SPD Group Meeting 06 May 2019

SPD Magnetic System

A.Kovalenko for the SPD magnet group

JINR (Dubna)

SPD MS: General remarks

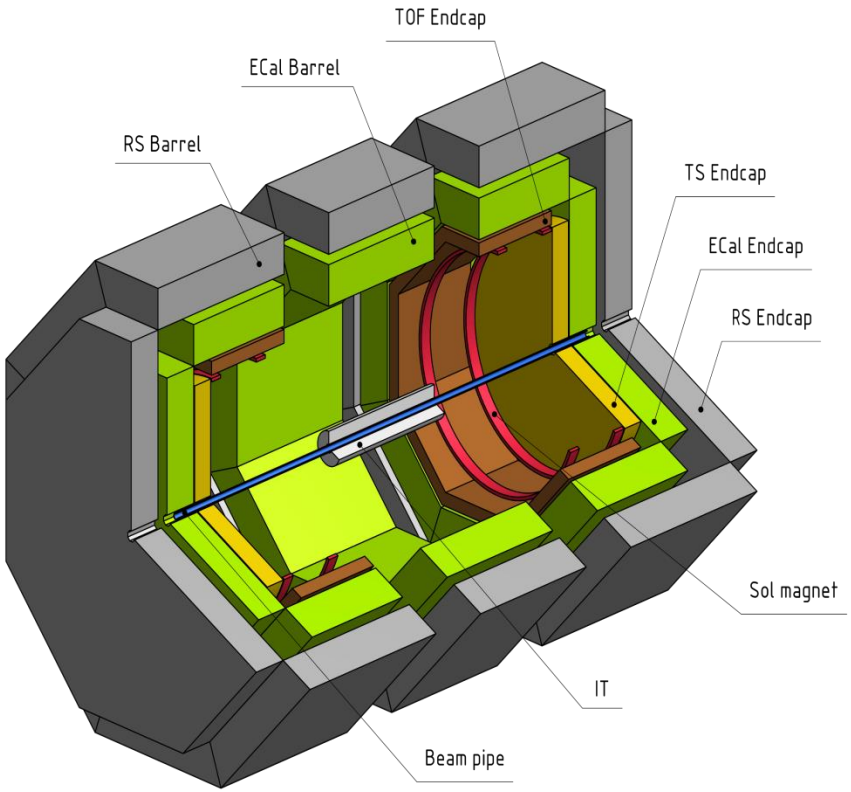
- Discussion on the optimal SPD MS has it's history and is continuing up to now.
- Two options were mainly discussed until 2018. These are: solenoid and toroid.
- Since the beginning 2018 the group involved in preparation of the SPD Conceptual Design also came to the problem of that choice.
- Basic criteria of the MS design were approved the SPD Committee meeting in February 2018.

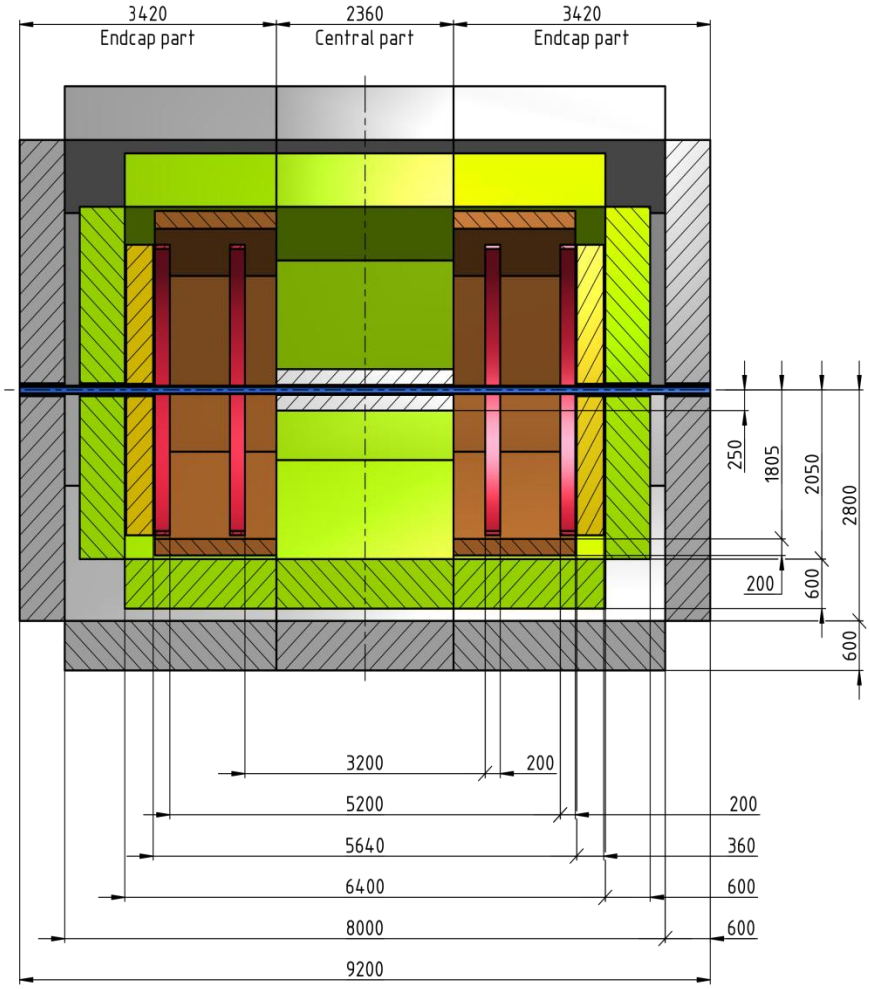
Basic criteria of the MS choice in 2018

- universality
- minimal influence on interacting particles spin
- minimization of the MS material inside the detector
- field integral of (1-2) T·m along the particle track
- minimization of the SPD total weight and sizes

Seven options have been considered and

SPD updated composition





SPD MS considered options

- solenoid (placed outside ECal);
- Toroid (inside ECal): 1) *barrel part*, 2) *barrel+2 end parts*, 3) *warm coils*, 4) *superconducting coils;*
- 4 separate coils inside the ECal;
- combination of the barrel toroid and 2 pairs of the coils inside the ECal.

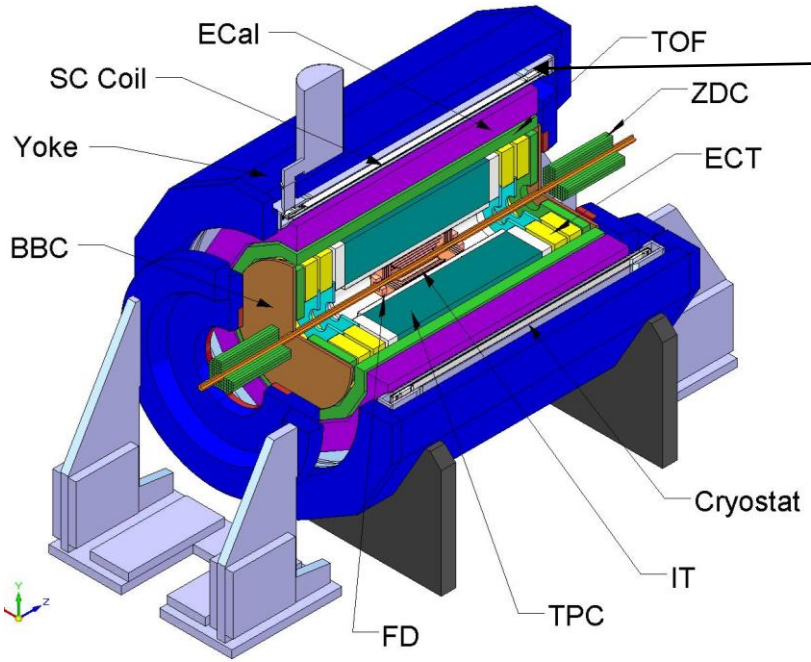
SPD Solenoidal MS (1)

Well-known for NICA design exists:
see MPD solenoid, the design have been performed, manufacturing is in progress. It's contribution of Chech Rep. (Vitkovice machinery plant) and ASG company (Italy).

Main advantages of such solenoid are: 1). Better uniformity of the field and 2) well – known design.

Main disadvantages: 1) magnetic field integral at the beam axis is large enough (spin!), 2) no any universality.

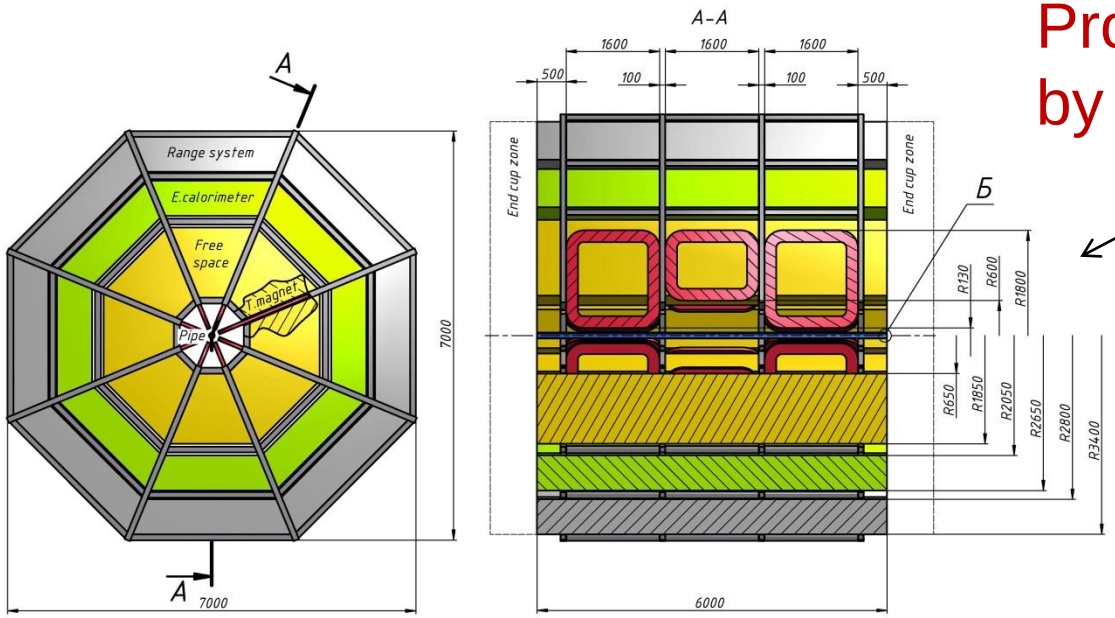
SPD Solenoidal MS (2)



MPD setup. Solenoid outside of all detectors.

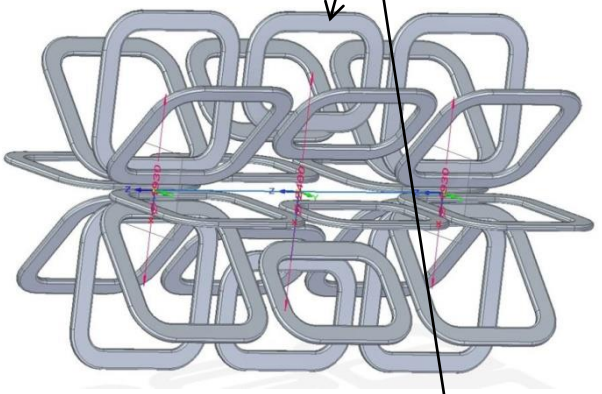
Some mechanical parts of MPD manufactured at Ostrava plant .

