We Have Great Opportunities Ahead

❖ We are on the verge of important discoveries

- The Standard Model has been very successful and we are getting ready for the inevitable next step.
- There are many hints that great physics is just over the horizon — understanding EWSB, neutrino mass, dark energy, dark matter and more — a time similar to the early 20th century.

❖ Possibilities for the new HEP tools are excellent

- Run II is starting (with some difficulty)
- LHC is being built (with the usual problems)
- A linear collider is being planned (and might be started in 5 to 10 yrs.)

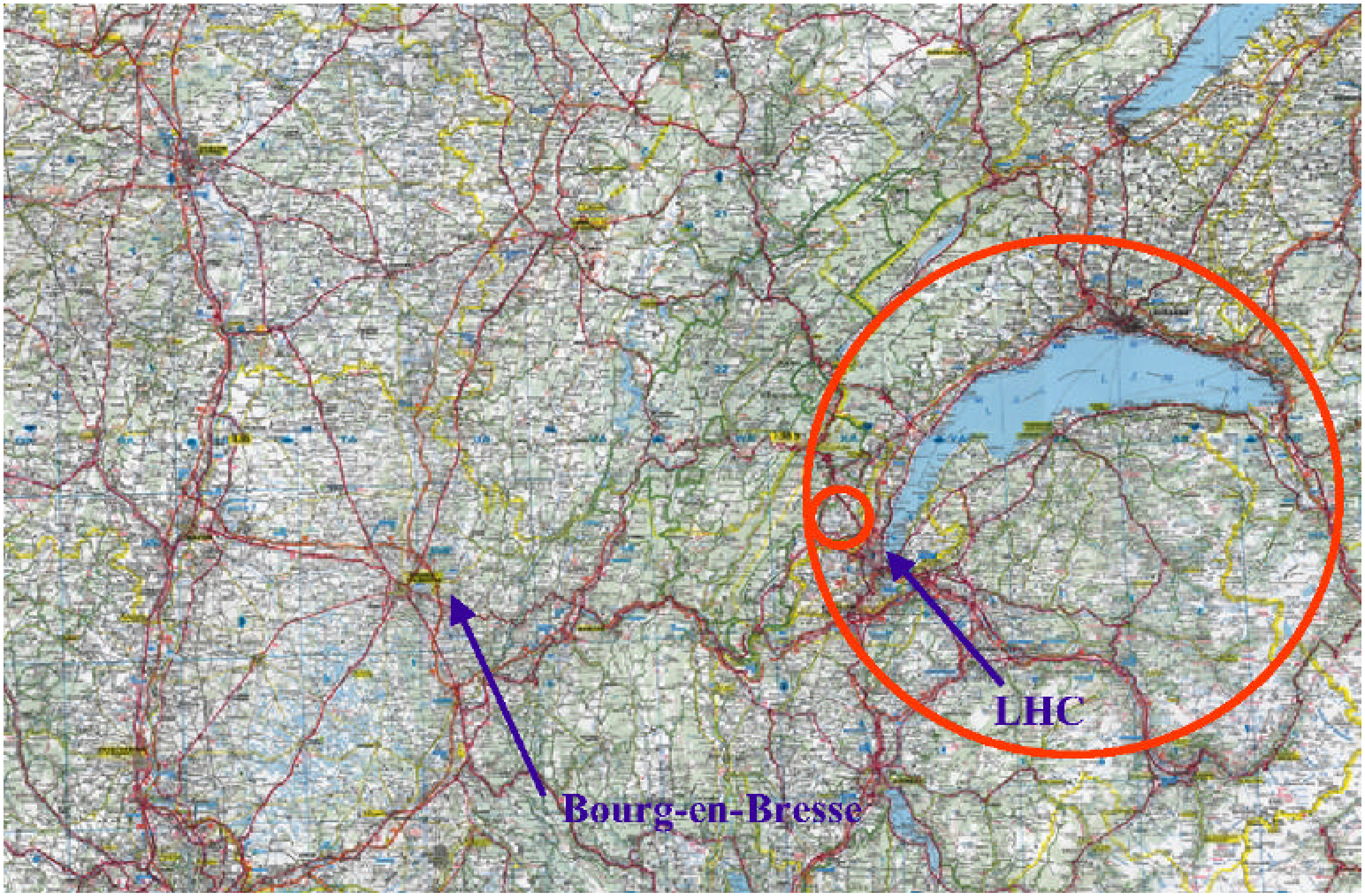
The Long-Range Plan

- **Eventually HEP must go to a higher energy scale**
  - The only sure way to get there is with a proton collider – a VLHC.

