(A/H Higgs Factory, Possible CP Violation and 6D Cooling

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Abstract

In the past the development of the proton-antiproton collider at CERN (and FNAL) relied on 6-D cooling of the beam. We briefly recount this and the following discovery of the W and Z bosons as an example of what we worked on. Currently, a possible discovery of similar magnitude could be made with a $\mu+\mu-$ collider. Again as in the collider, 6D beam cooling is crucial. The current version of the $\mu+\mu-$ collider was started in December 1991 at a UCLA workshop help in Napa, California. It was rapidly realized that such a □machine is also a Higgs boson factory. Workshops in the 1990s confirmed this fact. In the case of the supersymmetric A and H Higgs bosons the interference of these two states might be one origin of CP Violation in Nature. CP Violation can lead to an excess of matter over antimatter in the current universe. Again, 6D beam cooling is needed! We indicate some of the possible methods for 6D cooling including the use of a 50T solenoid - a great technical leap forward.

Detection of Possible Large CP Violation Suitable for Barogenesis at a Muon Collider

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Gail Hanson, UC Riverside

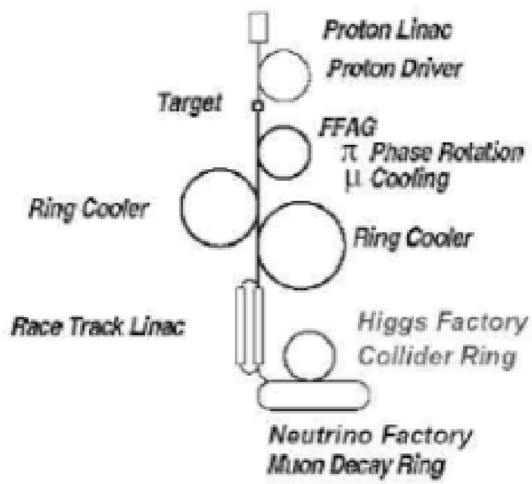
Abstract

We show that the production of the Proposed Supersymmetric A/H Higgs bosons at a muon collider and decays into $\bar{\tau}\tau$ states can lead to the discovery of CP violation of cosmological significance. This could satisfy the key conditions of barogenesis in the very early universe.

Outline

A. Discovery of the A/H at the LHC
   1. The conditions of barogenesis- large CP violation in the early universe
   2. Possible CP violation in the Interference of the CP even and odd states of the proposed A/H Higgs particles
   3. Use of a muon collider a A/H Higgs factory
   4. Detection of CP violation using the reaction A/H $\rightarrow \tau\bar{\tau}$ at a muon collider
   5. A simple example to demonstrate the possible discovery of the CP violation summary.

We describe the progress in the simulation of 6D cooling of μ beams for use in neutrino factories and muon beam colliders. We concentrate on the final cooling needed to reach the emmittance required for a SUSY Higgs factory using high-pressure gas ring coolers and Li lens ring coolers.



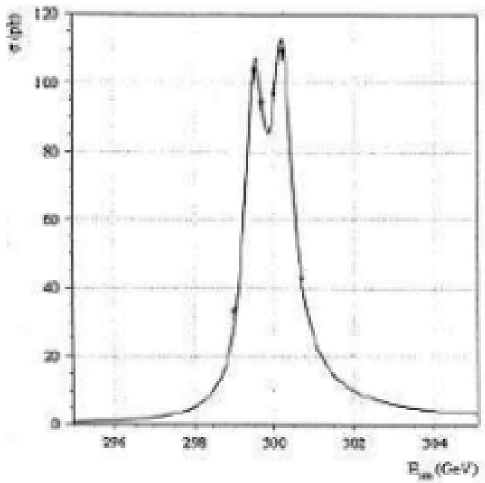


Figure 1a. Recent concept for a $\mu^+\mu^-$ collider Higgs factory. Figure 1b: Cross sections for productions of H and A bosons with small mass difference cross section.

