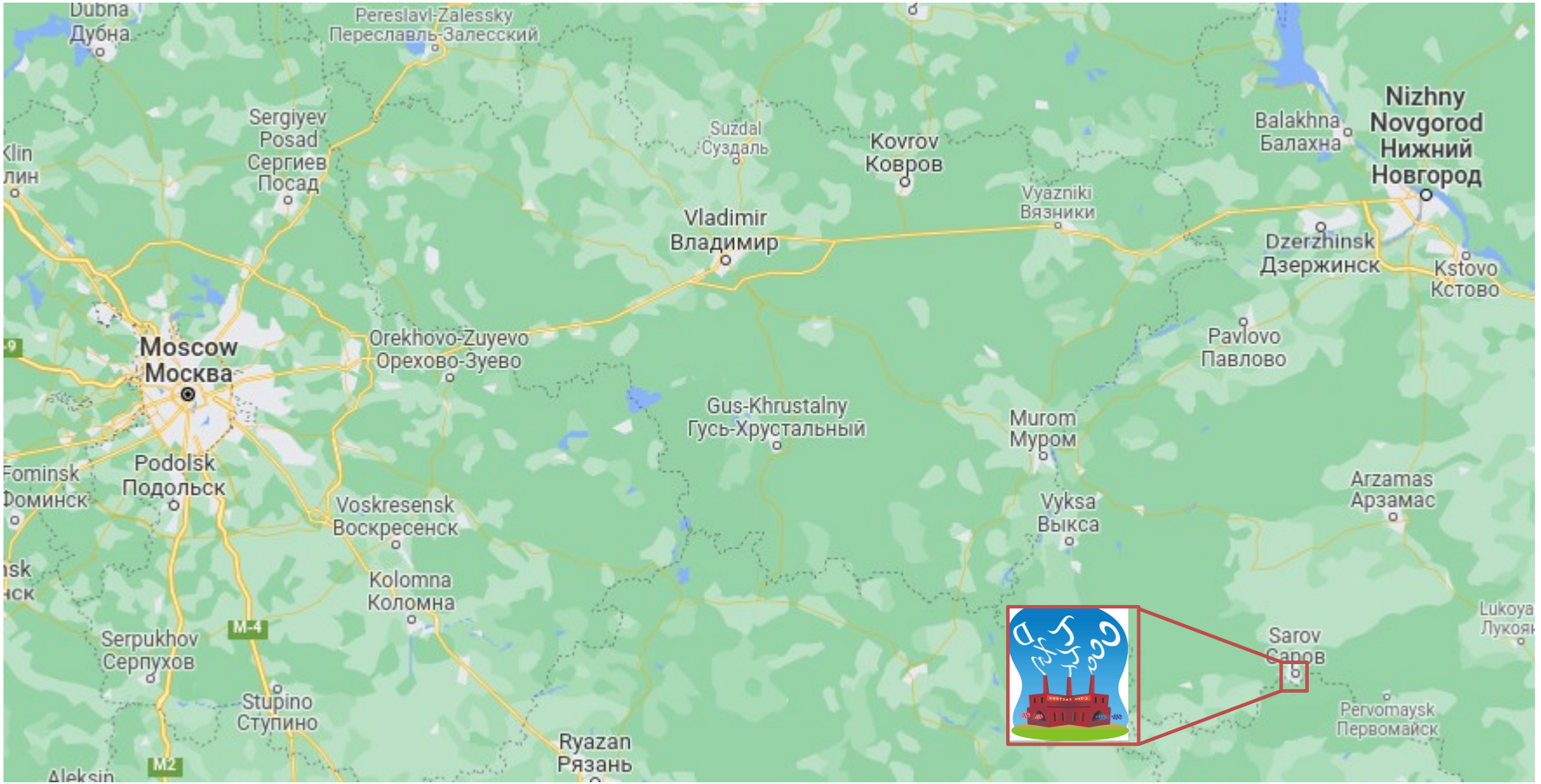
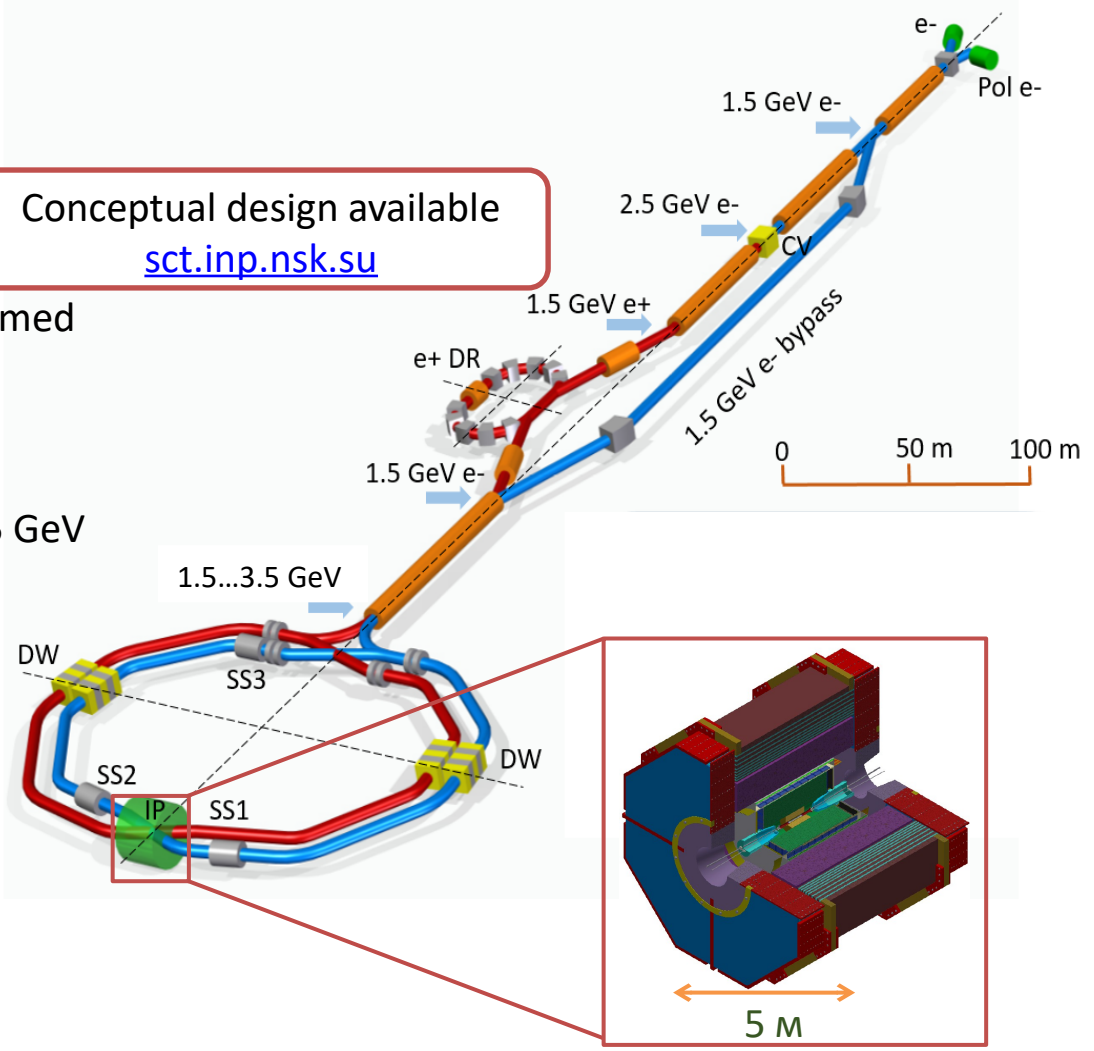
Super Charm-Tau Factory Project in Russia