    In principle a VLHC could be built in many places, but the best combination of infrastructure, space, geology and resources is in the U.S., at Fermilab.

- **An incomplete plan now could delay the step to higher energy for many years or even cancel it entirely.**
  - The plan we make now must look beyond linear collider
  - We need to pursue this plan during the era of the LHC. These things take time.
  - It will require worldwide cooperation to collect the economic and political resources necessary to build a VLHC at 100 to 200 TeV.

The VLHC at CERN?



A Complete Plan Now

- **If and when we build the VLHC may depend on what happens to the linear collider**
  - **Possibility 1: A linear collider is built in the U.S.**
  - **Possibility 2: A linear collider is built, but not in the U.S.**
  - **Possibility 3: No linear collider is built**
- **The path to higher energy with a VLHC is dependent on these choices**
  - **Therefore, the plan has to be complete. It has to include steps beyond the linear collider.**

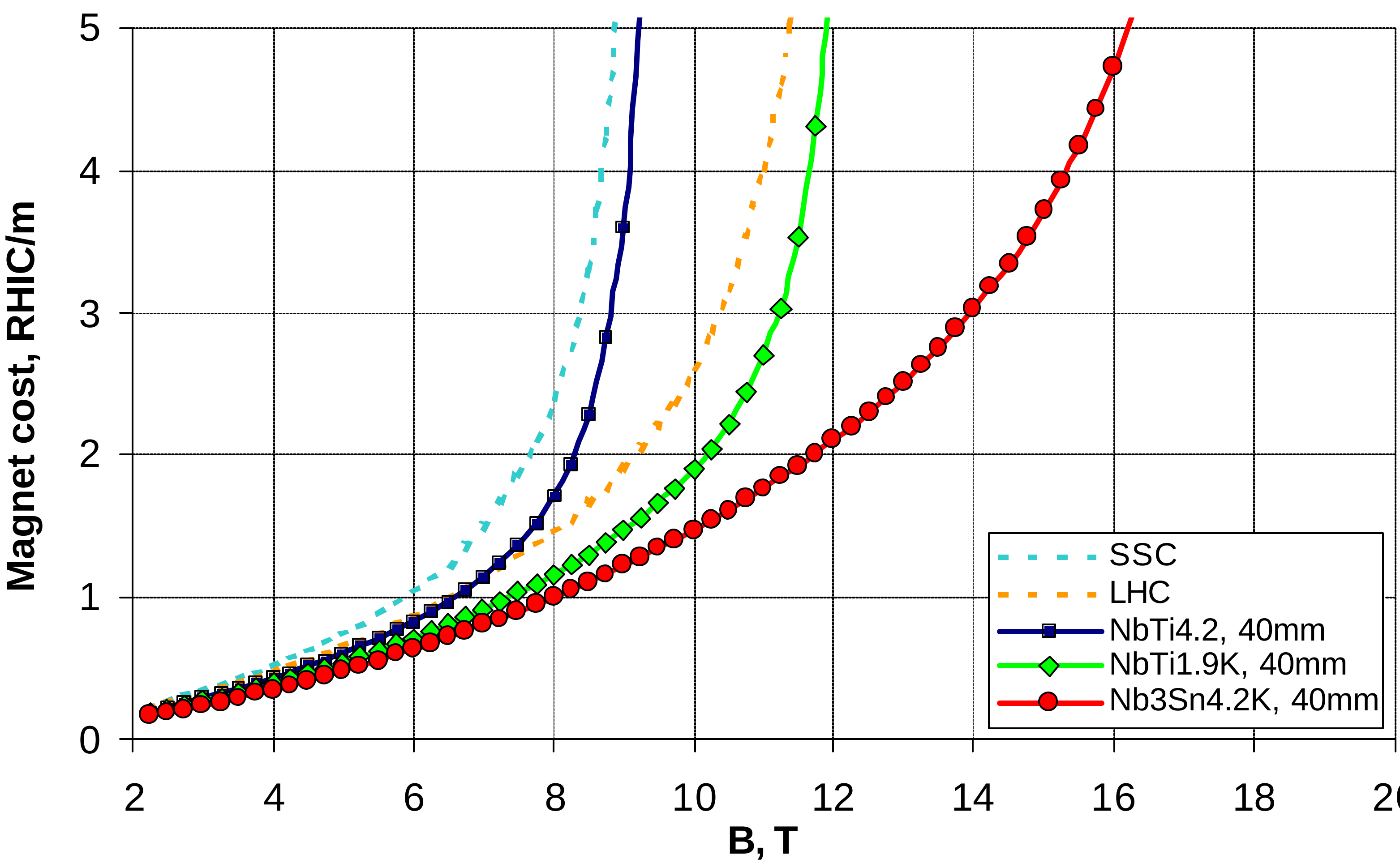
A Linear Collider Is Built In the U.S.