A Muon Cooling Ring with Curved Lithium Lenses

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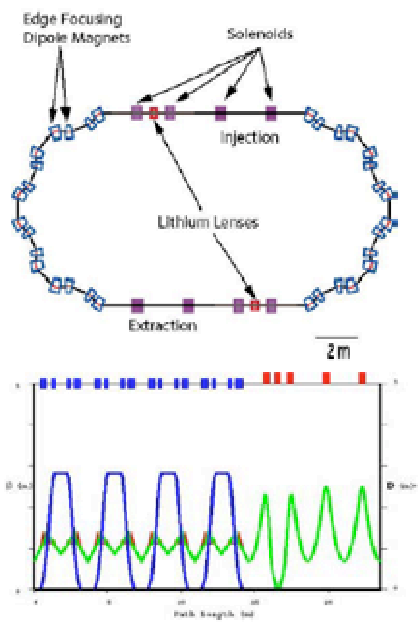
Harold Kirk, BNL, Brokhaven, New York, USA

We design a muon cooling ring with curved Lithium lenses for the 6 dimensional muon phase space cooling. The cooling ring can be the final muon phase space cooling ring for a Higgs factory, a low energy muon collider. Tracking simulation shows promising muon cooling with simplified magneti element models.


Edge Focusing
Dipole Magnets
Solenoids
Injection
Lithium Lenses
Extraction
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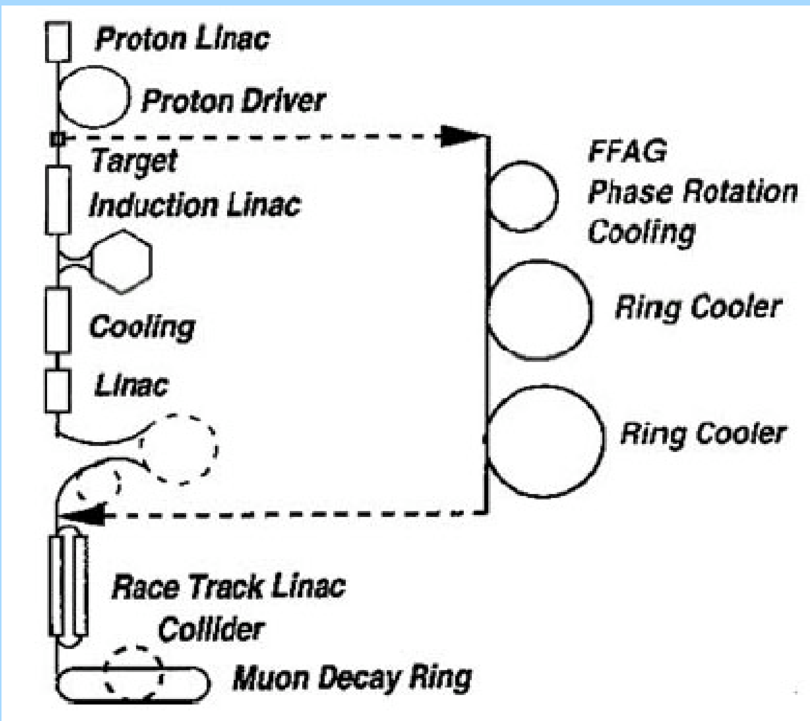
The concept of a muon collider

Schematic concept for a muon collider



Formulas for 6D cooling of muons

$$\frac{\mathrm{d}\varepsilon_\perp}{\mathrm{d}s} = \frac{1}{\beta^2}\frac{\mathrm{d}E_\mu}{\mathrm{d}s}\frac{\varepsilon_\perp}{E_\mu} + \frac{\beta_\perp^*}{2\beta^2}\frac{(0.014)^2}{E_\mu M_\mu L_R}$$

$$\frac{\mathrm{d}(\Delta E_\mu)^2}{\mathrm{d}s} = {}^{-}2\mathrm{d}[\mathrm{d}E_\mu/\mathrm{d}s]/\mathrm{d}E_\mu \langle(\Delta E_\mu)^2\rangle.$$

