



# PRELIMINARY STUDY

*If we extend the SPS straight sections  
where would the neutrinos come out to the  
surface of the earth?*

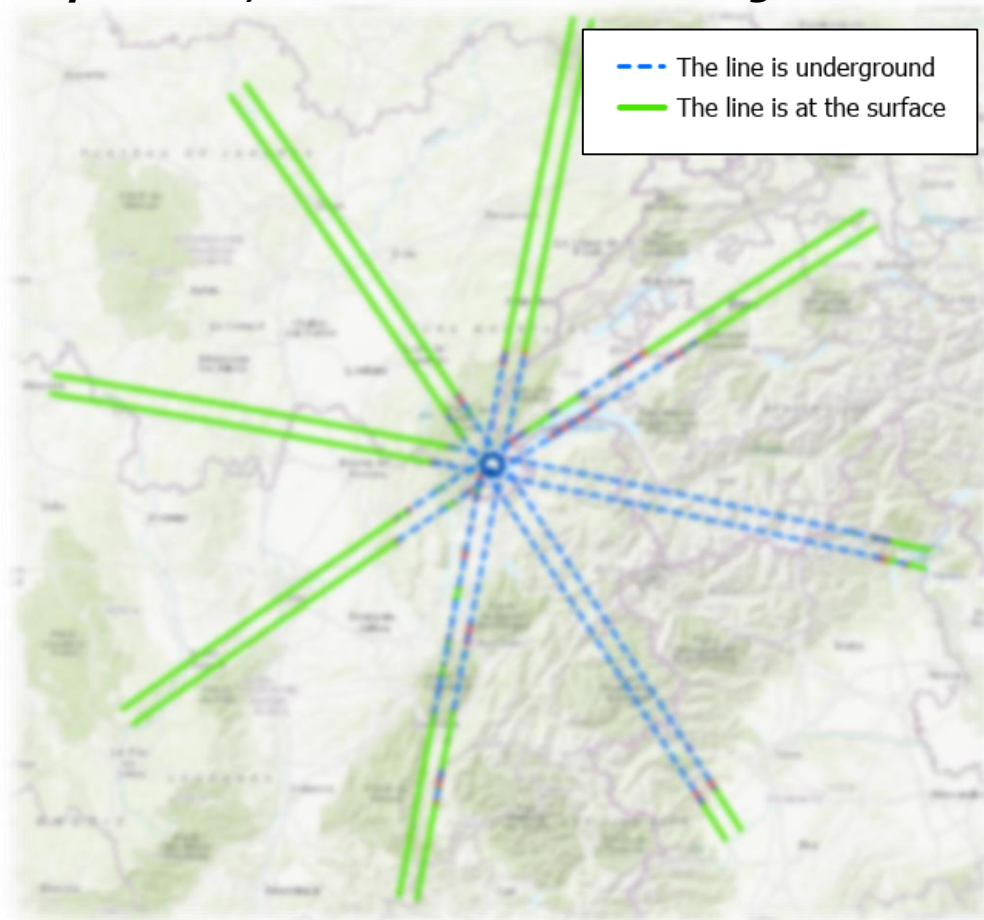
*If we extend the LHC straight sections  
where would the neutrinos come out to the surface?*

## Reminder :

***at the Muon collider meeting of the 11<sup>th</sup> of April 2019, we showed the following results for LHC***

Point	Side	First exit to the surface of the earth (Distance from IP in Km)
1	L	263
1	R	40
2	L	258
2	R	25
3	L	17
3	R	74
4	L	37
4	R	30
5	L	26
5	R	237
6	L	35
6	R	255
7	L	76
7	R	161
8	L	145
8	R	35