- **There may be no VLHC for many years**

  The U.S. is unlikely to start a LC soon, and even less likely to invest $5 billion in a LC and then invest another $5 billion in a VLHC.

- **In this case, the only path to higher energy is to increase the LHC energy**
  - **17 T magnets gets a factor of ~2 in energy**
  - **Requires a new higher-energy injector**
  - **Synchrotron radiation power is proportional to E^3B**
  - **Magnet costs run away at high field**

- **Very risky and very costly for very little gain**



Magnet cost, RHIC/m
0
1
2
3
4
5
2
4
6
8
10
12
14
16
18
20
B, T
SSC
LHC
NbTi4.2, 40mm
NbTi1.9K, 40mm
Nb3Sn4.2K, 40mm

A Linear Collider Is Built — But Not In the U.S.

- **The U.S. will be a major player, we hope, in the Linear Collider project and physics**
- **There will be resources available (and the desire) for VLHC construction in the U.S.**
- **There should be a vigorous magnet and machine R&D program in the U.S. in parallel with LC construction.**
- **It takes longer than you think to develop the components of a cutting-edge collider, and the price for not completing the R&D early is severe.**

How Long Does It Take?

Collider	B	Magnet R&D Start	Magnet Prod Start	Magnet R&D Duration (yrs)	Magnet Prod Completed
Tevatron	4.4	1973	1980	7	1983
HERA	5	1977	1987	7	1990
SSC	7	1982	Est. 1995 #	Est. 13 #	#
RHIC	4	1986	1994	8	1996
LHC	9	1986	2002	16	2007 (?)

Cancelled in 1993. Production never started. More than 20 successful prototypes were built at FNAL & BNL by 1992.

A Linear Collider Is Built — But Not In the U.S.