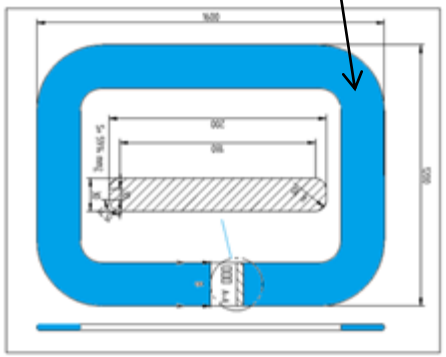
SPD Toroidal Magnetic System (1)



Proposed and described by A.Nagaitsev

Warm copper coils, 400 kA.turns each





3D - calculations were performed by E.Perepelkin, R. Polyakova et al. (LIT)

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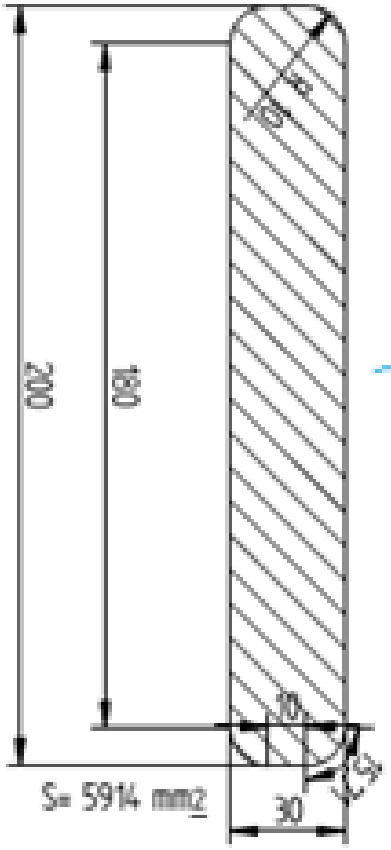
SPD Toroidal Magnetic System (2)

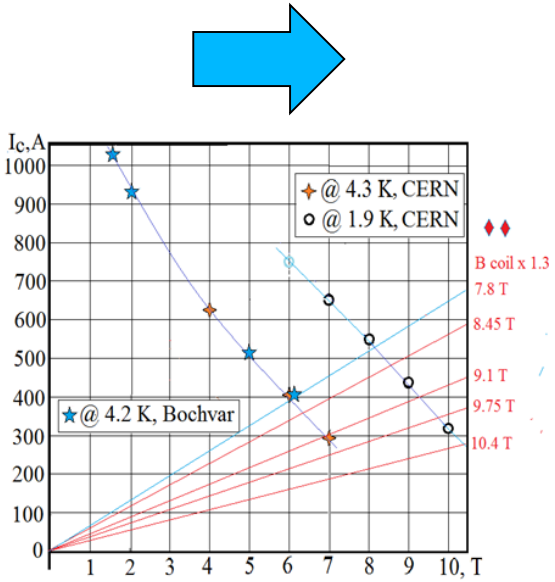
Warm copper coils: the coil cross section is too large for the providing of 400 kA·turns in each coil that is necessary to obtain the specified field.

Other solution: superconducting coils, based on a hollow NbTi composite cable, like that have been designed for the Nuclotron or the design approach used usually for tokamak set-ups.

SPD Toroidal Magnetic System (2)

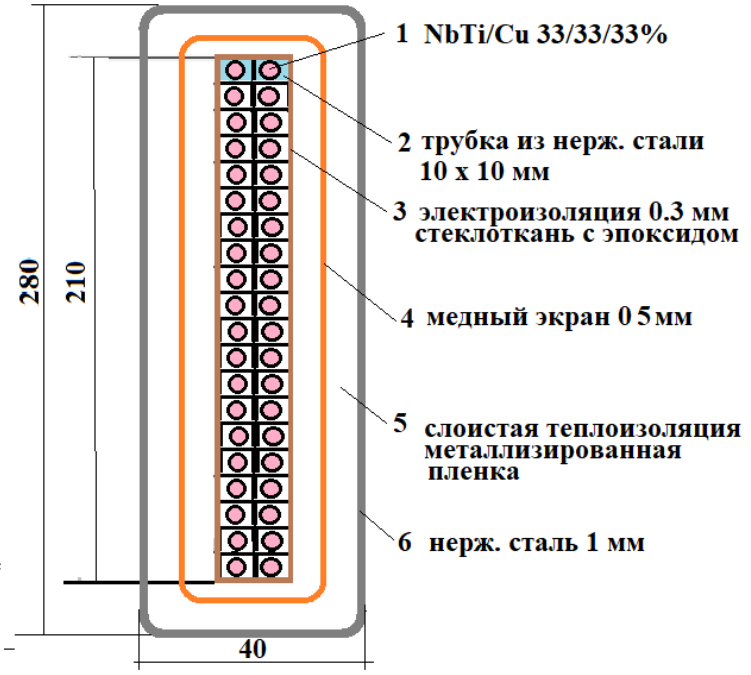
Cross sections of warm and SC-coil





Critical current data measured at CERN and by thewire manufacturer (October-November 2018).

Ic =800 A, at 4.2 K
per wire 0.81 mm



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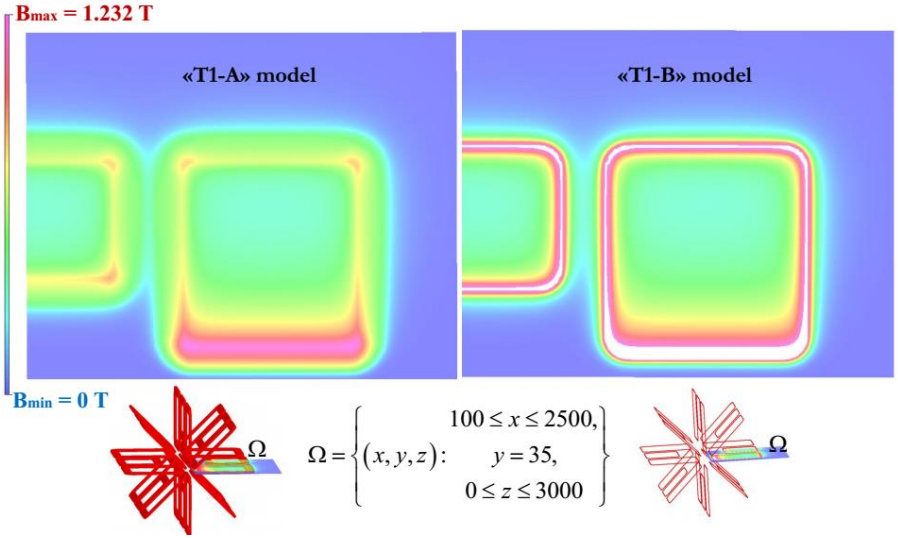
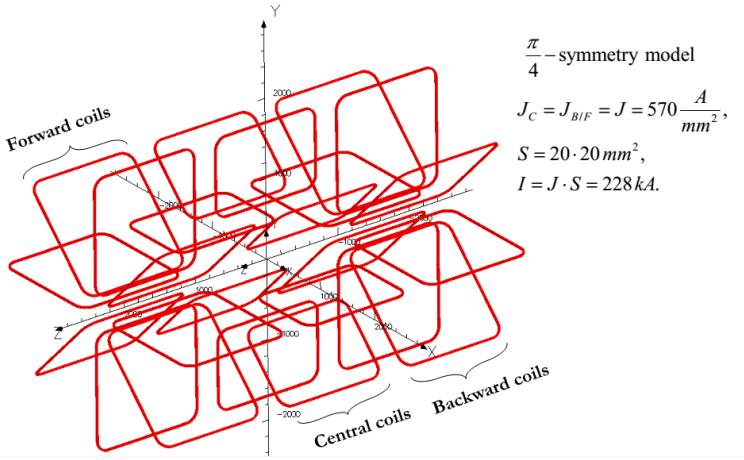
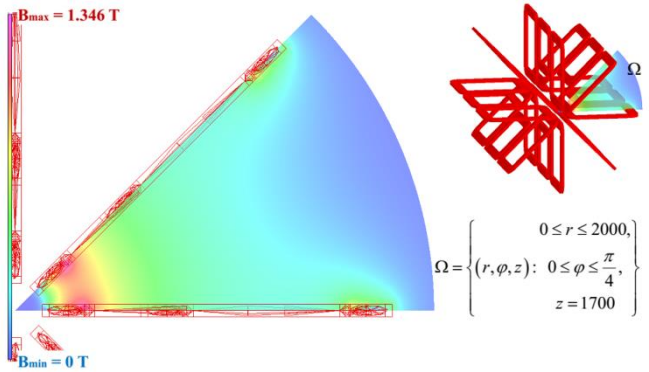
SPD Toroidal Magnetic System (3)





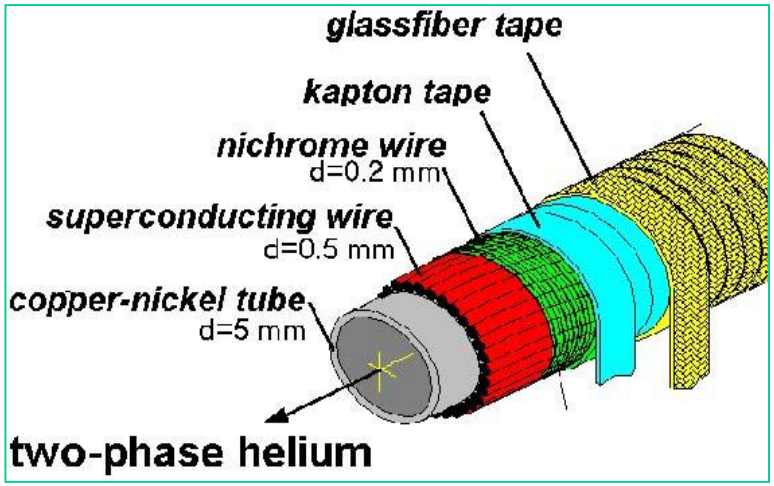
- 3D-magnetic field distribution was calculated for the both cases:

- The system complexity is high



SPD MS: Nuclotron/ITER technology

Dubna hollow SC cable



NICA booster magnets

We have unique technology and technological base for fabrication MS model coils at the LHEP. Designer and manufacturer of the SPD MS can be found also.