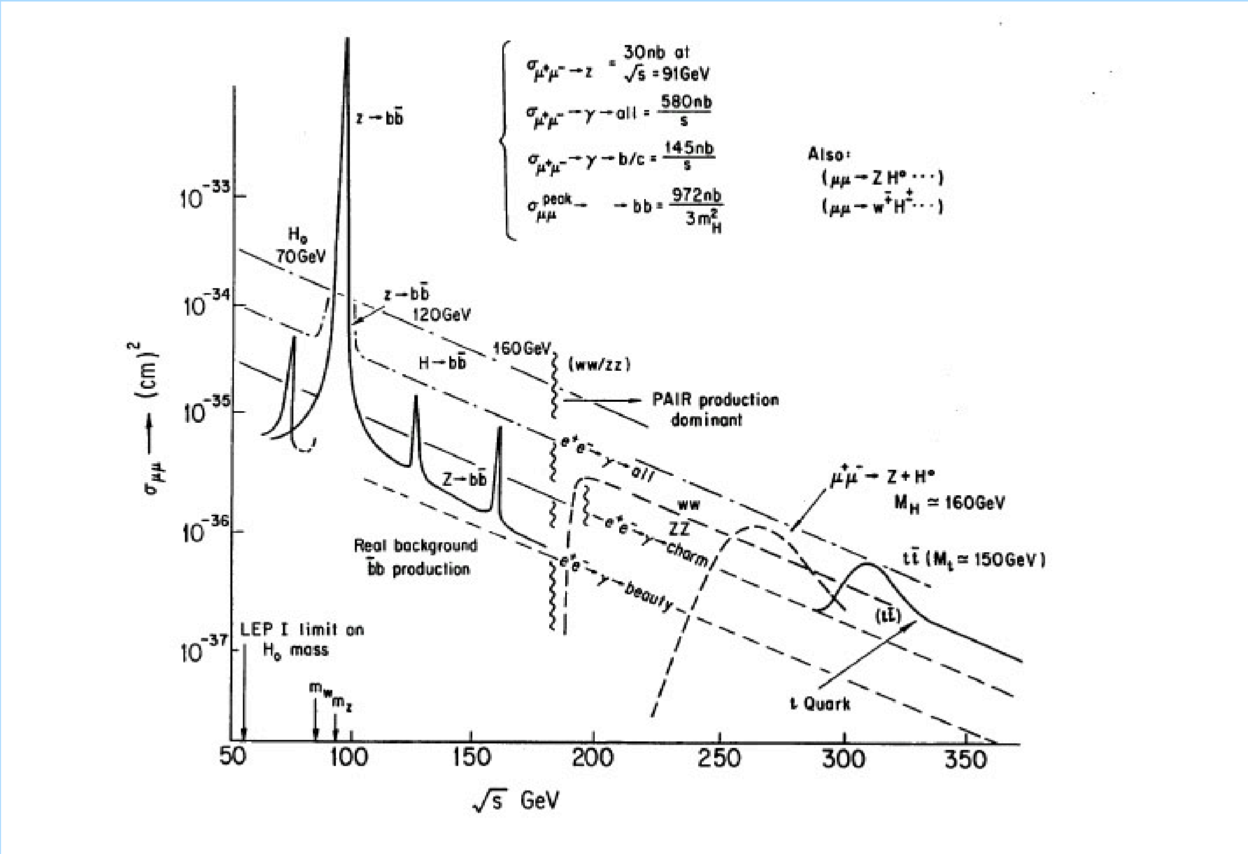
Arguments for a Higgs Factory

TABLE 1. Arguments for a Higgs-Factory $\mu^+\mu^-$ Collider.[1,5]