The SCT experiment

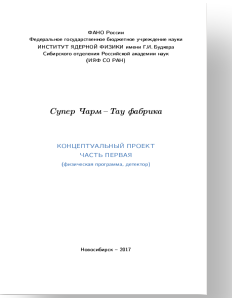
Conceptual design available
[sct.inp.nsk.su](sct.inp.nsk.su)

- Precision experiments with tau lepton and charmed hadrons, and search for BSM phenomena
- Electron-positron collider
  - Beam energy varying between 1.5 and 3.5 GeV
  - Luminosity $10^{35}cm^{-2}s^{-1}$
  - Longitudinal polarization of the e-beam
- Universal particle detector
  - Tracking system
  - Crystal electromagnetic calorimeter
  - Particle identification system



Physics program of SCTF

SCTF – experiment with a wide program of precision measurements



sct.inp.nsk.su

- ✓ Measurement of strong phases of -meson decay amplitudes
- ✓ Measurement of absolute decay probabilities
- ✓ Search for rare charm quark decays
- ✓ Search for violations in charmonia
- ✓ …

Necessary for studying mesons on LHC and Belle II

charm

QCD

- ✓ Physics of excited quarkonium
- ✓ Molecular states
- ✓ Threshold interactions of baryons
- ✓ Search for glueballs in decays
- ✓ …