Min	<b>17 km</b>
Max	<b>263 km</b>



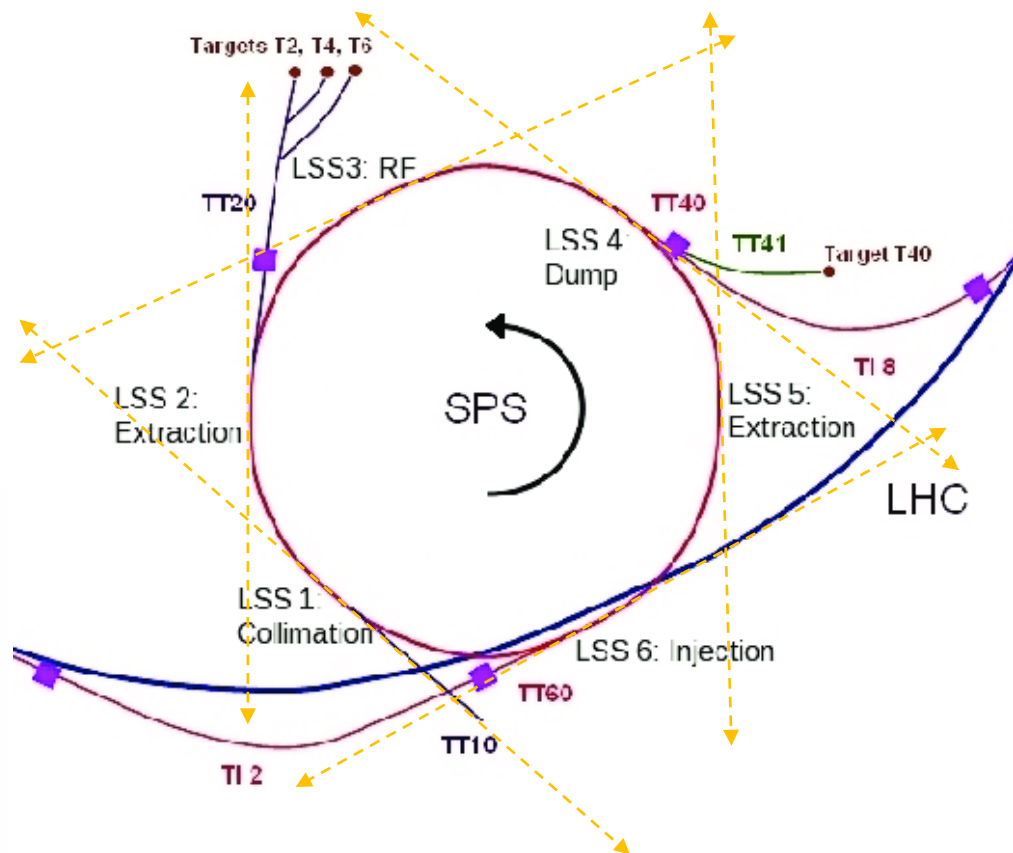
*If we extend the SPS straight sections  
where would the neutrinos come out to the surface of the earth?*

## Problem:

« If we extend the SPS straight sections where would the neutrinos come out the surface of the earth? »

## Hypothesis:

The SPS straight sections directions are given by the lines built on dipole **MBA X1590 beam exit points on one side and MBA X2030 beam entrance point on the other side.**  
(X for the SPS point)



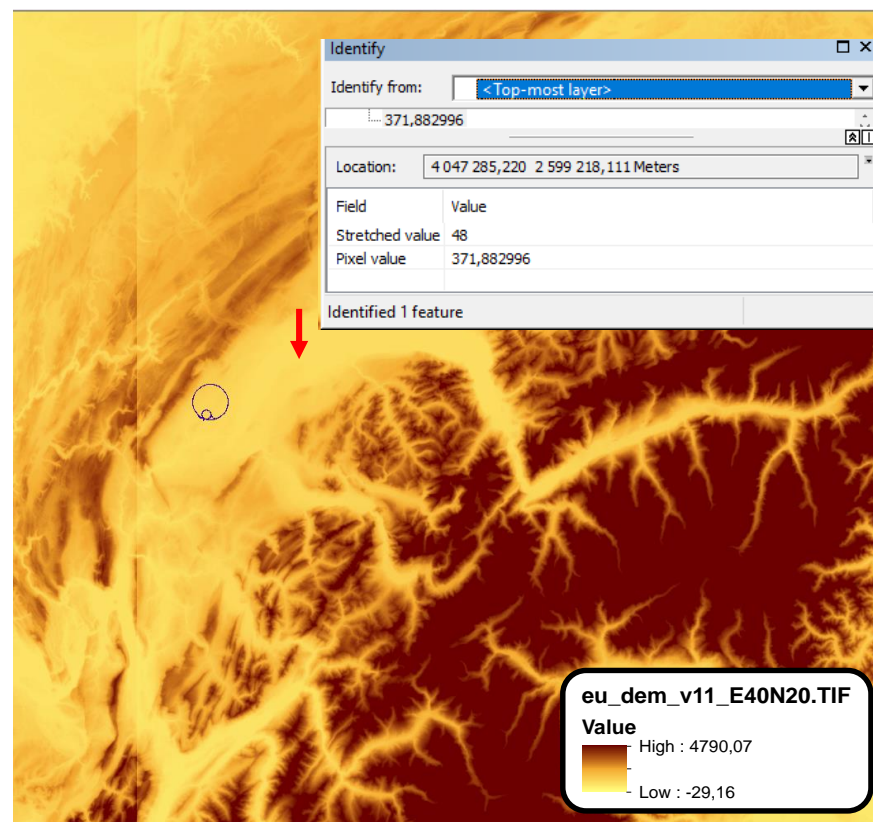
## Data:

### ➤ Coordinates of MBA beam points

- ❖ from Geode Survey database
- ❖ in CCS (XYZ) coordinate system

### ➤ EU-DEM v1.1 : Digital Surface model for Europe

- ❖ The spatial reference system is geographic, lat/lon with horizontal datum ETRS89, ellipsoid GRS80 and **vertical datum EVRS2000 with geoid EGG08.**
- ❖ [https://opendem.info/opendem\\_eu\\_meta\\_eudem.html](https://opendem.info/opendem_eu_meta_eudem.html)



## Methodology:

- 1) SPS straight sections lines are extended in CCS coordinate system
- 2) One point is created every **200 m** along these lines (CCS coordinate system) – **(Discretisation of the Beam lines)**

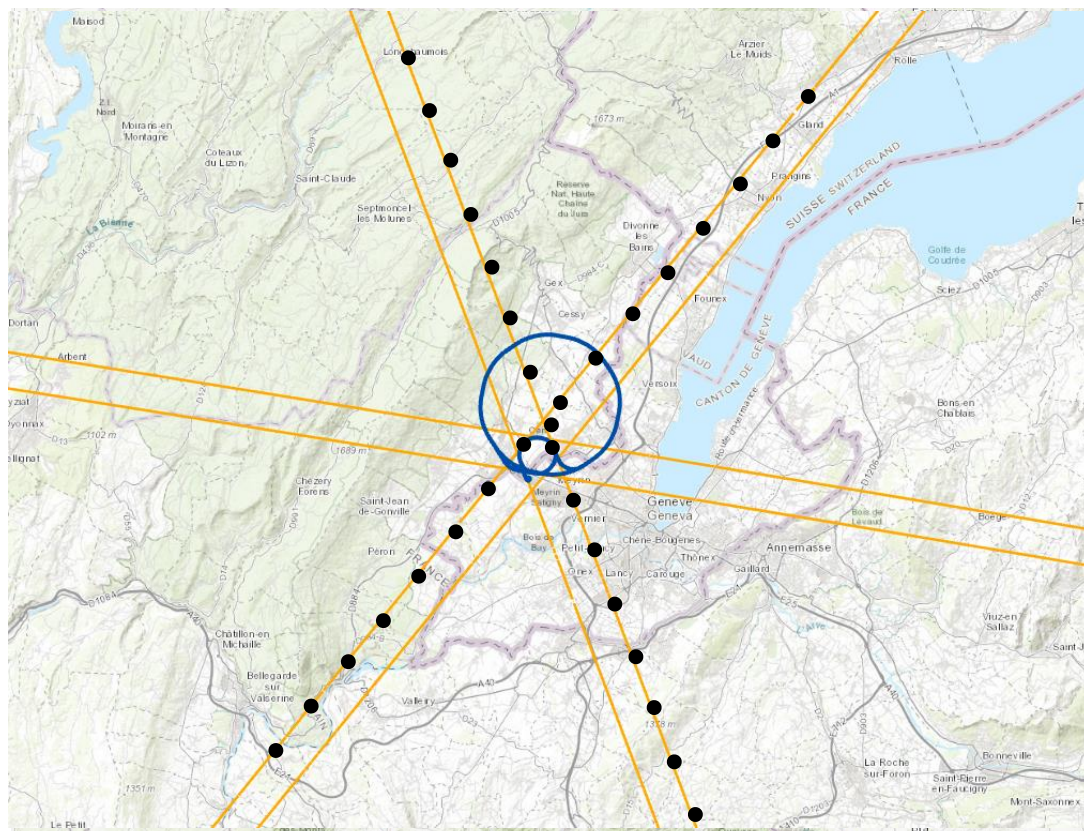


- 3) XYZ Coordinates of each point are converted to WGS84 Geodetic Coordinates System

❖ The results is geographic coordinates (lat, long) with ellipsoidal heights ( $H_e$ ) of each point.