Operating current – 10 kA
Critical current -17 kA

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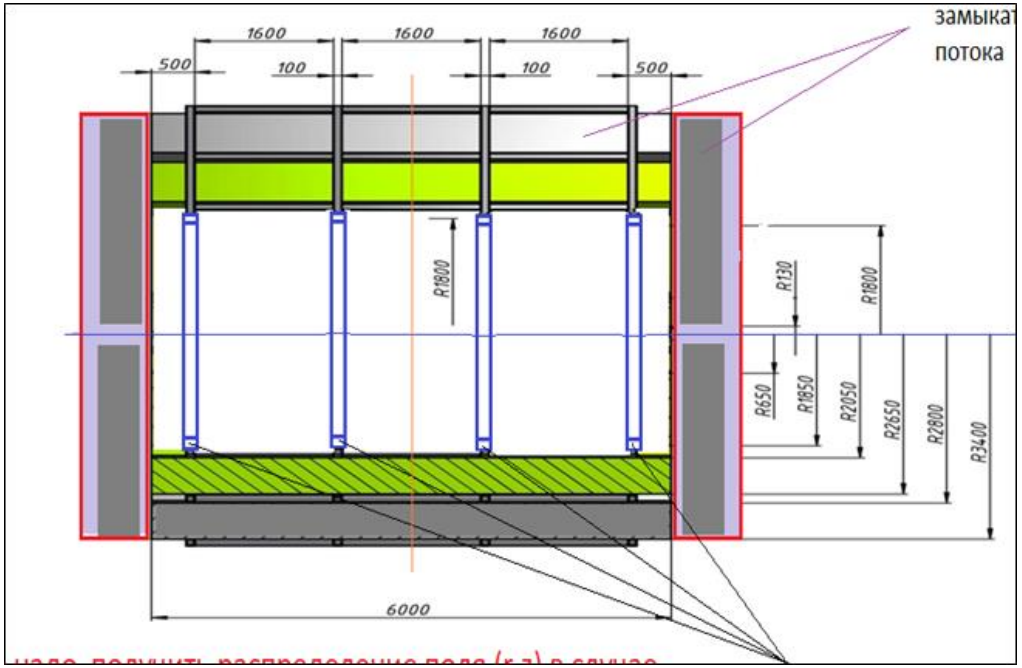
SPD Separate Coils MS (1)

Proposed in February 2018 as alternative to traditional solenoid and toroidal MS (Kovalenko et al)



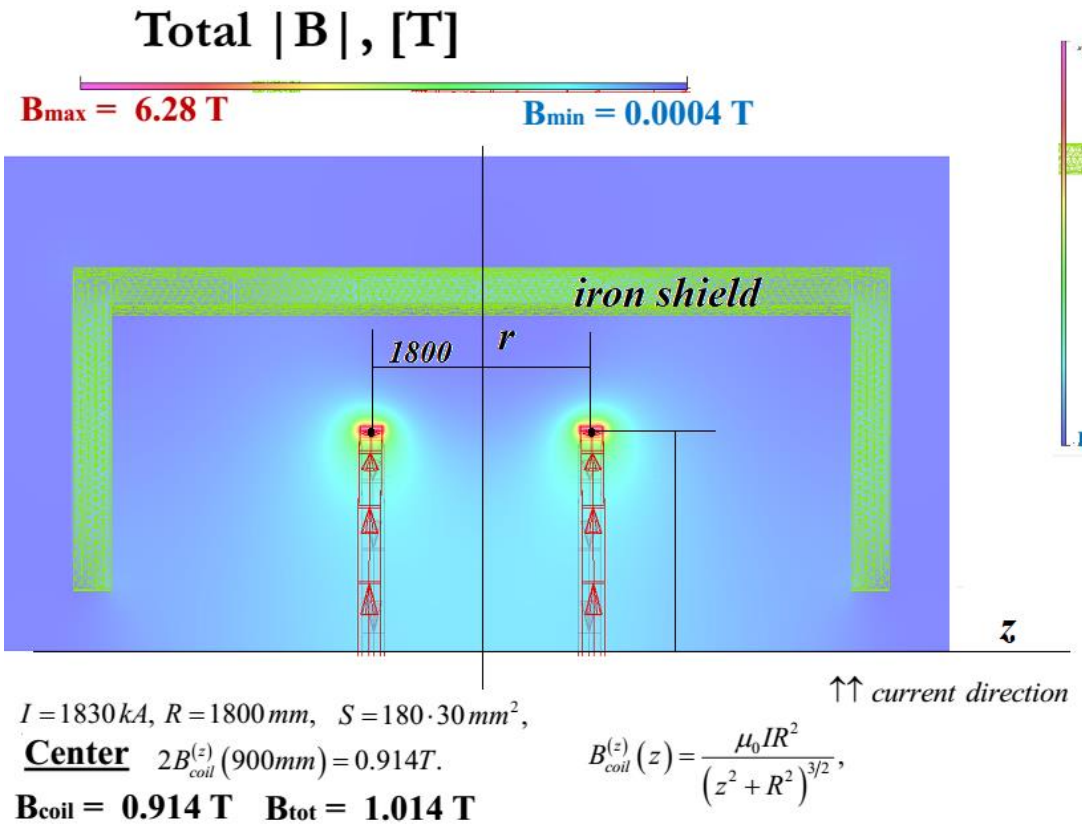
3D-field distribution taking the iron shield outside was calculated for different directions of current in the coils.

Main advantage: Minimization of the MS material in the detector volume

Main disadvantage: Non uniform field, nevertheless measurable.

Zero field at the center of system is obtained in the case of opposite current direction of the coil pairs. Separation of barrel and end parts of the setup is possible also.

SPD Separate Coils MS (1)

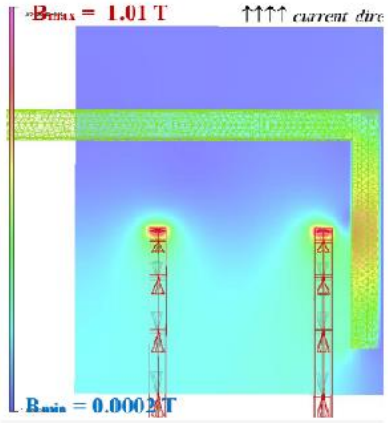


$I = 1830\,kA,\ R = 1800\,mm,\quad S = 180 \cdot 30\,mm^2,$

Center $2B_{coil}^{(z)}(900mm) = 0.914T.$

$$B_{coil}^{(z)}(z) = \frac{\mu_0 I R^2}{\left(z^2 + R^2\right)^{3/2}},$$

Bcoil = 0.914 T **Btot = 1.014 T**



3D-field distribution taking the iron shield outside was calculated for different current directions in the coils

Coil system is practically transparent for secondary particals, but better to form azimuthal field for barrel part of the detector.

SPD Combined MS (1)

Proposed in February-March 2018 as multipurpose system that could be adopted for different particle analysis (Kovalenko, Nagaitsev, Shimansky)