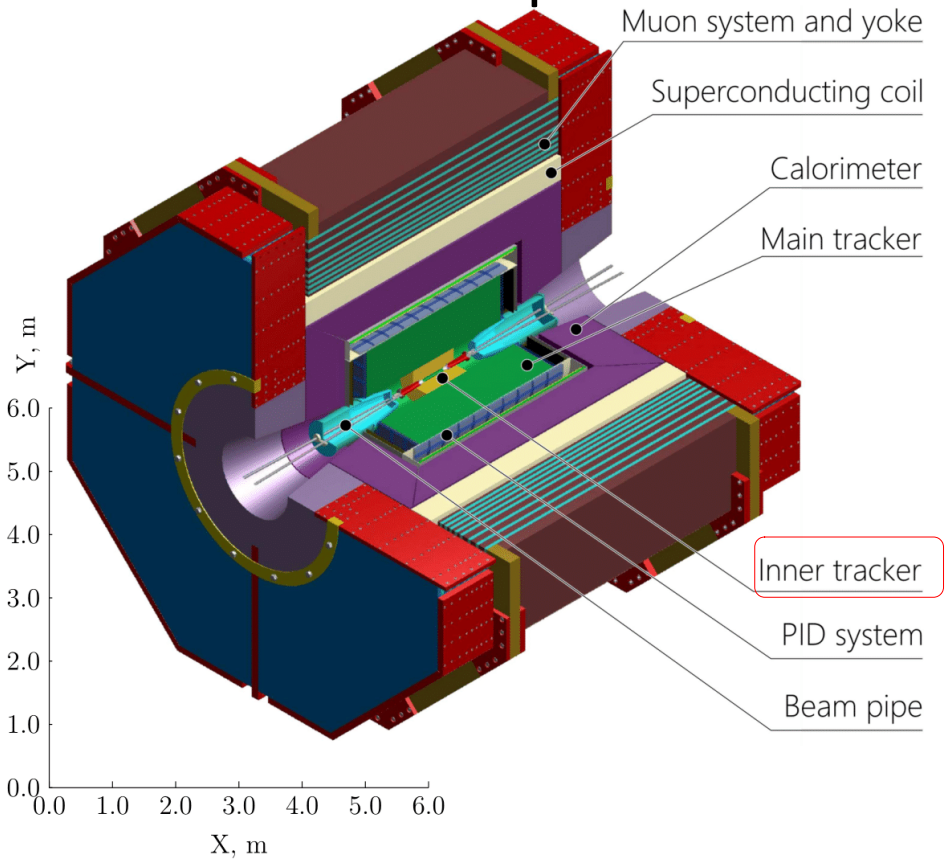
tau

- ✓ Precision measurement of lepton properties
- ✓ Michel parameters, lepton universality test
- ✓ Precision measurement of hadronic lepton decays
- ✓ Search for breaking and T symmetries in decays
- ✓ …

