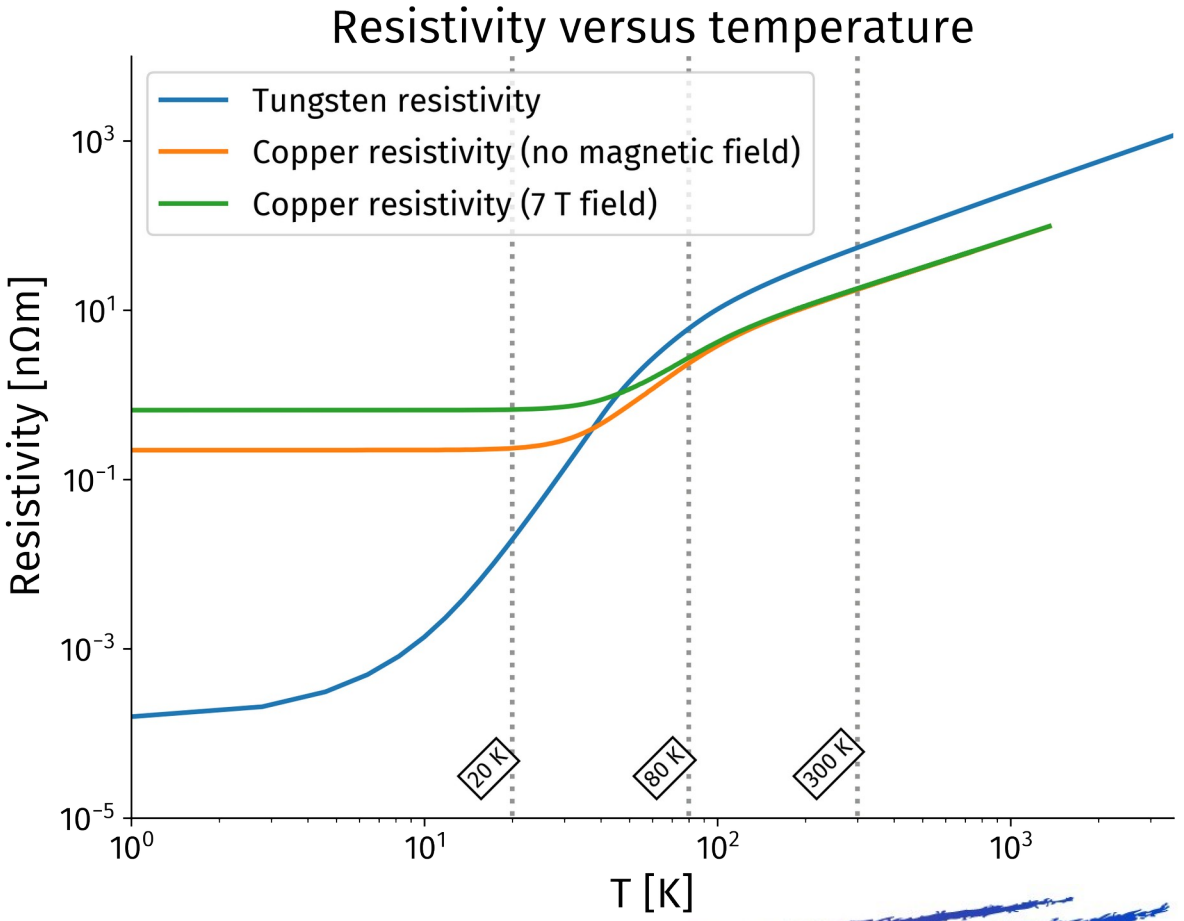
International MUON Collider Collaboration