- 4) The EU-DEM is converted to WG84

❖ The Geoid heights ( $H_g$ ) are unchanged as the ellipsoids WGS84 and GRS80 are slightly equivalent).



## Methodology:

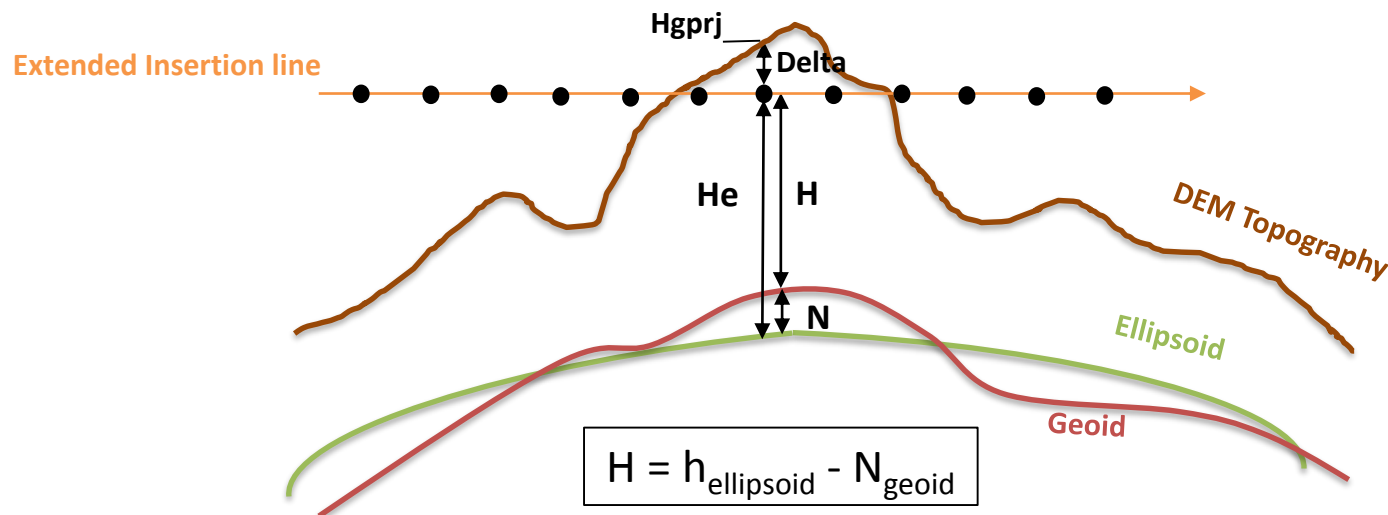
5) The Geoidal ellipsoidal heights ( $H_e$ ) of the beam points are converted to Geoidal Heights ( $H$ ) :  $H = H_e - N$

- ❖  $N$  is the ondulation of geoid in the studied area **estimated to 50 m**. In reality it varies from + 47 m to + 54 m.

6) The difference between the heights ( $H$ ) of each point and their projection to the DEM ( $H_{gprj}$ ) is calculated.

- ❖ If the Delta > 0, the point is at the surface of the earth
- ❖ If Delta is < 0 the point is underground.