Check of the electroweak model

QCD, Checking the electroweak model, searching for non-standard contributions

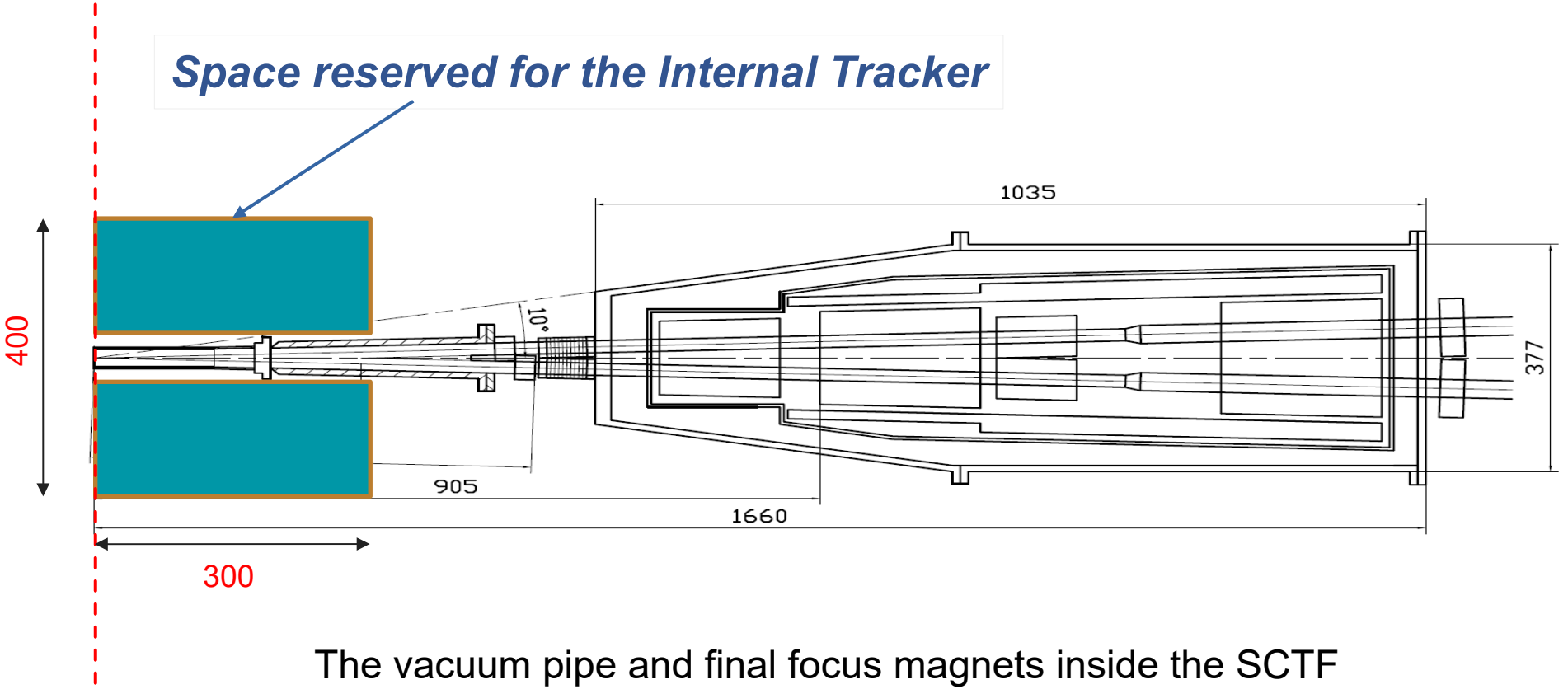
Detector concept for Charm-Tau Factory



Physics requirements:

- **Good for charged particles.**
- **Good symmetry and hermeticity;**
- **Soft track detection**
  - **Inner tracker to work with rate of charged tracks ≥10^4 cm^{-2} s^{-1}**
- **Good μ/π/K-separtion up to 1.5 GeV/c;**
  - **Good resolution;**
  - **Specialized PID system for μ/π and π/K-separation;**
- **Good -separation and -detection with**
  - **EM calorimeter with as close as possible to physics limit;**
  - **Fast calorimeter (and small shaping time) to suppress beam background and pileup noise;**
- **DAQ rate ~300 kHz at - peak**

Machine-Detector Interface



The vacuum pipe and final focus magnets inside the SCTF detector (one-half is shown)

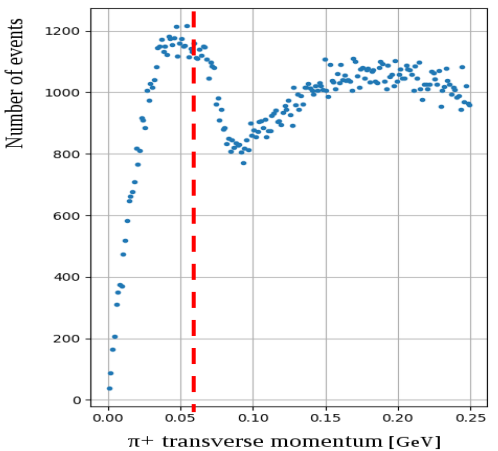
Internal Tracker

Tasks

- ✓ Detect secondary vertices from the decays of short-lived particles such as K^0_S or Λ
- ✓ Increase the lever arm of the drift chamber in measuring the momenta
- ✓ Soft $\pi^{\pm}$ mesons registration (with momenta < 100 MeV/c)
- ✓ *d*E/*d*x capabilities (optional)

Requirements

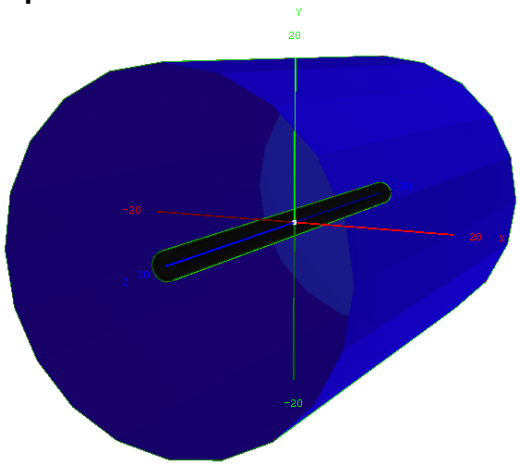
- ✓ Deal with high particle flux - luminosity of 10^{35} cm^{-2} s^{-1}
- ✓ Have a spatial resolution of about 200 micron.
- ✓ The angular coverage close to 4π



Distribution of π^+ transverse momentum distribution from $e^+e^- \longrightarrow$ DD* reaction. The dashed red line shows the low momentum cutoff due to material of beam pipe and inner wall of TPC.