CERN

Colliders: material resistivity

Tungsten resistivity versus temperature

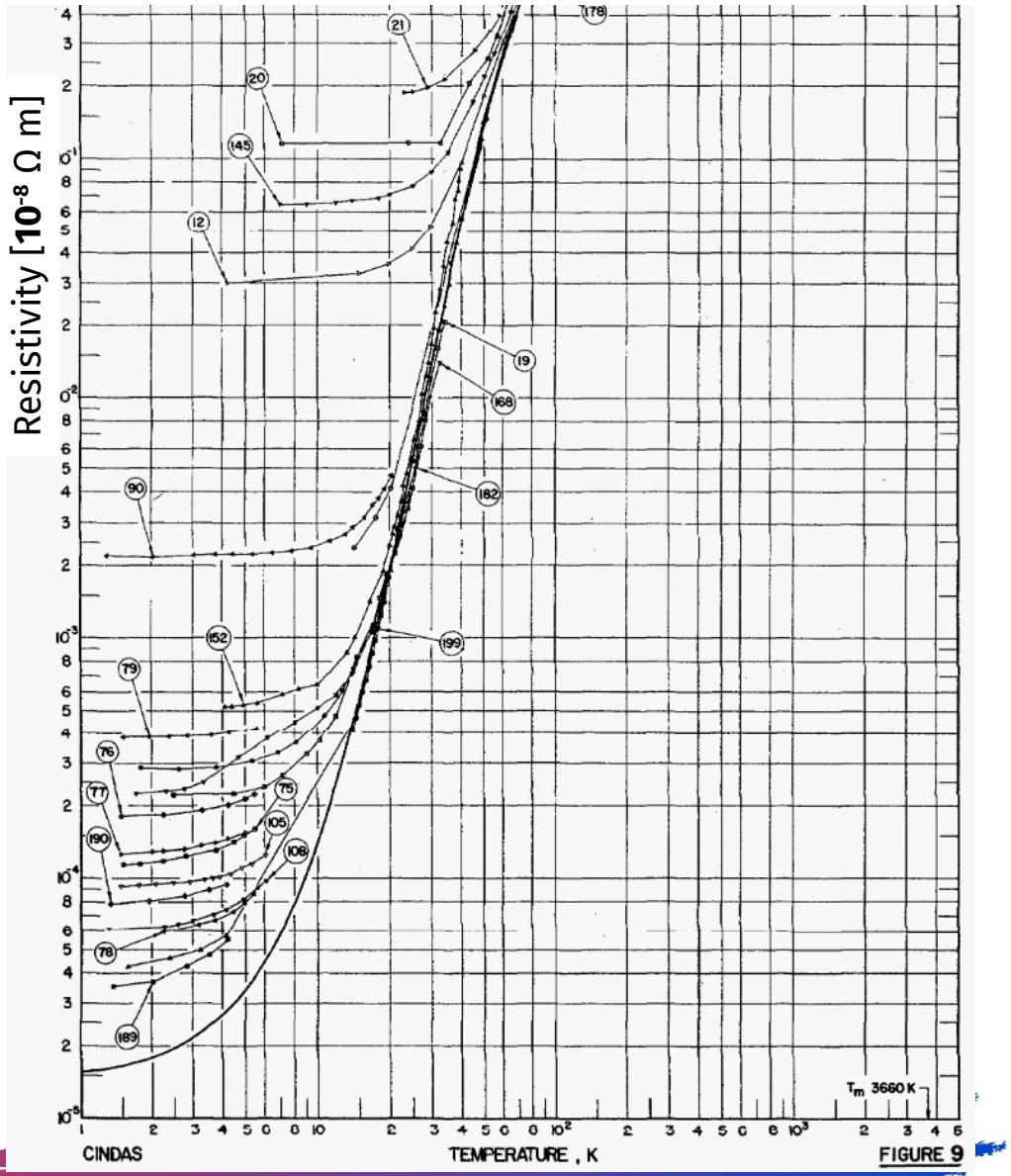
- Resistive wall impedance and wake are proportional to √ρ
- Copper resistivity versus temperature and magnetic field
  - Simon, Drexler and Reed “Properties of copper and copper alloys at cryogenic temperatures”, 1992
- Tungsten resistivity versus temperature
  - Desai et al. “Electrical Resistivity of Selected Elements”, 1984