$$B^{(z)}(x,y,0)=0.$$

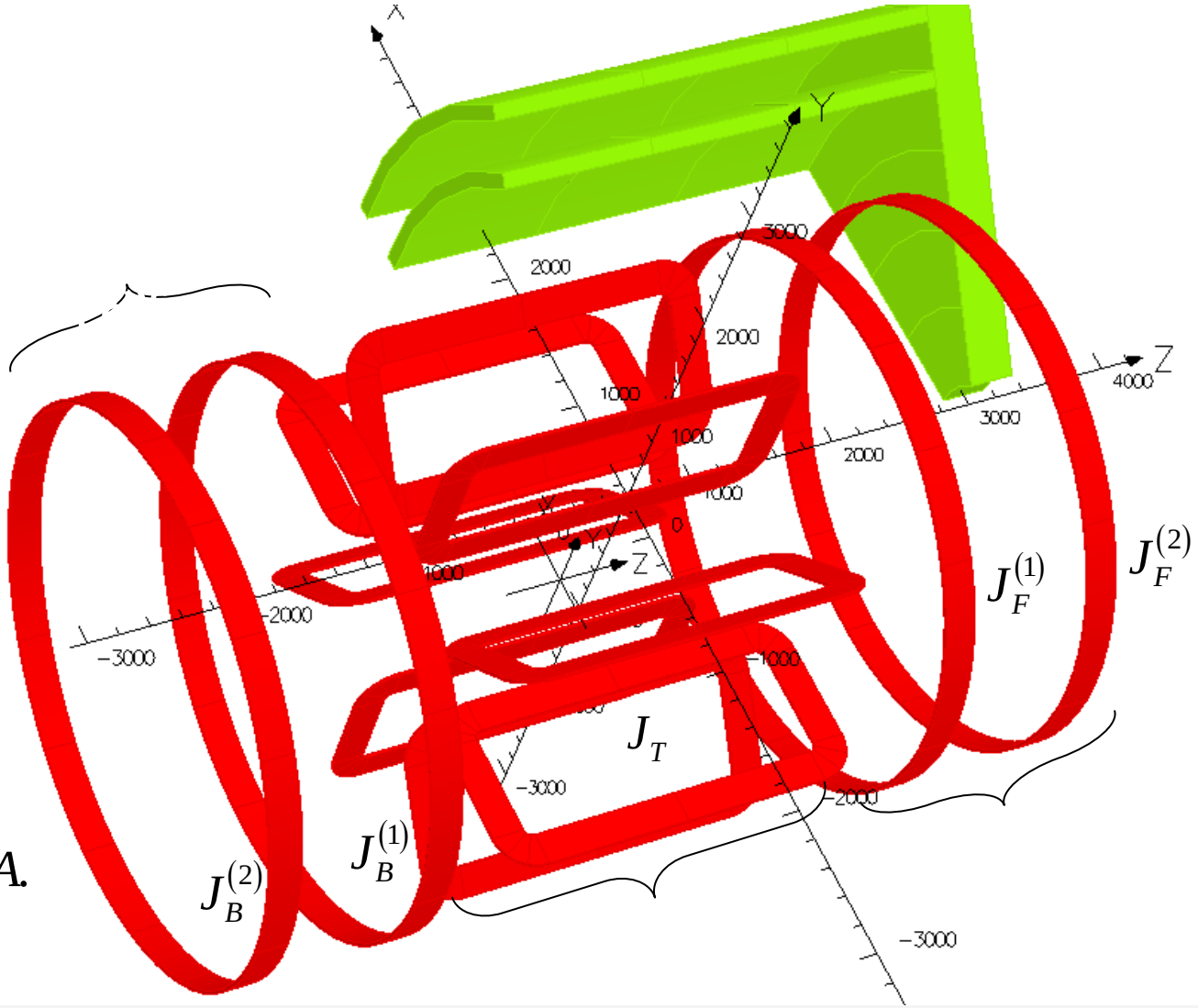
$$J_T = 40\frac{A}{mm^2},$$

$$J_{B\backslash F}^{(1,2)} = \mp 80\frac{A}{mm^2},$$

$$S = 200\times 20\, mm^2,$$

$$I_T = J_T \cdot S = 160\, kA,$$

$$I_{B\backslash F} = J_{B\backslash F} \cdot S = \mp 320\, kA.$$



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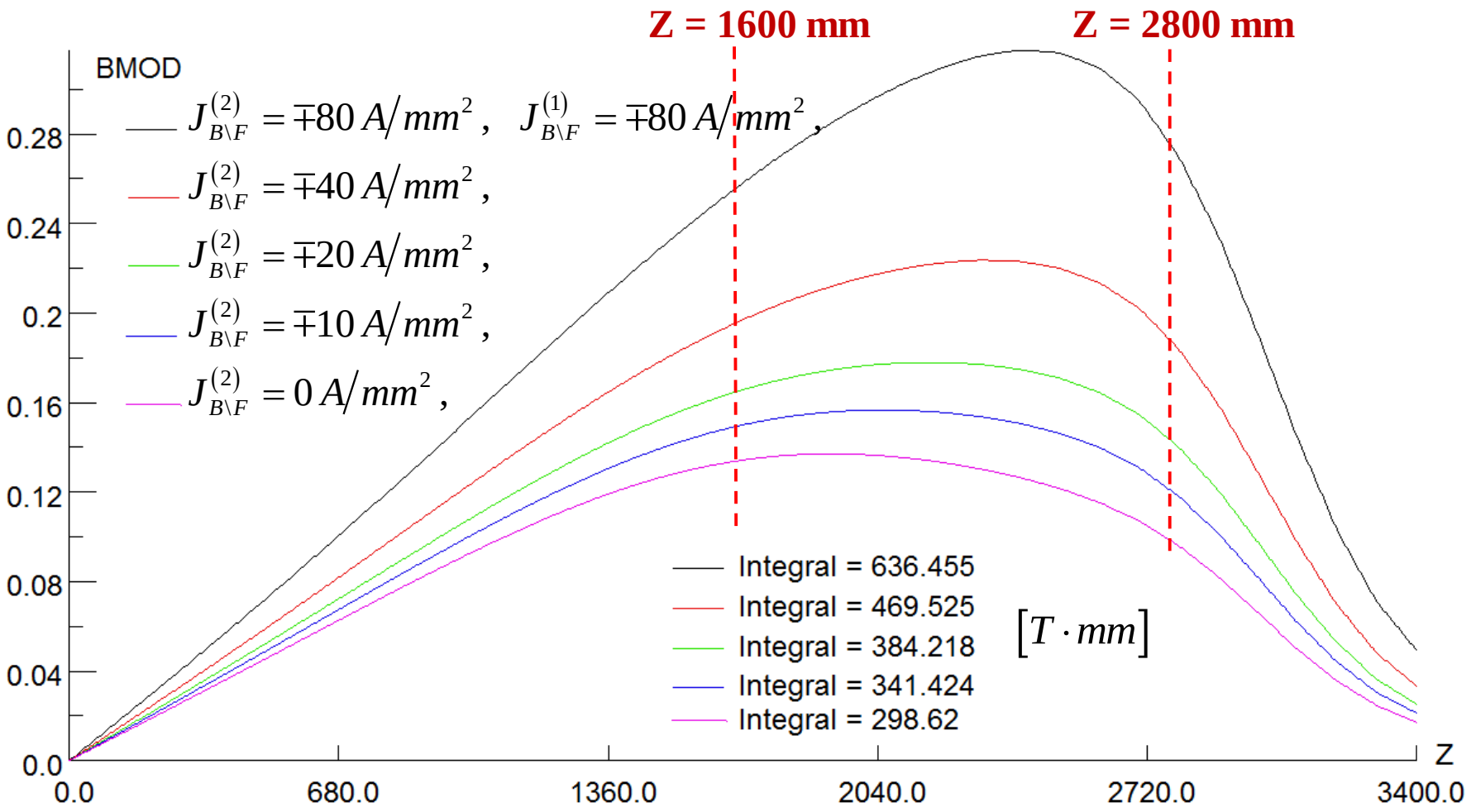
SPD Combined MS (2)



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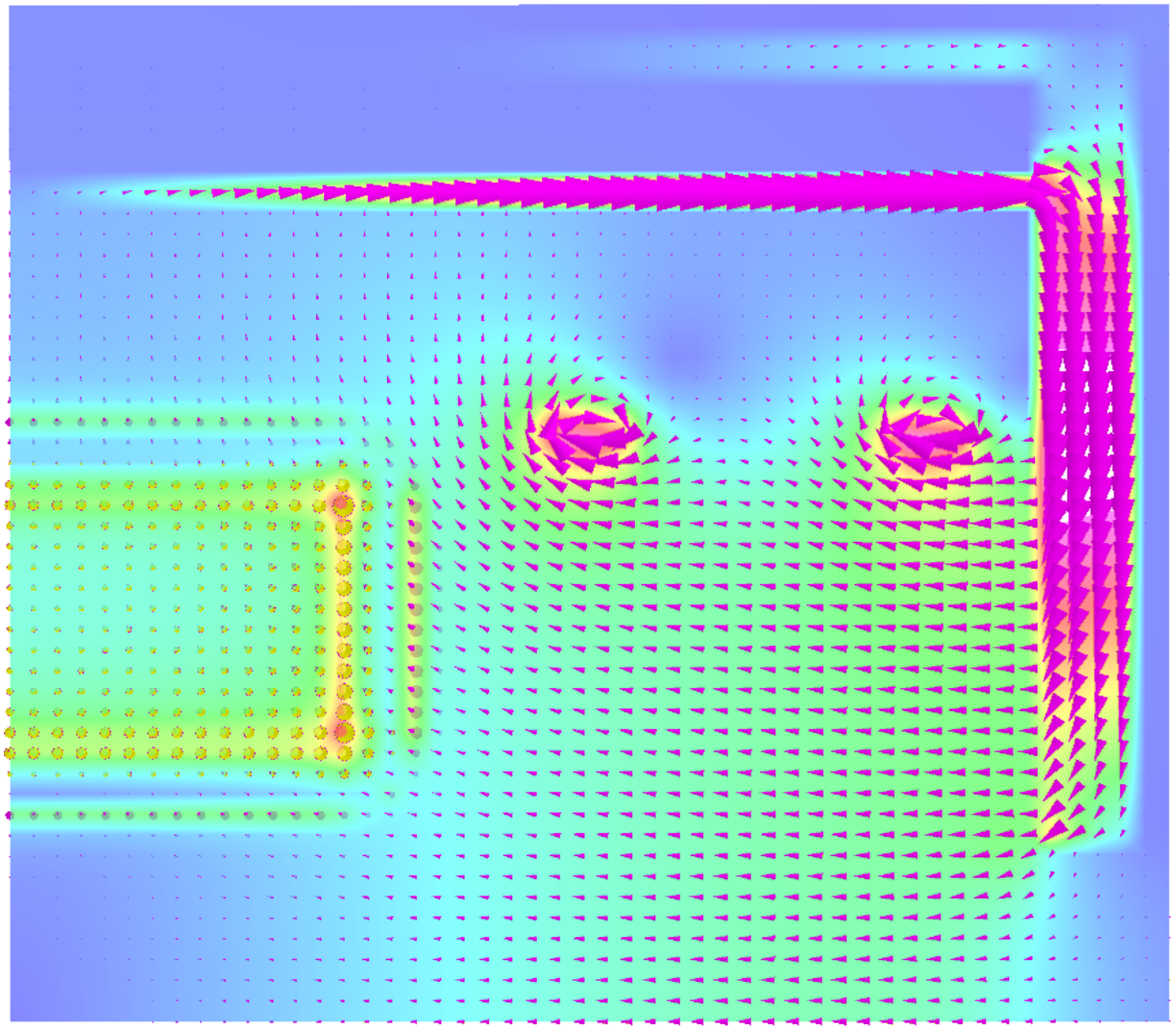
SPD Combined MS (3)

$$\Omega = \left\{ (r, \varphi, z): \begin{array}{c} 0 \le r \le 3000 \\ \varphi = 0 \\ 0 \le z \le 3400 \end{array} \right\}$$

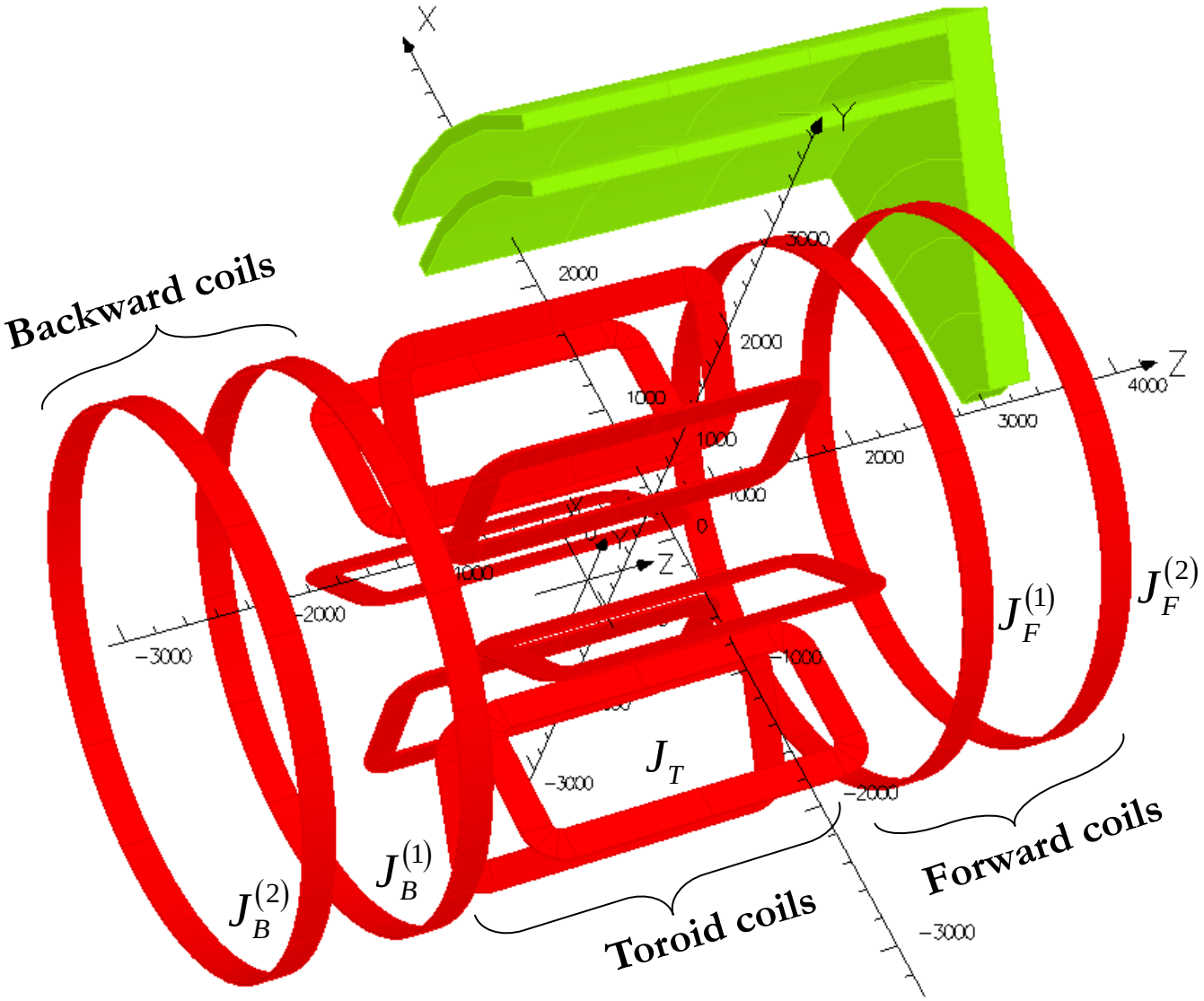


SPD Combined MS (4)