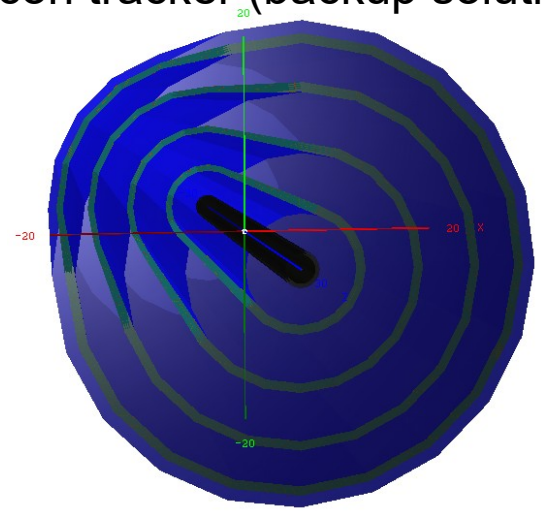
Internal Tracker options

Three options are considered for Internal Tracker at the moment: TPC, cylindrical μ-RWELL tracker and the Silicon tracker (backup solution).



TPC with MPGD readout

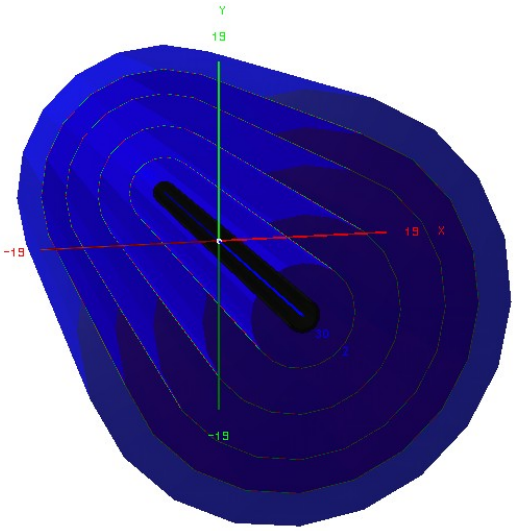
Developed by Budker INP



Cylindrical μ-RWELL tracker

Developed by INFN-LNF within CREMLIN PLUS

Connecting Russian and European Measures for Large-scale Research Infrastructures