Tungsten resistivity

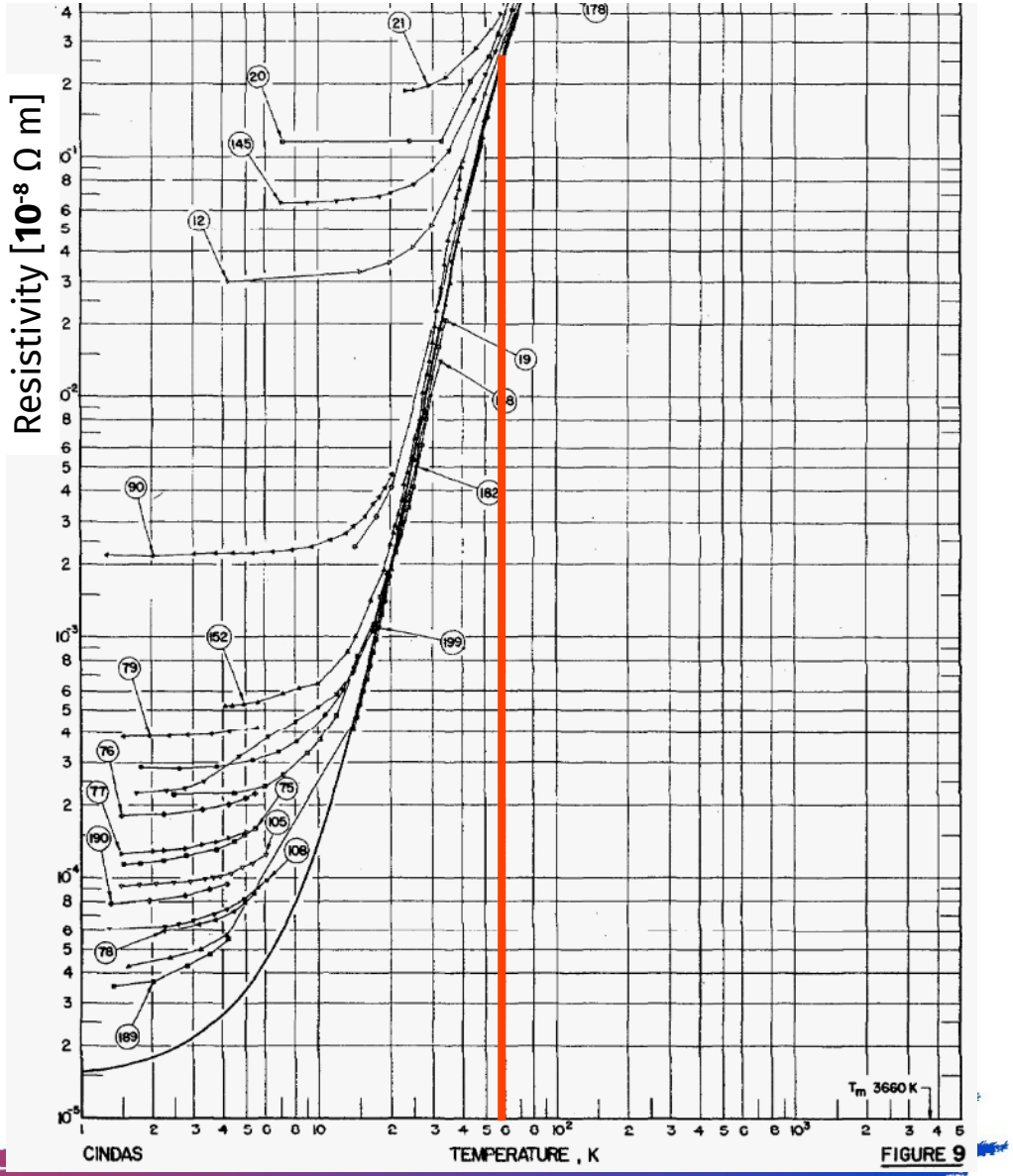
- Tungsten resistivity versus temperature
  - Plot shows low temperature region of resistivity curve: very low resistivity below 60 K
  - Different data sets are plotted (dotted lines)
  - Recommend curve is the solid one: specimen with lowest residual resistivity

set 182). The present recommendations for the electrical resistivity of tungsten at temperatures below 40 K are based on the data of Batdalov *et al.* The values are for a specimen with residual resistivity of $0.000\,015\,0 \times 10^{-8}\ \Omega$ m reported by Berthel (data set 199) which represents the lowest value and, hence, the purest sample reported in the literature for tungsten.