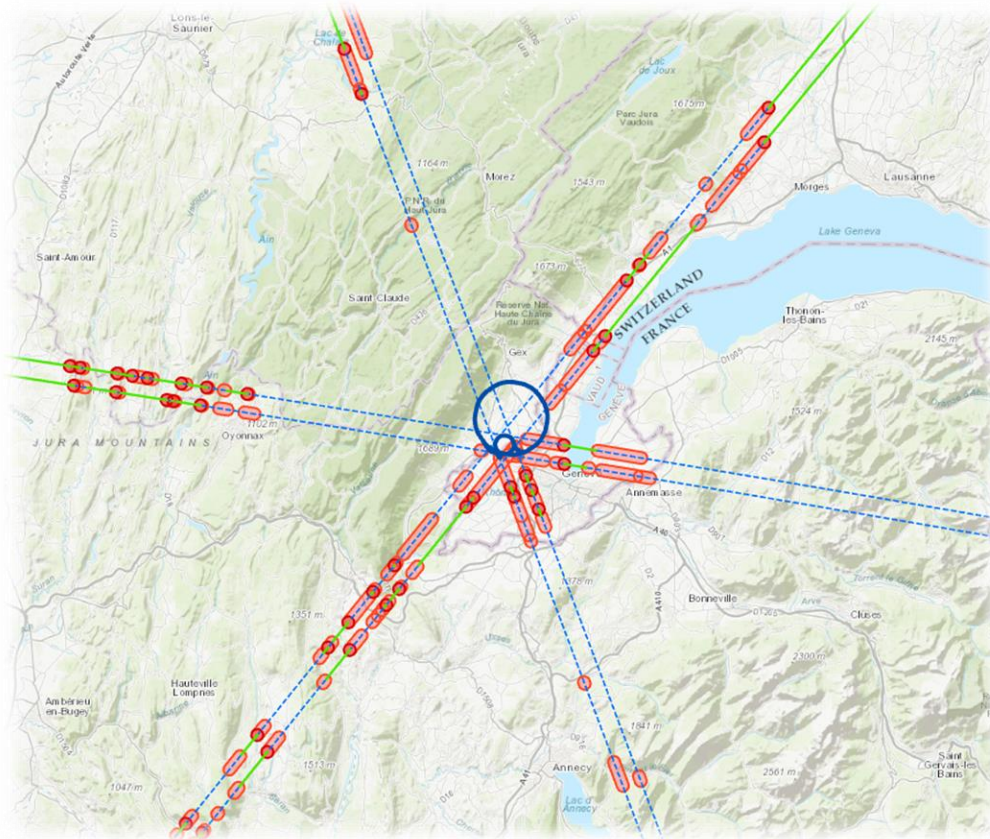
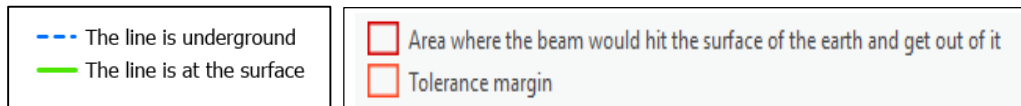
$$\Delta = H - H_{gprj}$$



## Results:

Point	Side	First exit to the surface of the earth (Distance from SPS point in Km)
1	L	64
1	R	7
2	L	28
2	R	35
3	L	44
3	R	10
4	L	80
4	R	6
5	L	10
5	R	21
6	L	51
6	R	10

Min	6 km
Max	80 km

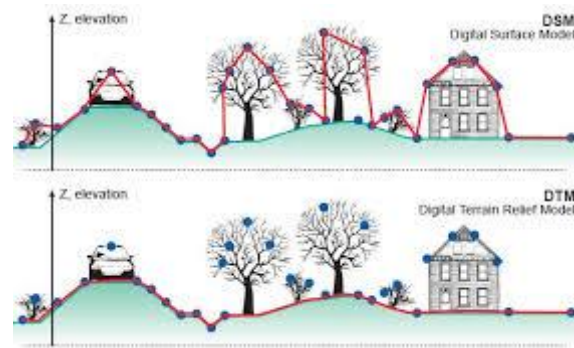


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## Tolerance and accuracy:

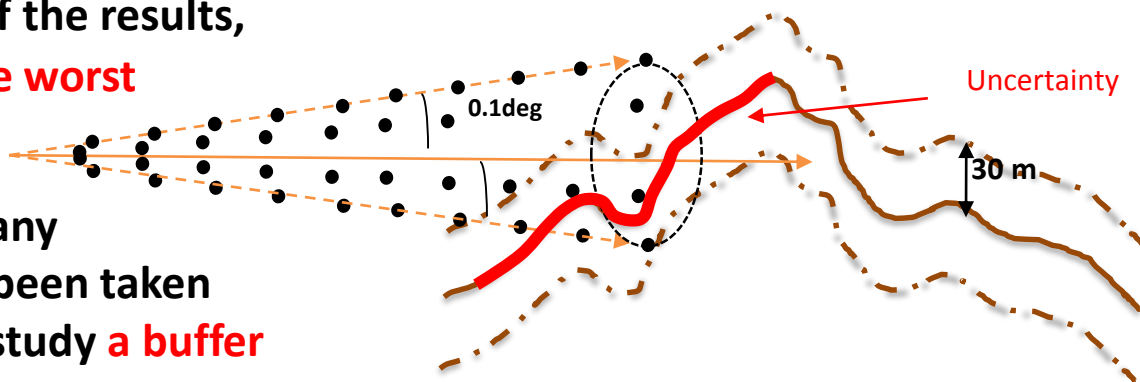
- Heights
  - EU-DEM: Accuracy : **+/- 7.0 m RMSE**
  - EU-DEM is a DEM, and not a DTM (Digital terrain Model).  
An error of **+ 20.0 m** is estimated
  - The assumption for the Geoid undulation is **+/- 3.0 m**
- LHC straight insertions directions:

The error is estimated to max **0.1 degree** in both horizontal and vertical directions. This corresponds to **20cm /100 m**



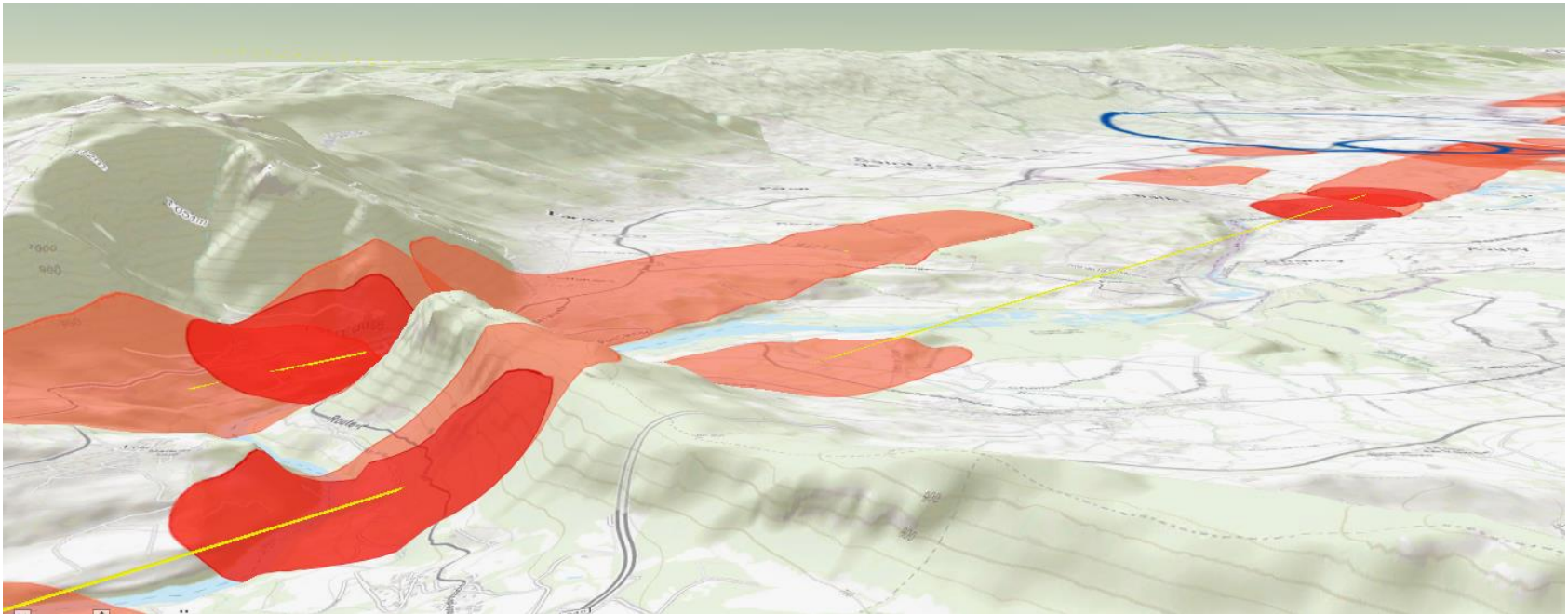
=> To simulate the uncertainty of the results,  
the calculations are made for **the worst possible cases**

=> To get rid of the influence of any  
parameter that would not have been taken  
into account in this preliminary study **a buffer of 1000 m is added**



# 3D View

- Area where the beam would hit the surface
- Tolerance margin



## Conclusions:

- The presented map is a very quick and preliminary study of the question.
- The geographic tools and the data are available
- The depth of the SPS and its “horizontality” bring some uncertainty on the exact locations. The beam is grazing the surface of the earth
- For LHC the longest distance was on the other side of the alps. For SPS, it is on the other side of the Jura
- For a more precise study, some more investigations have to be performed