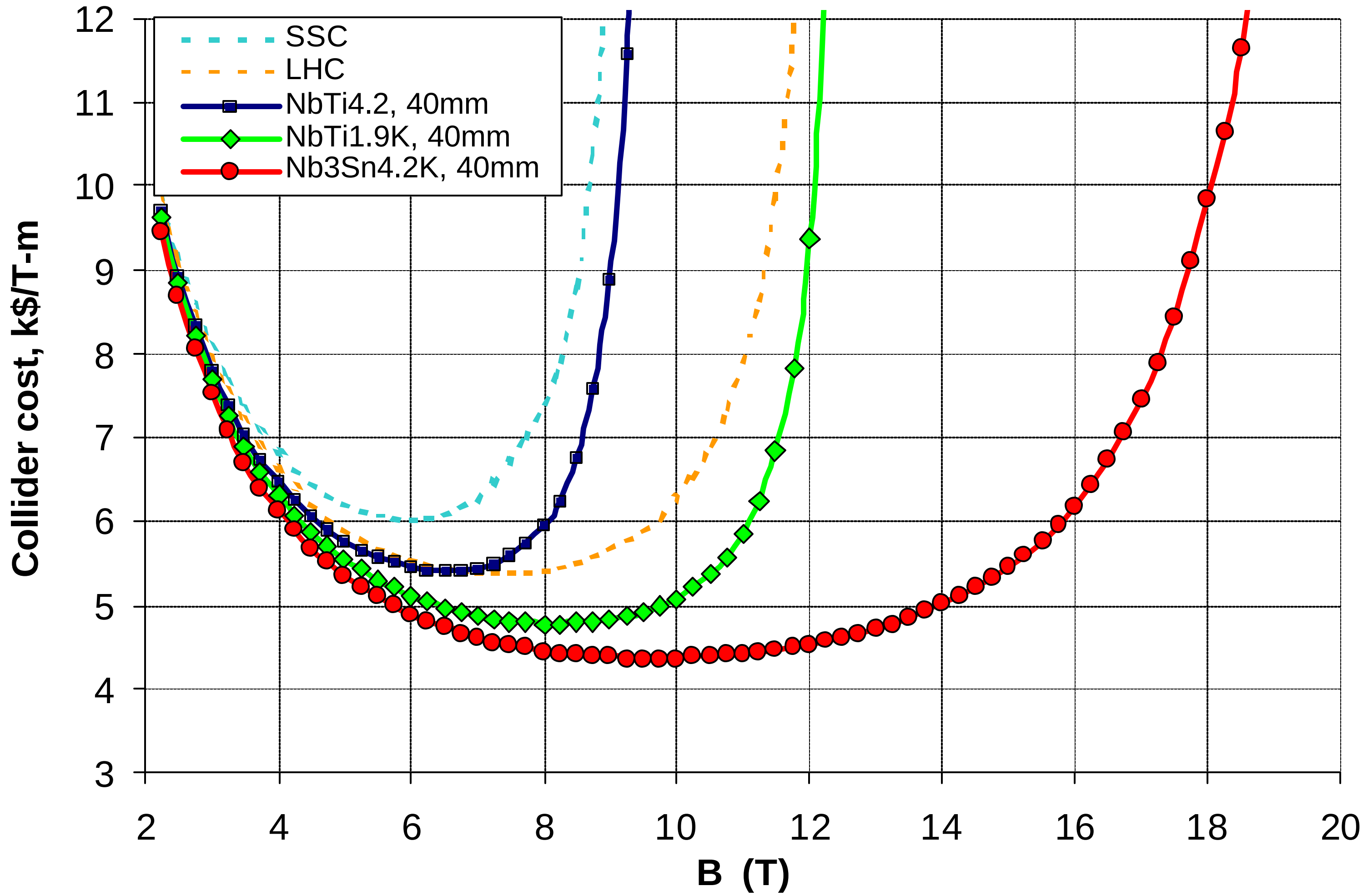
- We will need to decide early what sort of VLHC—energy, size, magnet, staging
  - Our model is based on a staged design with the ultimate energy of 200 TeV (CM), but there are many options
- Hopefully, the LHC results will tell us the energy
- The R&D emphasis for a very-high-energy VLHC is different from the R&D for a Super-LHC
  - For technical and cost reasons, lower field and larger circumference is optimum for a very-high-energy collider.