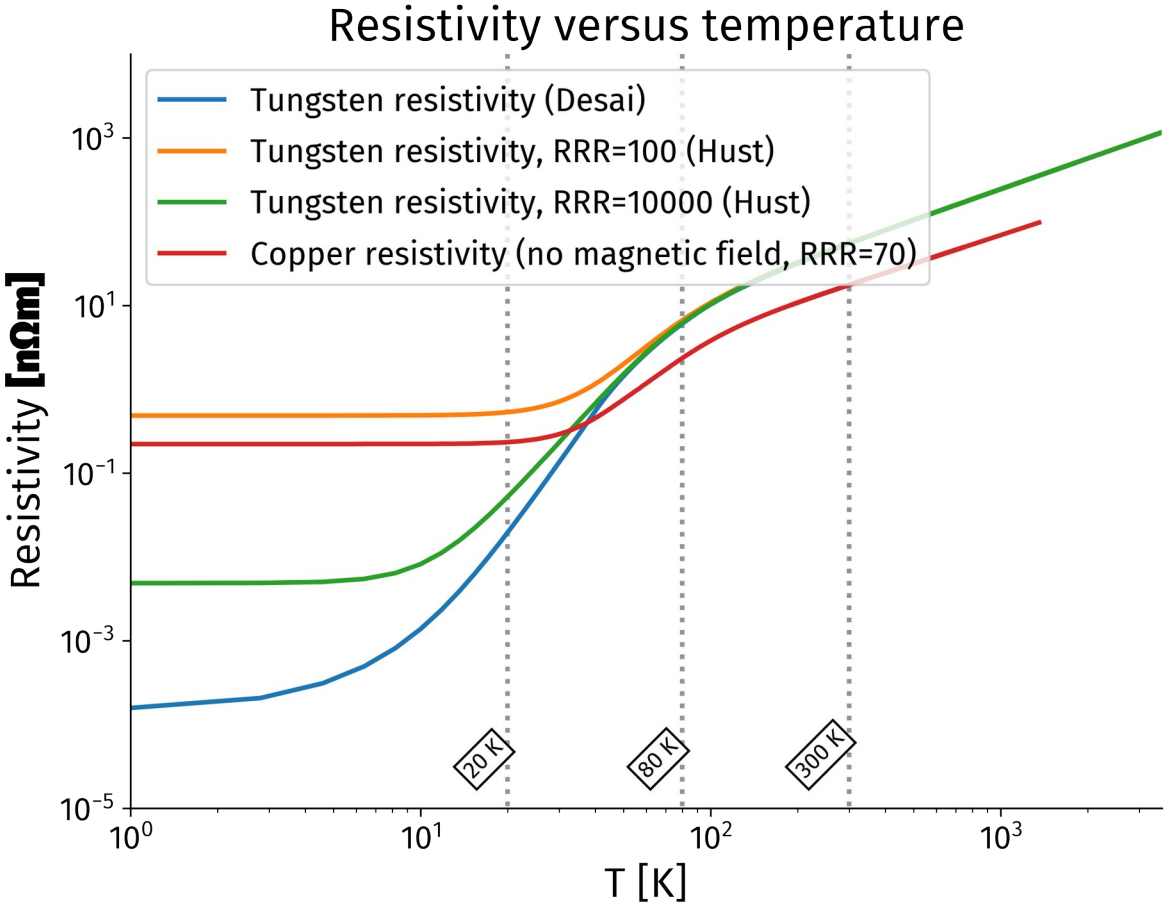
Tungsten resistivity

- Lowest resistivity below 60 K is achieved for the purest tungsten sample
- Above 60 K, the different data sets (e.g different tungsten purities) become similar
- Also above this temperature tungsten resistivity becomes higher than copper resistivity