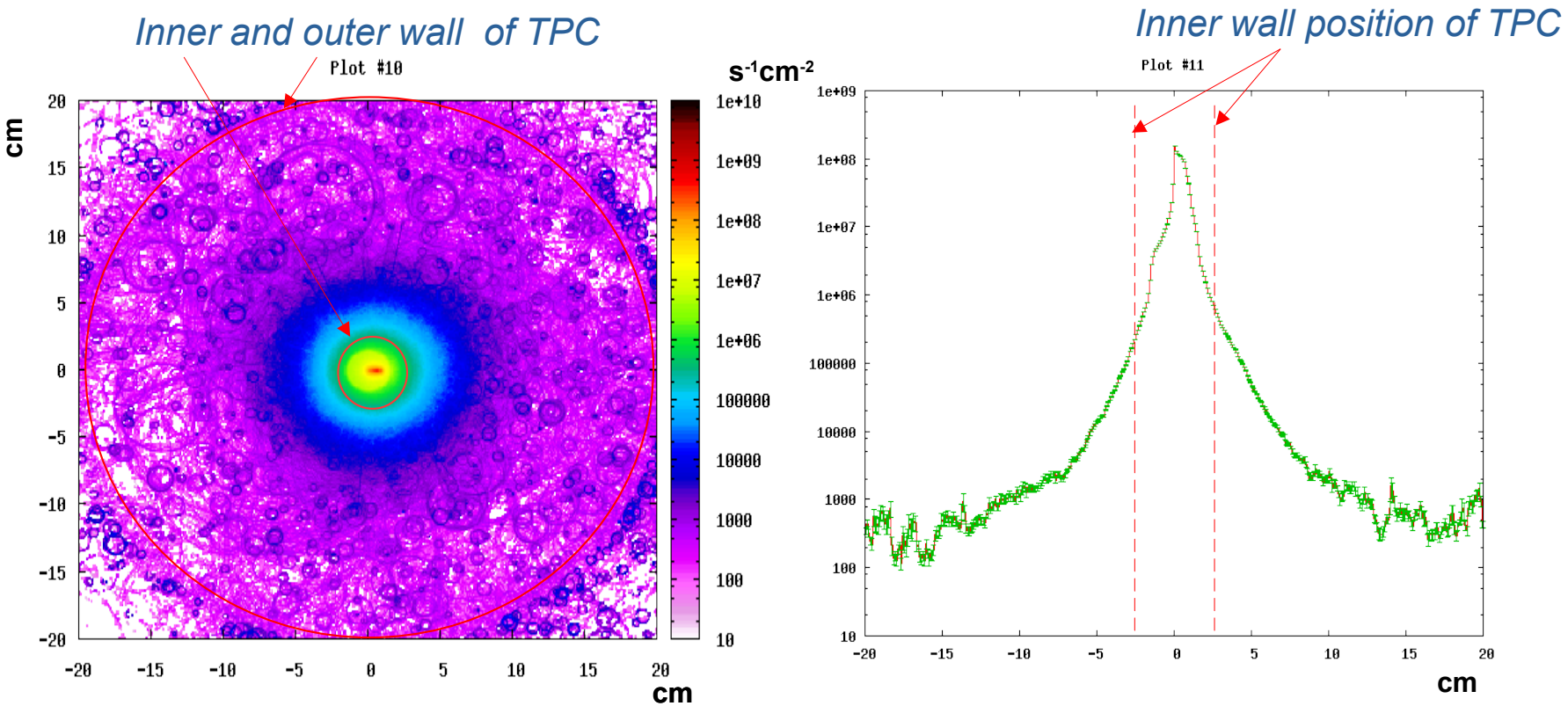
Silicon tracker

Reference project

BELLE-II SVT

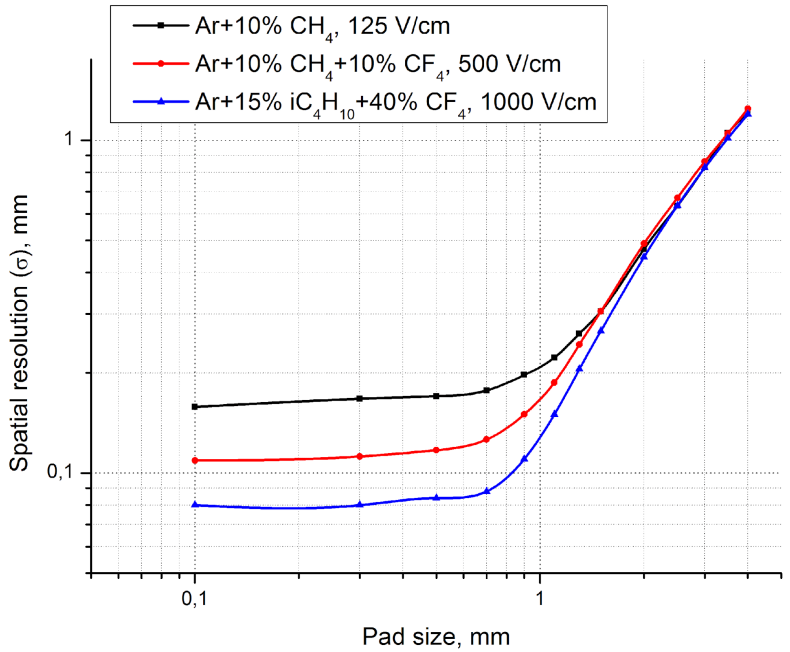
Backup solution

Background Simulation for TPC option



Simulation of the physics background flux is performed with the FLUKA. The main source of physics background $e^+e^- \rightarrow \gamma\gamma \rightarrow e^+e^- e^+e^-$ and $e^+e^- \rightarrow e^+e^-\gamma$ reactions. Simulation results show that the TPC concept is quite feasible.