No symmetry

$$J_T = 40\frac{A}{mm^2},$$

$$J_{B\backslash F}^{(1,2)} = 80\frac{A}{mm^2}.$$



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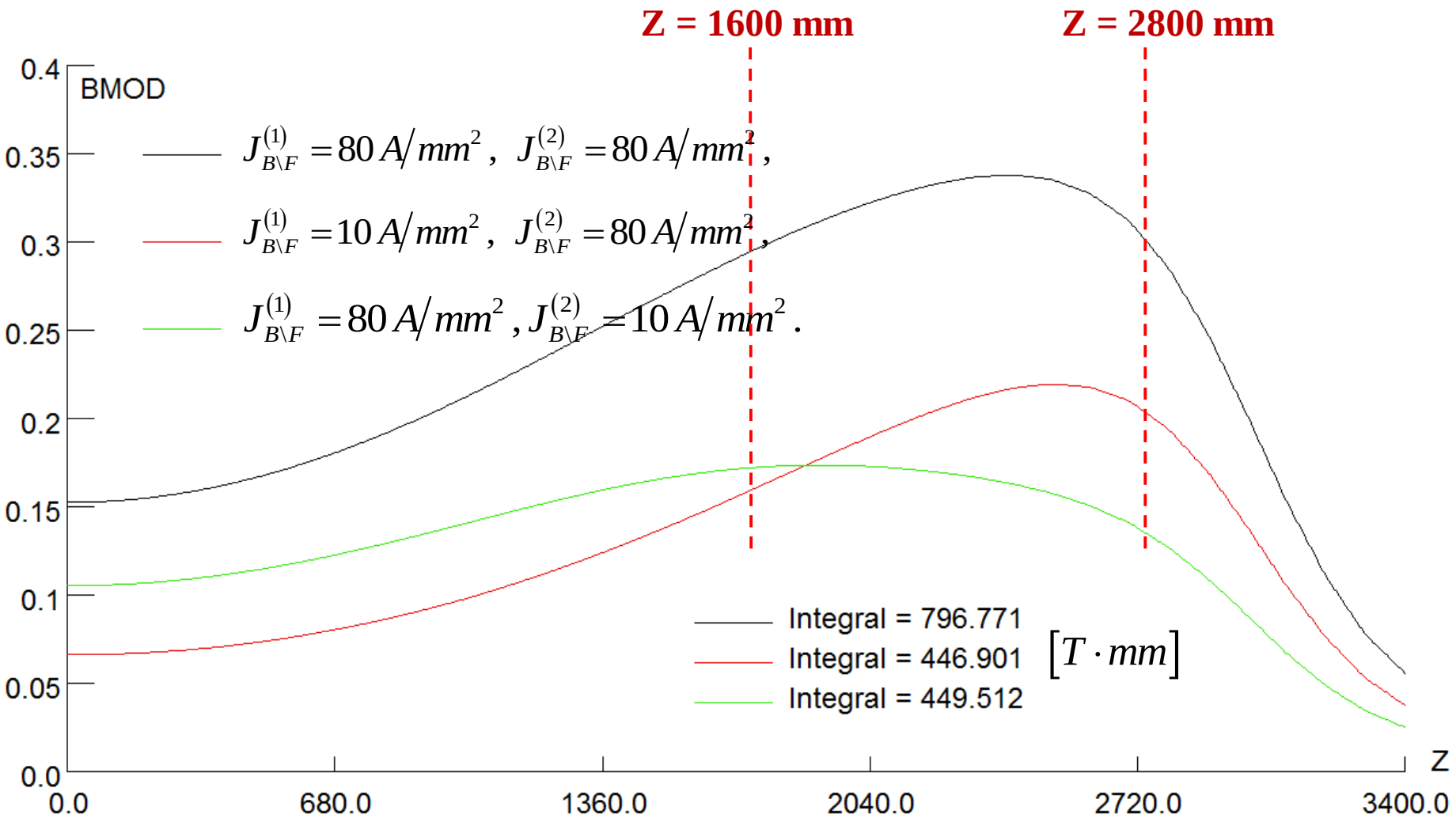
SPD Combined MS (5)



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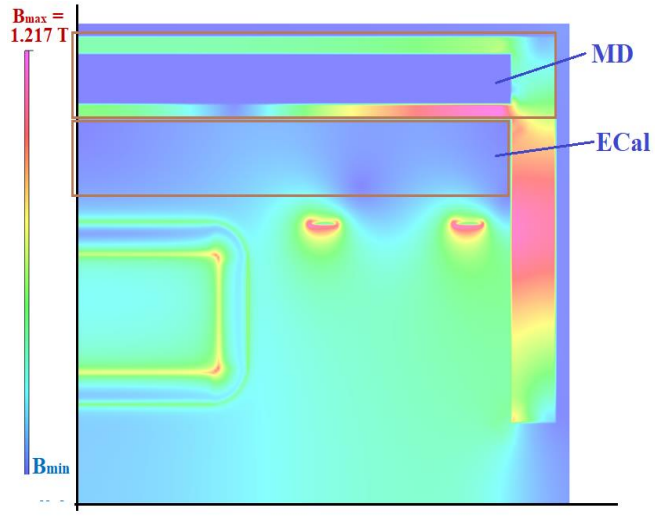
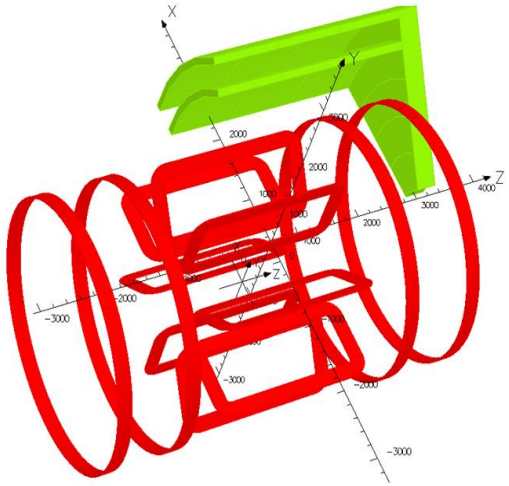
SPD MS used for modeling