Magnets for a VLHC

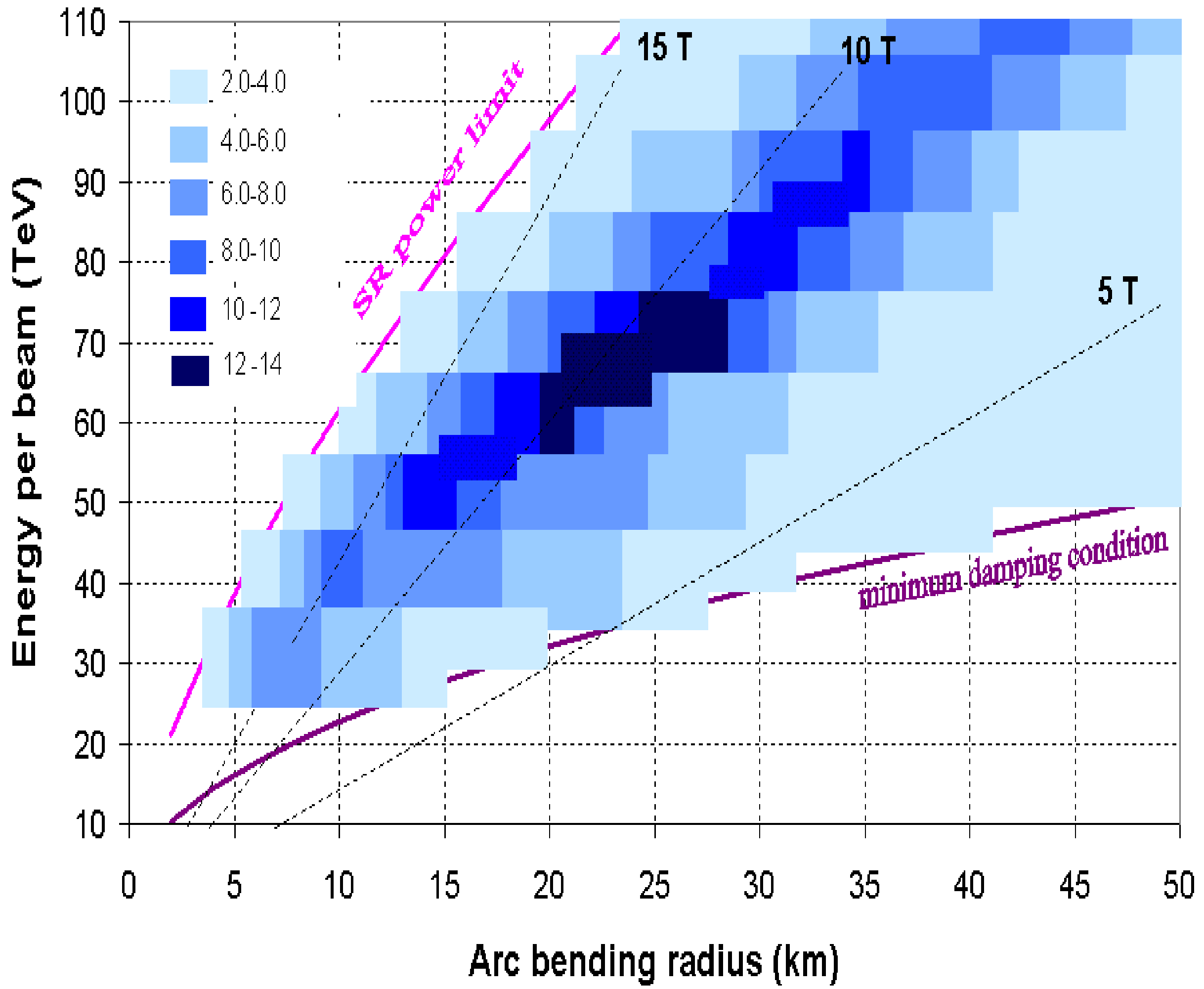
❖ High magnetic field is not optimum

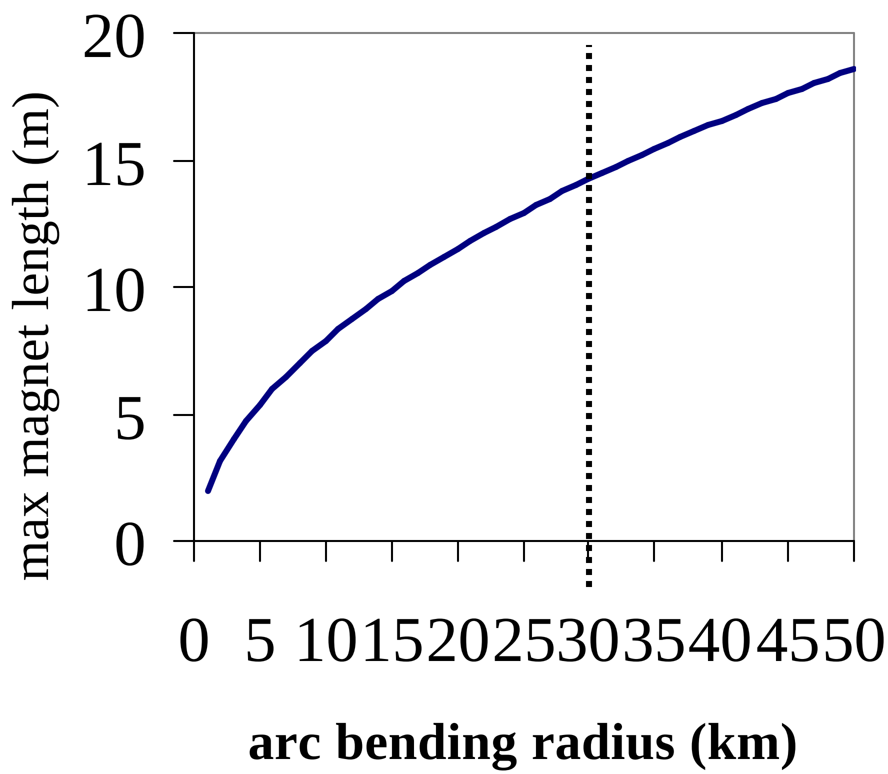
- Colliders with high-field magnets cost more.
- Synchrotron radiation limits the energy and luminosity for high-field colliders.
- Large-circumference rings allow "photon stops," which removes most of the limits due to synchrotron radiation.
- Even at "merely" 10 T–12 T the development will be difficult, because the materials are unfamiliar.

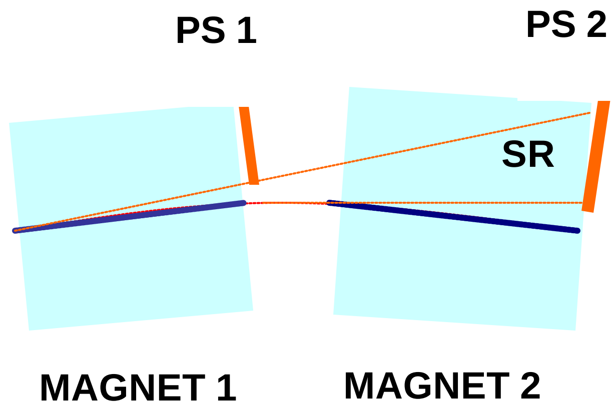
VLHC Cost based on SSC cost distribution



P_{SR}<10 W/m/beam peak $t_L > 2\ t_{sr}$ Int/cross < 60 L units $10^{34}\ cm^{-2}s^{-1}$




max magnet length (m)
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50
arc bending radius (km)


PS 1
PS 2
SR
MAGNET 1
MAGNET 2

While We Wait for an LC Decision

- **VLHC R&D continues**
  - **The issues are magnets, magnets and magnets**
    - And studies of tunneling, synchrotron radiation & accelerator physics.

- **In the U.S. there are still vigorous SC magnet programs.**

- **A DOE-funded program to help upgrade and improve LHC performance will (we hope) begin soon in the U.S., and will greatly strengthen VLHC R&D.**
  - **The main part of the program will be development of large-aperture strong quadrupoles using Nb3Sn.**

Conclusions

- **The most important requirement for the future instruments of HEP is worldwide cooperation and a global plan.**
- **The global plan for the instruments of particle physics must go beyond the linear collider and include a long-range vision.**
  - This is similar to the NASA Strategy, in which the goals are truly large and visionary, and the instruments are missions along the way.
- **The parameters,schedule and R&D for a VLHC will depend the timing and location of a linear collider in addition to results from the LHC. The global plan should recognize these couplings.**
- **If we ever want to build a VLHC we need to have a vigorous R&D program now, because magnet development takes a long time, and the penalty for late development is severe.**