Spatial resolution of TPC



Spatial resolution as a function of readout pad size for three gas mixtures:

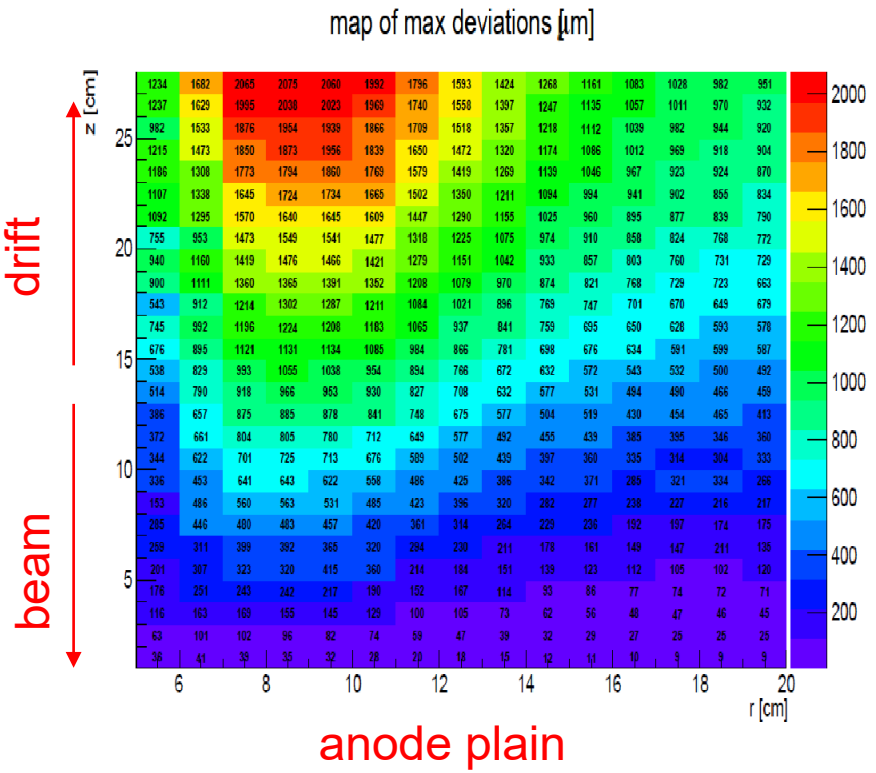
1) Ar+10%CH_4 at 125 V/cm drift field;
2) Ar+10%CH_4+10%CF_4 at 500 V/cm;
3) Ar+15%iC_4H_{10}+40%CF_4 at 1000 V/cm.

In order to determine an optimal gas mixture for the best spatial resolution simulations, based on GARFIELD++ code, are performed.

Spatial resolution was determined for pieces of tracks, perpendicular to the end plane, that correspond to 50 ns of drift time.

Then the center of gravity (COG) method was applied to determine the final coordinate of each piece of track, and the distribution of residuals between actual positions and simulated positions was obtained. Spatial resolution was determined as *RMS* of such distribution.

Ion space charge effects



Map of the electrons drift lines deviations for the gas mixture Ar+15%i-C_4H_{10}+40%CF_4 at 1000 V/cm initial drift field, gas gain of the readout detector of 10000 and IBF=1%.

In order to estimate the distortion of the drift lines a dedicated simulation was performed. Ion space charge distribution along radius was calculated according to the background charged particles flux distribution. Distribution of space charge along Z was uniform. For the calculation of actual space charge density, the gas amplification of the readout detector was fixed at 10000 and ion back-flow (IBF) value was varied from 1% to 5%.

We assumed that we would be able to optimize the readout detector in order to reach the necessary IBF value at a gain of 10000. After the actual space charge distribution in the TPC volume is fixed, the electric field is calculated with the COMSOL program. Then the deviation of electron drift passes from the straight lines were calculated.