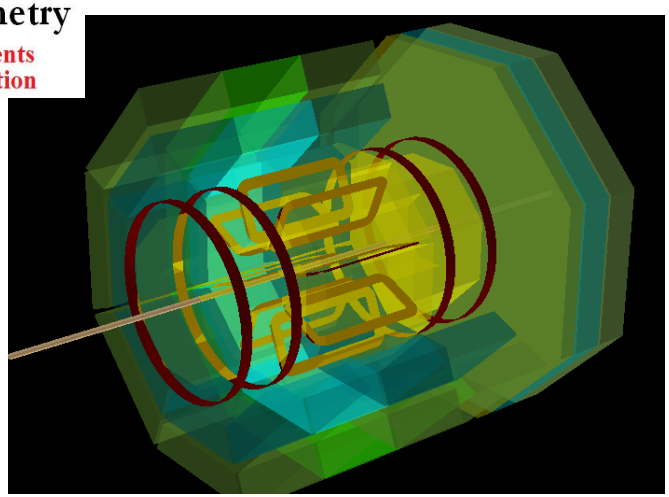


«TS-2». Total |B| field. RZ- distribution

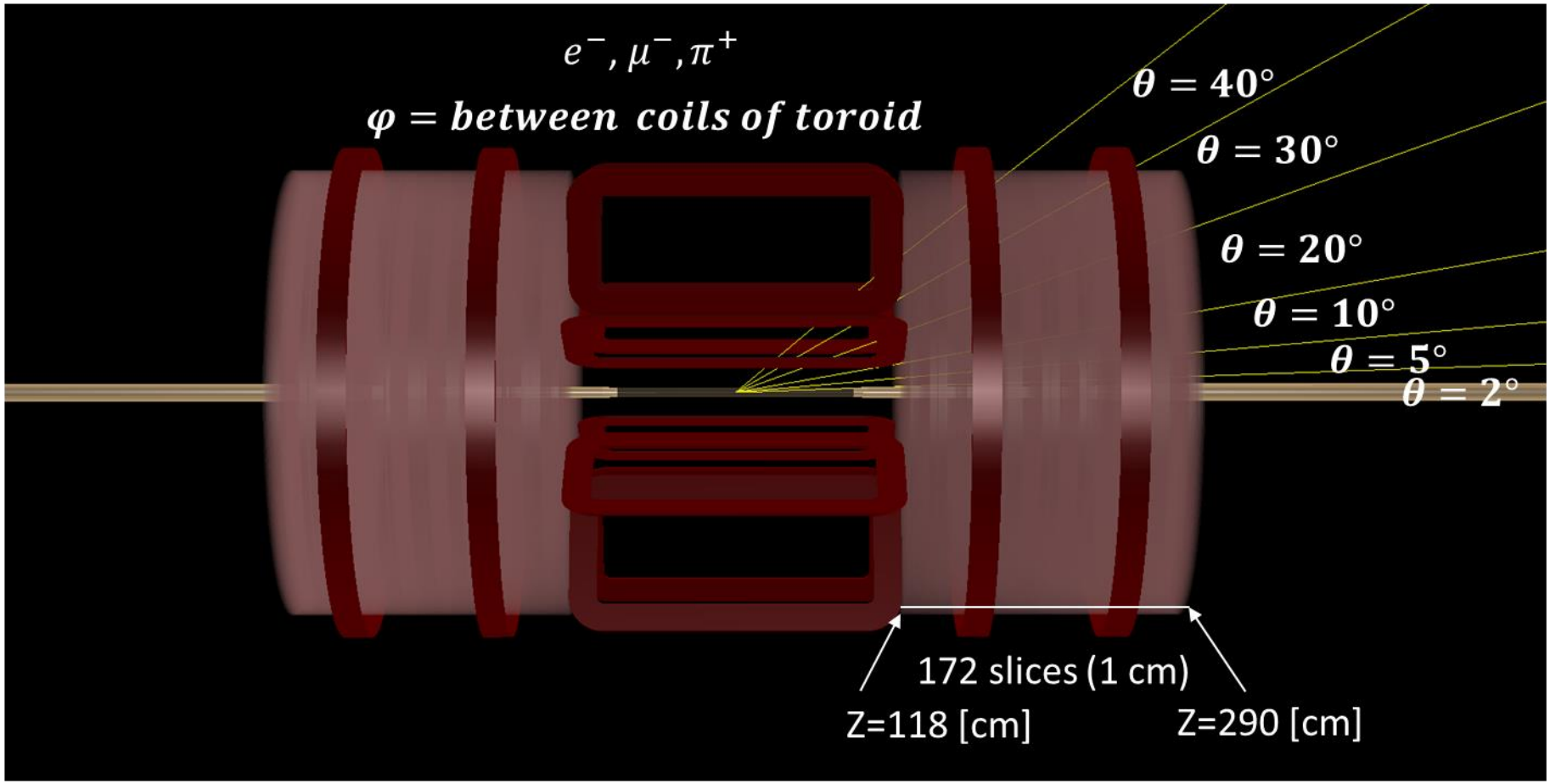


«TS-2» model geometry

No symmetry Coil currents the same direction



Settings

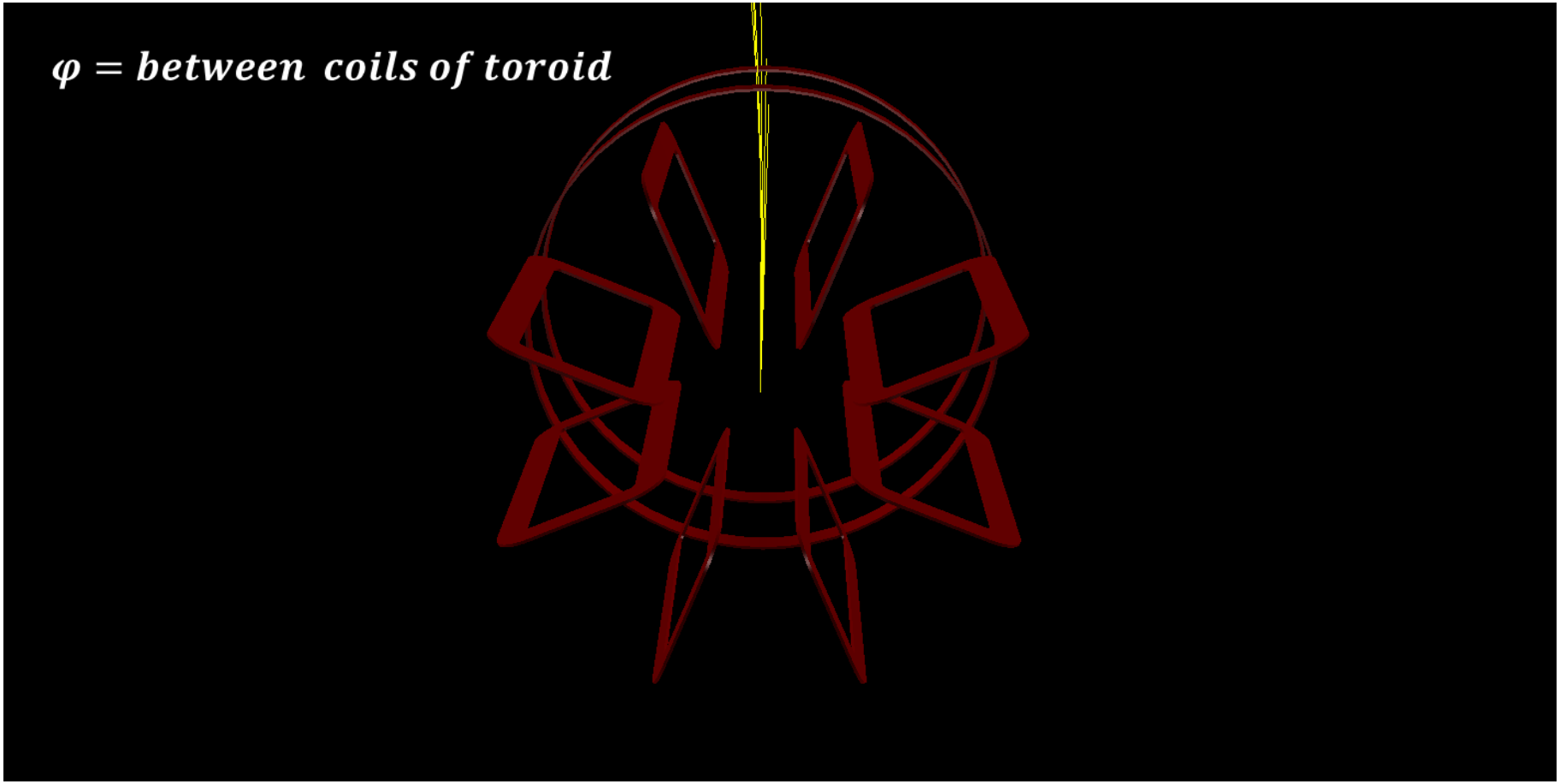


In each slice (perpendicular to the beam axis), we check θ and φ of track

standard field map

-2.5 2.5 x-axis, step 0.05
-2.5 2.5 y-axis, step 0.05
-2.9 2.9 z-axis, step 0.05

Settings



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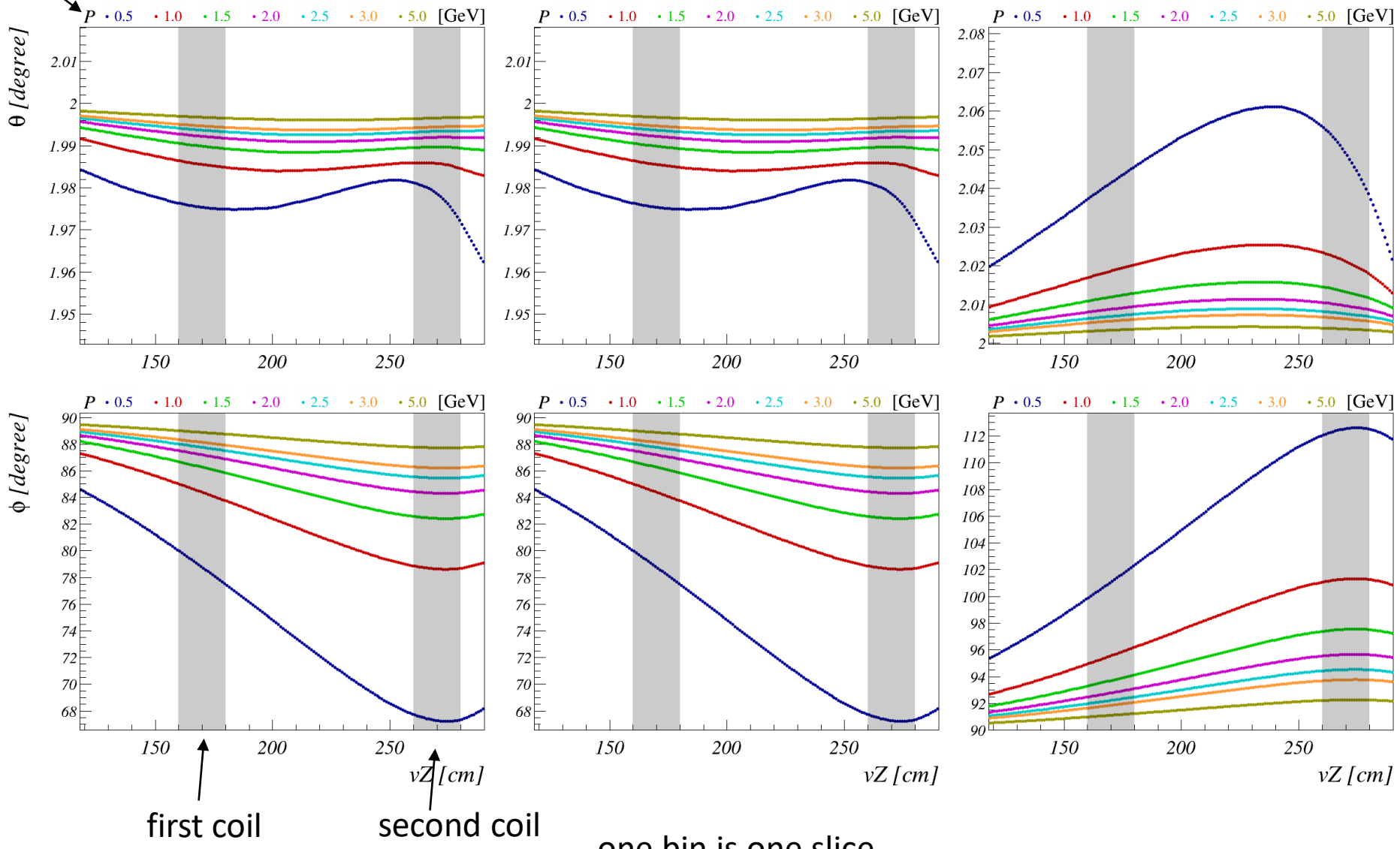
Distributions: φ vs Z and θ vs Z

$\theta = 2°$, $\varphi = 90°$

momentum

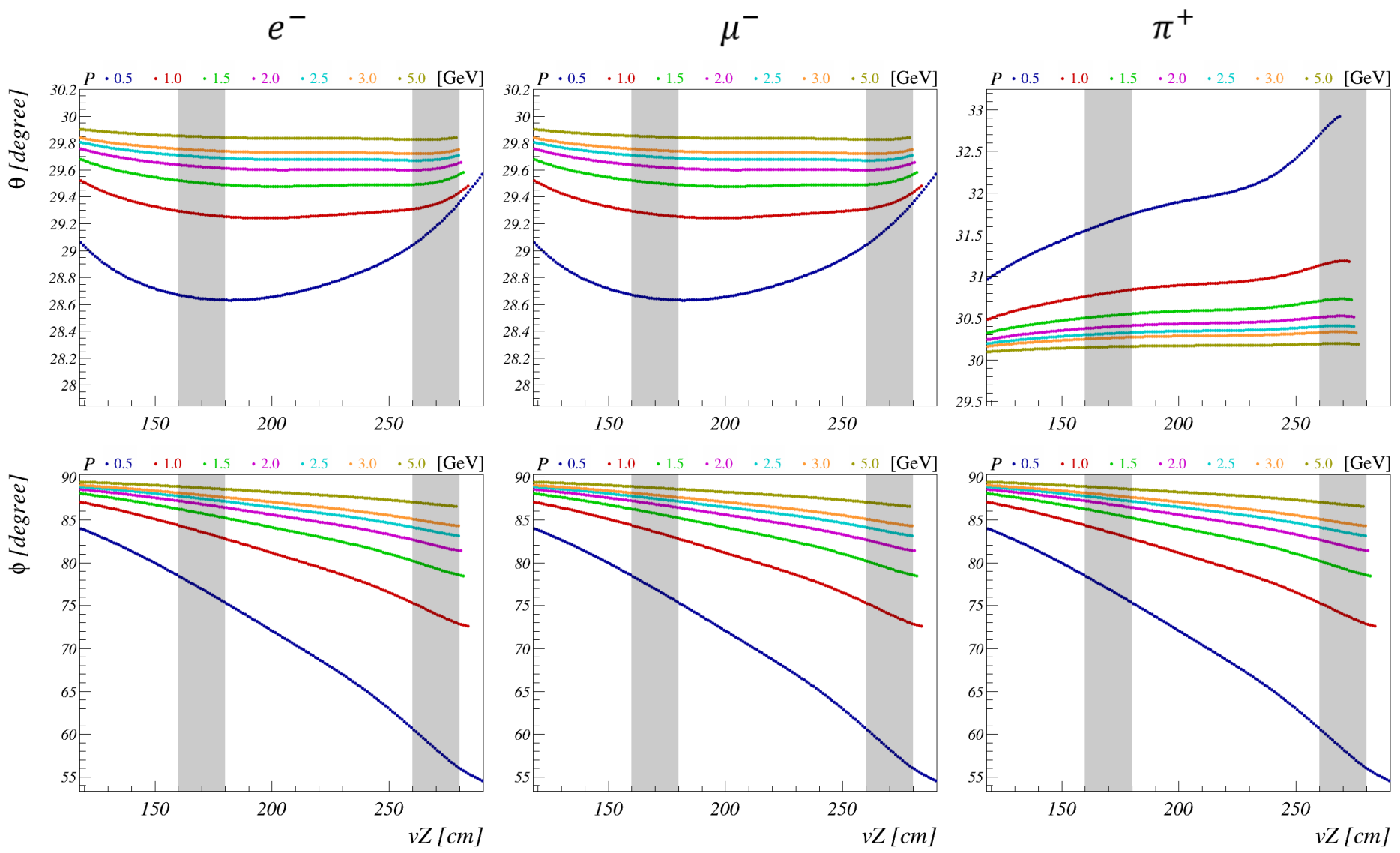
e^- μ^- π^+



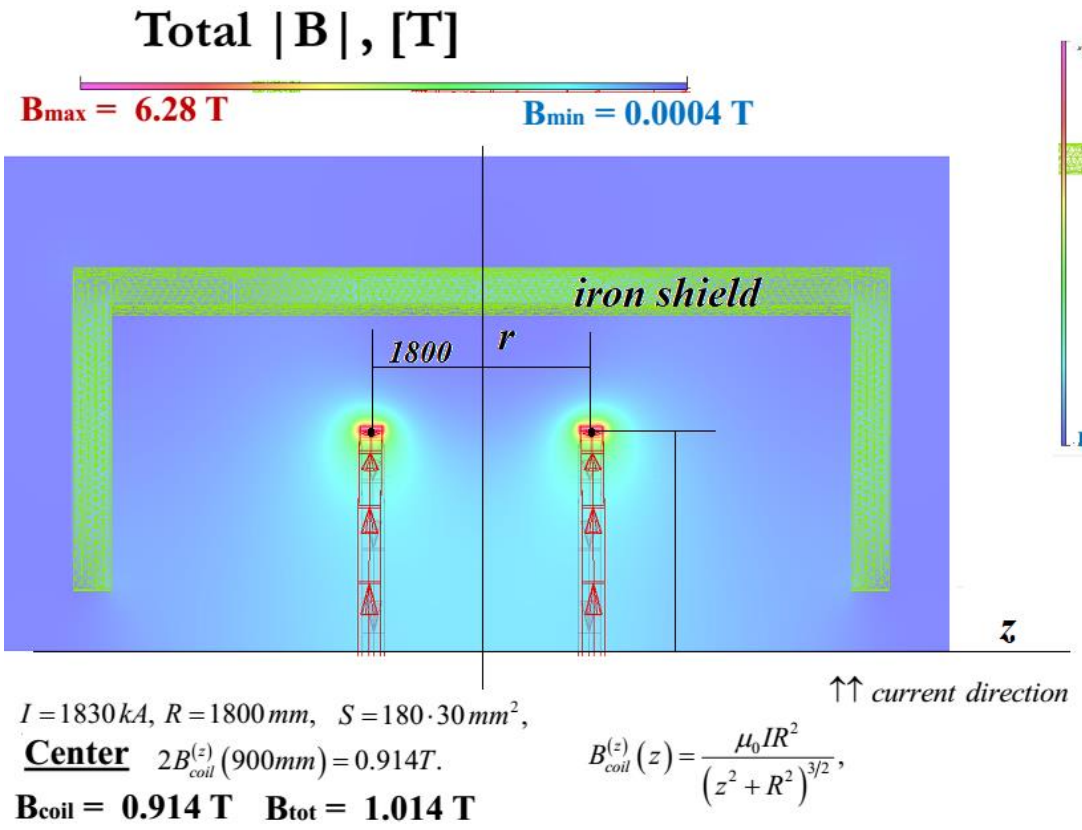
one bin is one slice

Distributions: φ vs Z and θ vs Z

$\theta = 30°$, $\varphi = 90°$



SPD Separate Coils MS (1)