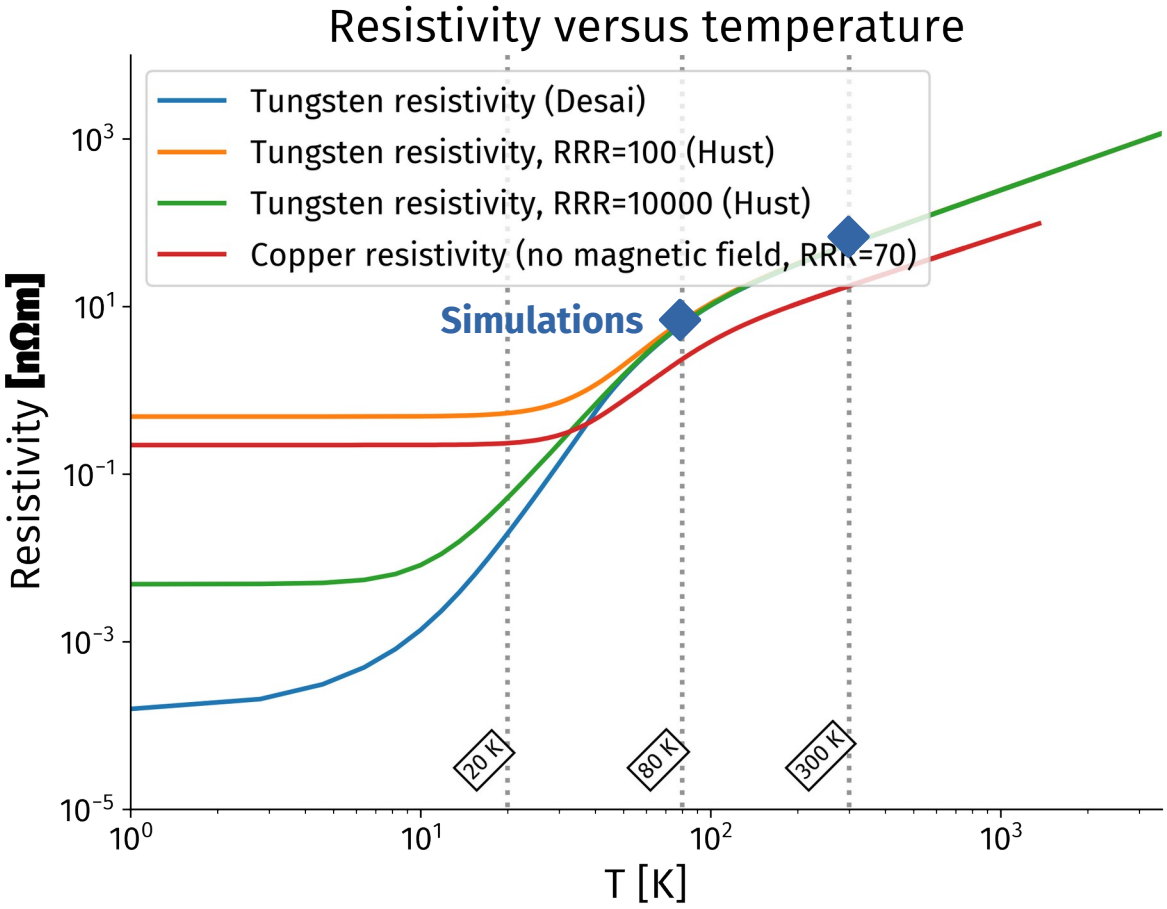
Tungsten resistivity

- Effect of RRR can be accounted for
  - Hust and Landford, “Thermal Conductivity of Aluminum, Copper, Iron, and Tungsten for Temperatures from 1 K to the Melting Point”, 1984
- RRR (and therefore material purity) has a clear impact for temperature below 80 K



Tungsten resistivity

- Simulations for the colliders resistive wall impedance were performed with tungsten at 80 K or 300 K
- RRR has a small effect on tungsten resistivity at this temperature



Electric resistivity of some materials

- Other materials could be investigated to optimize shielding heat dissipation/mechanical strength/conductivity/cost

Electric resistivity of different materials, in **nΩ m**

	Copper (0 T)	Copper (7 T)	Tungsten [1]	Tungsten RRR=100 [2]	Tantalum [1]	Tungsten-Copper [3]	Tungsten-Rhenium [3]
10 K	0.746	0.657	1.37e-3	48.7	1.022	?	?
80 K	2.83	2.75	6.06	6.66	26.2	?	?
300 K	18	17.9	54.4	55.4	13.48	43.0	290

1 : Desai et al. “Electrical Resistivity of Selected Elements”, 1984

2 :

Hust and Landford, “Thermal Conductivity of Aluminum, Copper, Iron, and Tungsten for Temperatures from 1 K to the Melting Point”, 1984

2 : https://www.matweb.com/search/DataSheet.aspx?MatGUID=7ce3abb99e274e18916b062affefff7e&ckck=1

3 : https://www.matweb.com/search/datasheet.aspx?matguid=ec5e2badc6cf467191fd545182b139ef&ckck=1