Space charge effects in the TPC

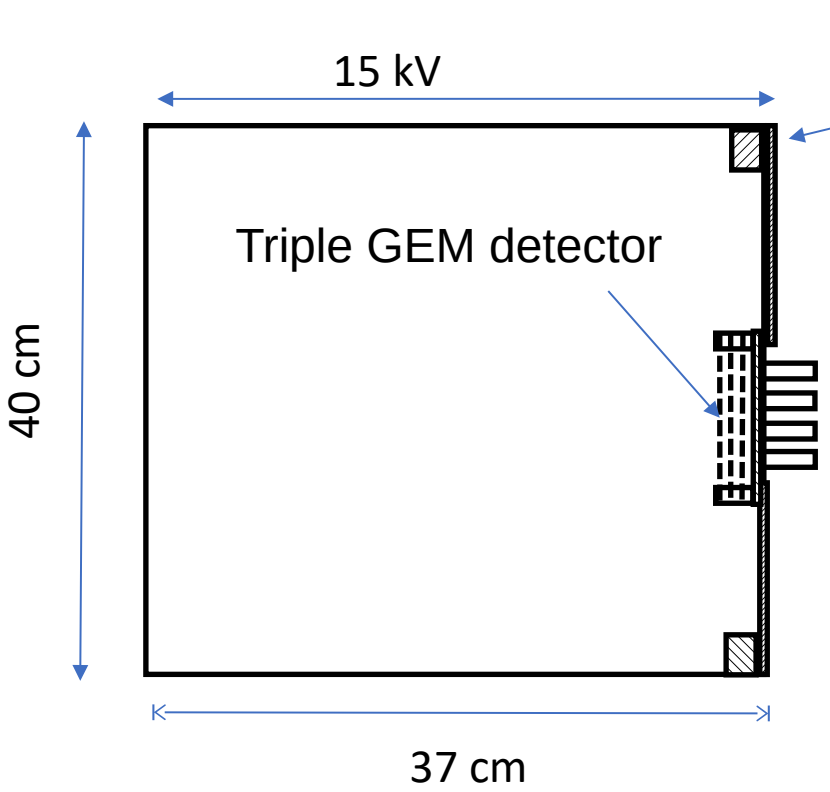
Summary of the results of the simulations of space charge effects in the TPC.

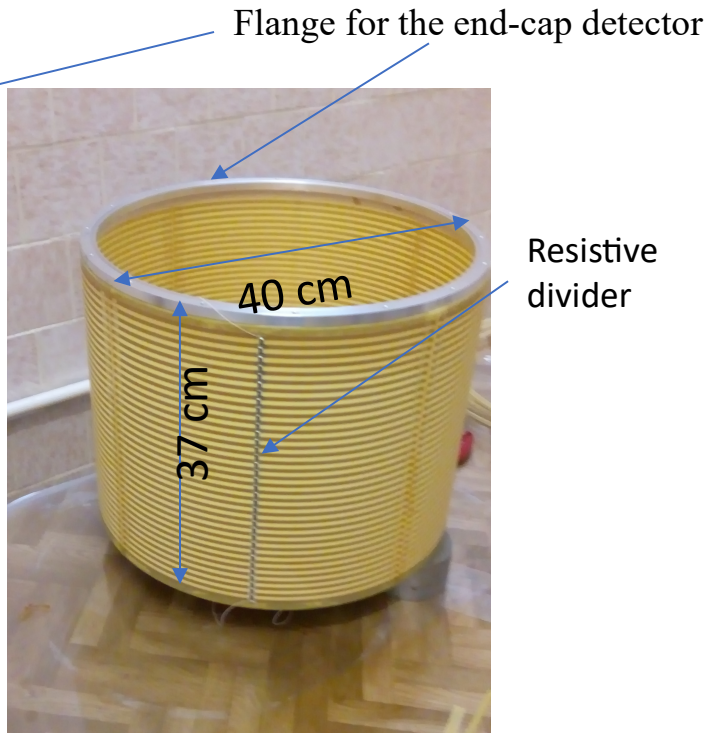
Gas mixture	E, V/cm	dn_e/dx, cm^{-1}	t_{drift}, s	IBF*	Max deviation, mm
$Ar+10\%CH_4$	125	90	0.14	1%	94
$Ar+10\%CH_4+10\%CF_4$	500	90	0.03	1%	5.0
$Ar+10\%CH_4+10\%CF_4$	500	90	0.03	3%	15.1
$Ar+15\%iC_4H_{10}+40\%CF_4$	1000	112	0.02	1%	2.1
$Ar+15\%iC_4H_{10}+40\%CF_4$	1000	112	0.02	3%	6.2

* Ion Back Flow

TPC prototype

The TPC prototype is now under construction. It consists of two main parts: first is the field cage with high voltage distribution, resistive divider, high voltage flange and electrode, and second is the readout flange with the detector. The main dimensions are shown on the plot.





Conclusions

1. The compact TPC is proposed to use as an Internal Tracker for the detector for Super Charm-Tau Factory;
2. The simulation of the background and the drift line distortion shows the feasibility of this concept;
3. The simulation of the spatial resolution have been done in order to choose the best gas mixture;
4. The best performance was demonstrated by the gas mixture of Ar+15%iC_4H_{10}+40%CF_4 with a pixel size of about 0.7 mm;
5. A prototype of the TPC is currently under construction. It will be used to check all simulation results.
6. In addition the prototype will be used to test various readout concepts;
7. The full simulation of the TPC is currently being developed as part of the AURORA simulation package.