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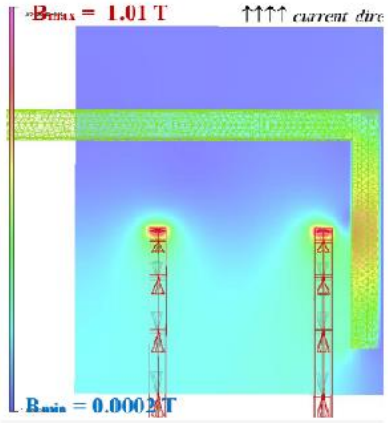

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Coil system is practically transparent for secondary particals, but better to form azimuthal field for barrel part of the detector.

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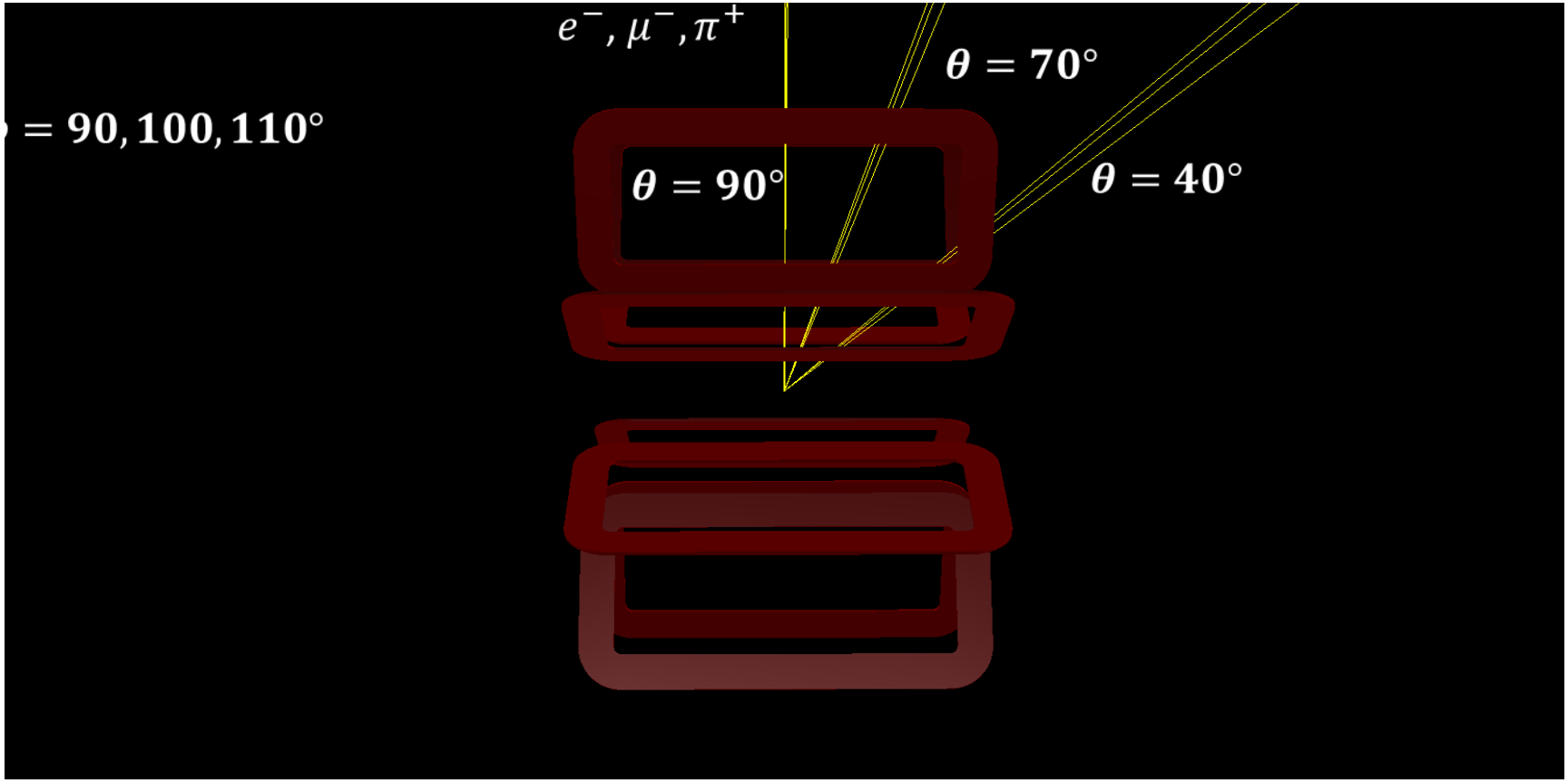

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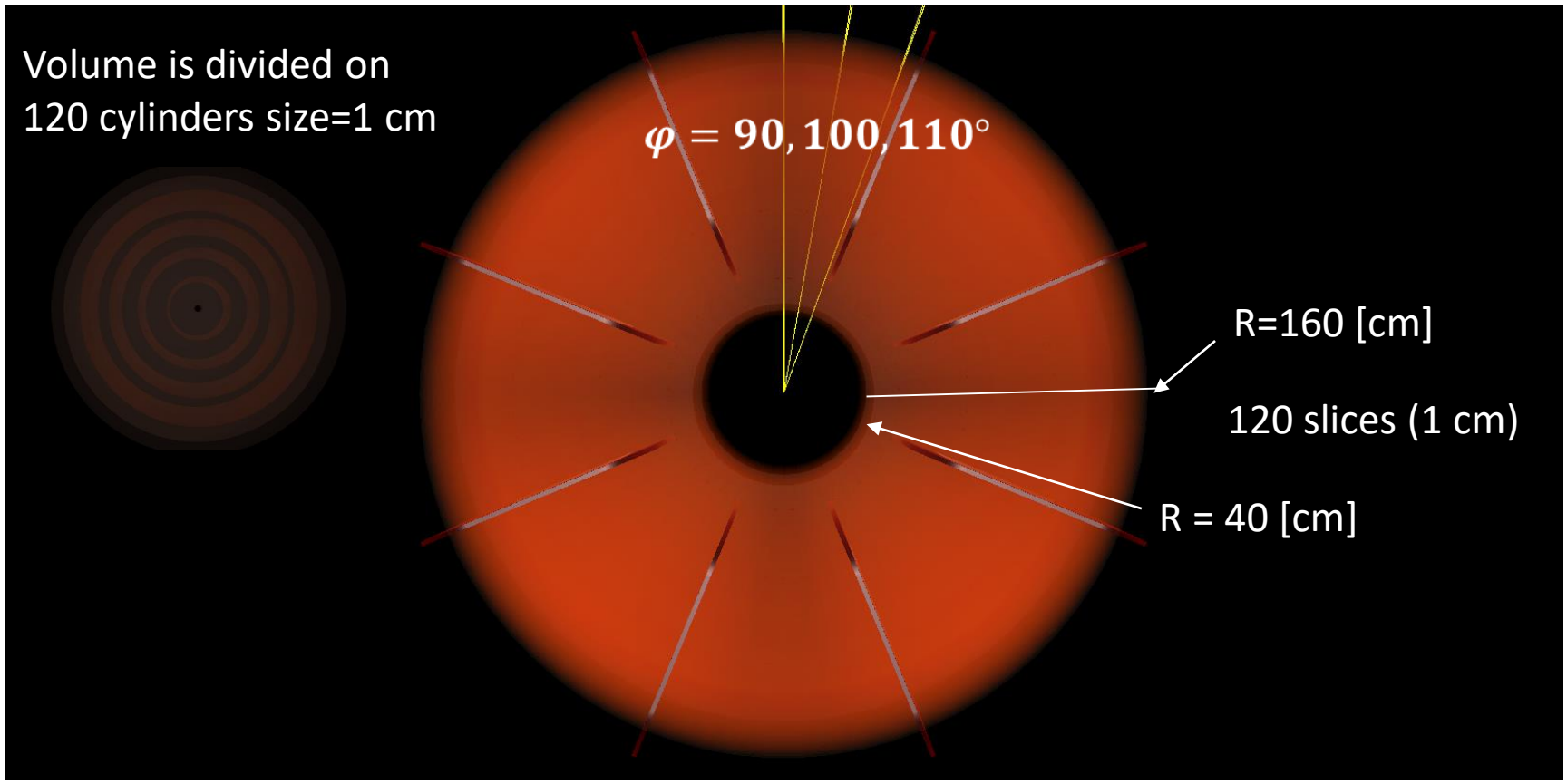

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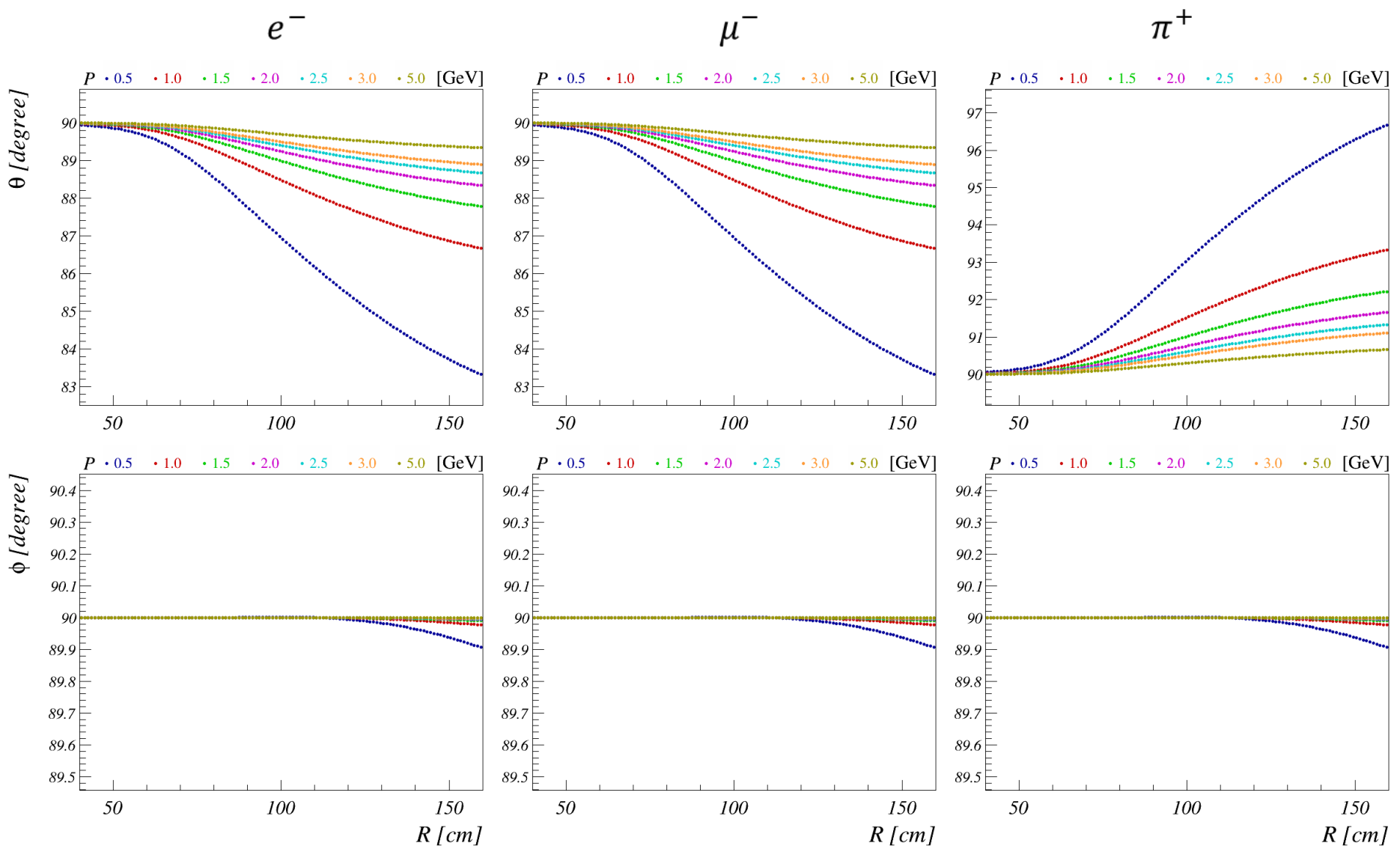
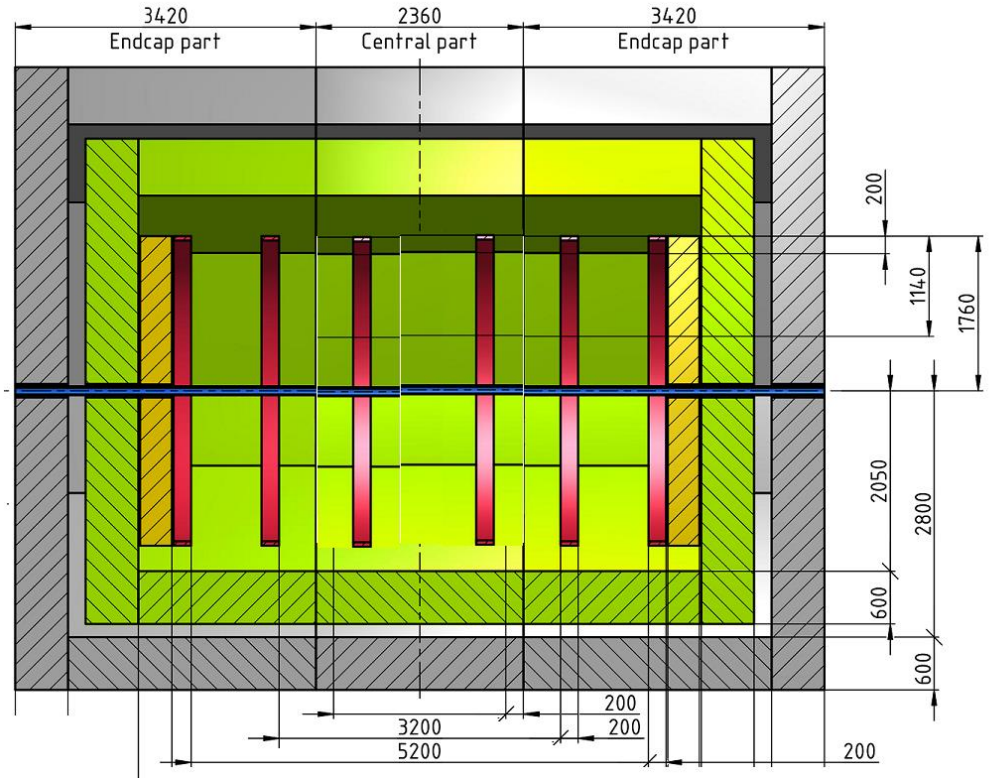
Distributions: φ vs Z and θ vs Z

$\theta = 90°$, $\varphi = 90°$



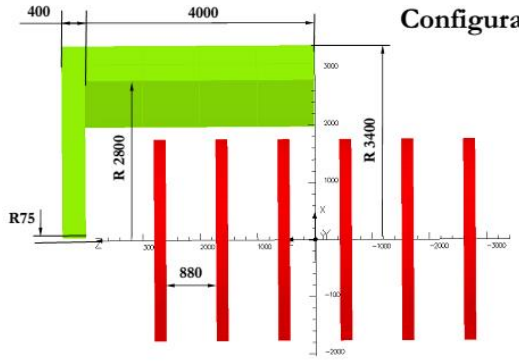
SPD 6 Separate Coils MS (1)

Proposed by R.Tsenov



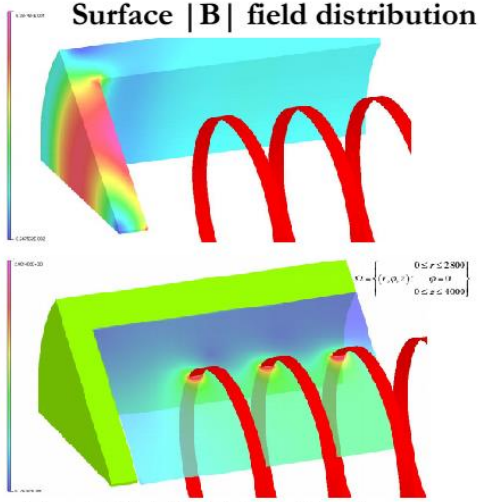
3D - calculations of different configurations of coils supply schemes were considered.

SPD 6 Separate Coils MS (2)



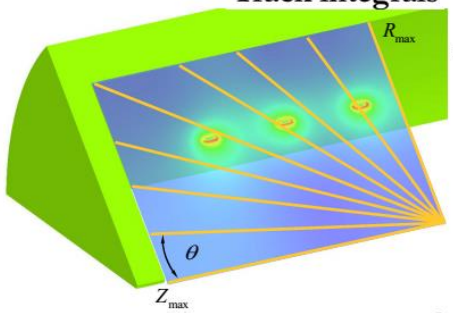
Configuration ↑↑↑↑↑↑

Surface |B| field distribution



Total |B| field distribution

Track integrals



$$R(\theta)=\begin{cases}\frac{Z_{max}}{\cos\theta}, & 0\le\theta\le\theta_d\\ \frac{R_{max}}{\sin\theta}, & \theta_d\le\theta\le\frac{\pi}{2}\end{cases}$$

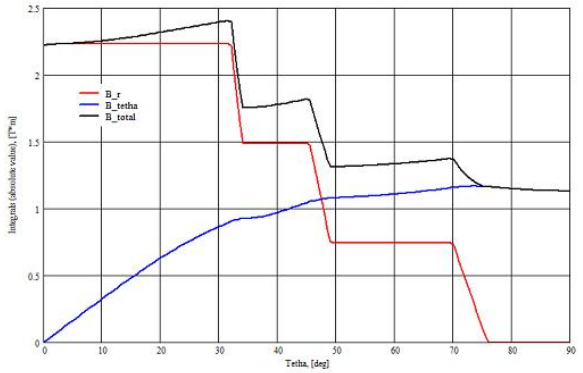
$$\theta_d=\operatorname{arctg}\frac{R_{max}}{Z_{max}}$$

$$I_R(\theta)=\int_0^{R(\theta)}B^{(r)}(r,\theta)dr$$

$$I_\Theta(\theta)=\int_0^{R(\theta)}B^{(\theta)}(r,\theta)dr$$

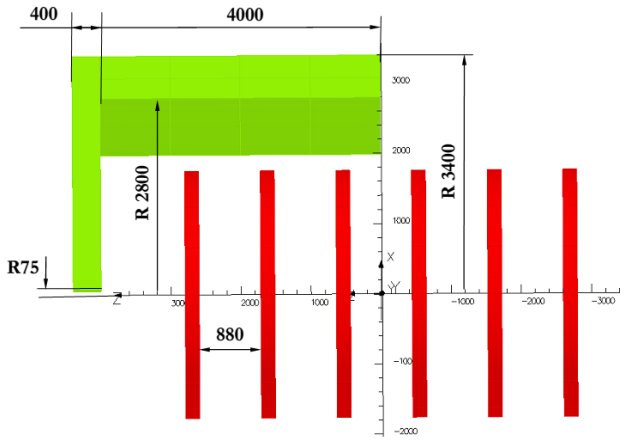
$$I_{Total}(\theta)=\sqrt{I_R^2(\theta)+I_\Theta^2(\theta)}$$

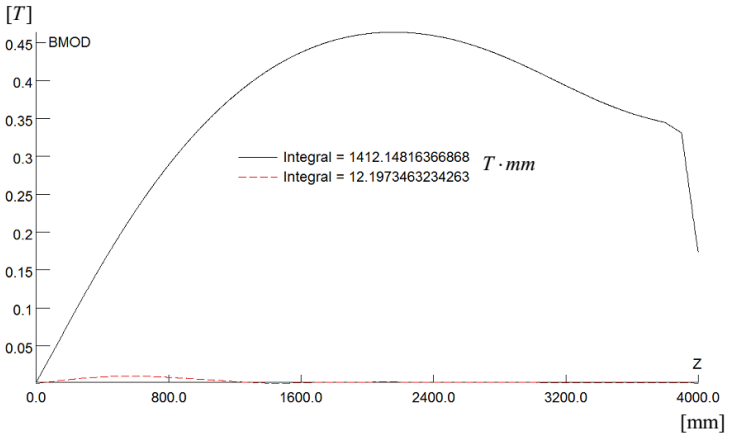
Track integrals



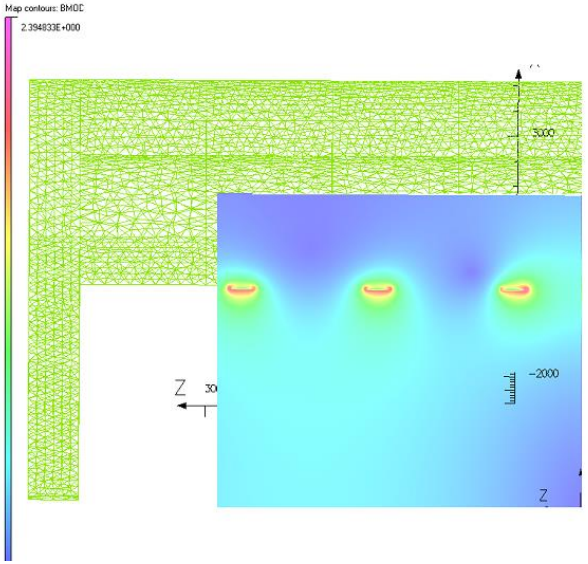
SPD 6 Separate Coils MS (3)

Model «↑↑↑↓↓↓» geometry





Surface |B| field distribution «↑↑↑↓↓↓»



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SPD MS: further steps

- Perform new set of calculations and upgrade of the SPD MS composition base on the results of physics modeling;
- Continue steps to technical design of the MS system including SC-wire, cable coil design and support system.

Thanks a lot for your attention