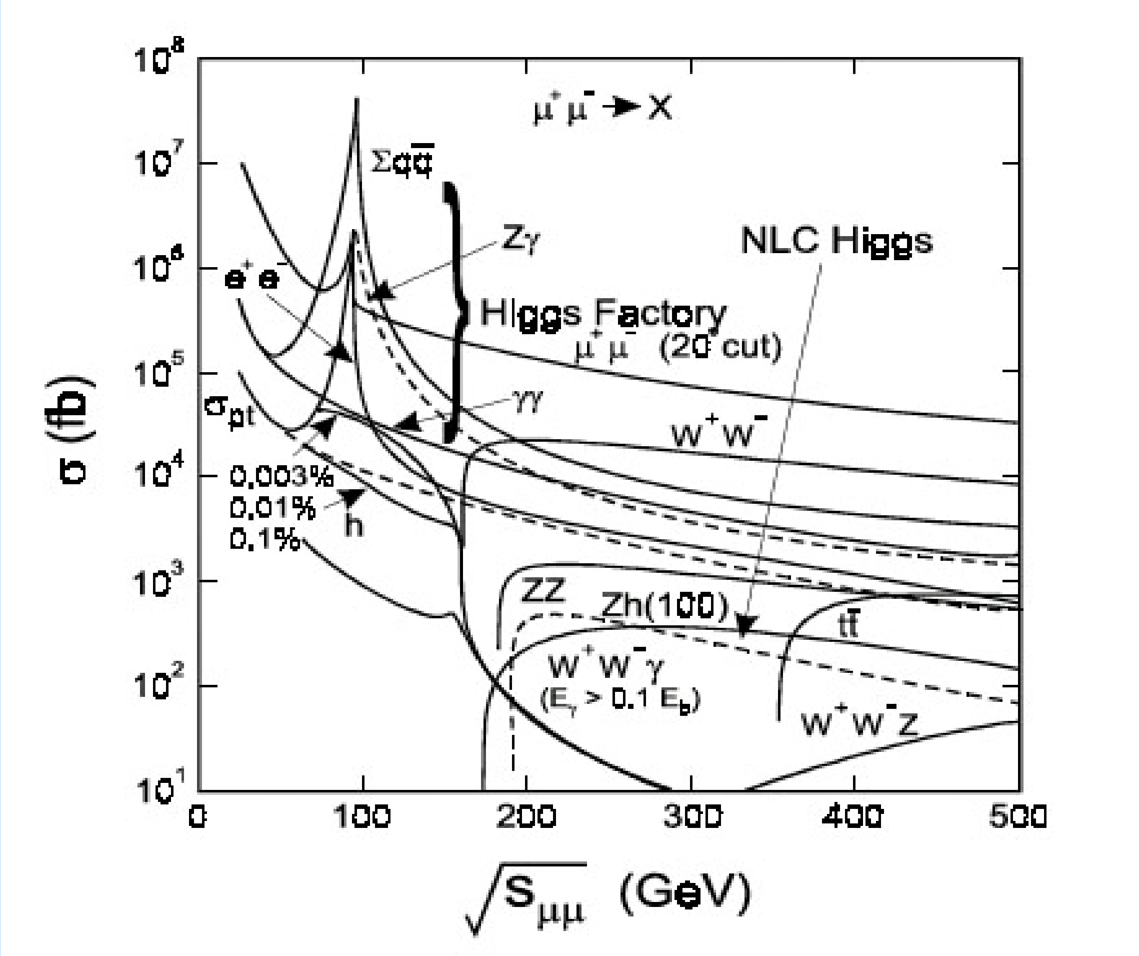
1. The $m_\mu \backslash m_e$ ratio gives coupling 40,000 times greater to the Higgs particle. In the SUSY model, one Higgs $m_h < 120$ GeV!!
2. The low radiation of the beams makes precision energy scans possible.
3. The cost of a "custom" collider ring is a small fraction of the $\mu^\pm$ source.
4. Feasibility report to Snowmass established that $\mathfrak{L} \sim 10^{33}$ cm^{-2} s^{-1} is feasible.

A Higgs factory and CP violation at a muon collider A/H Higgs boson

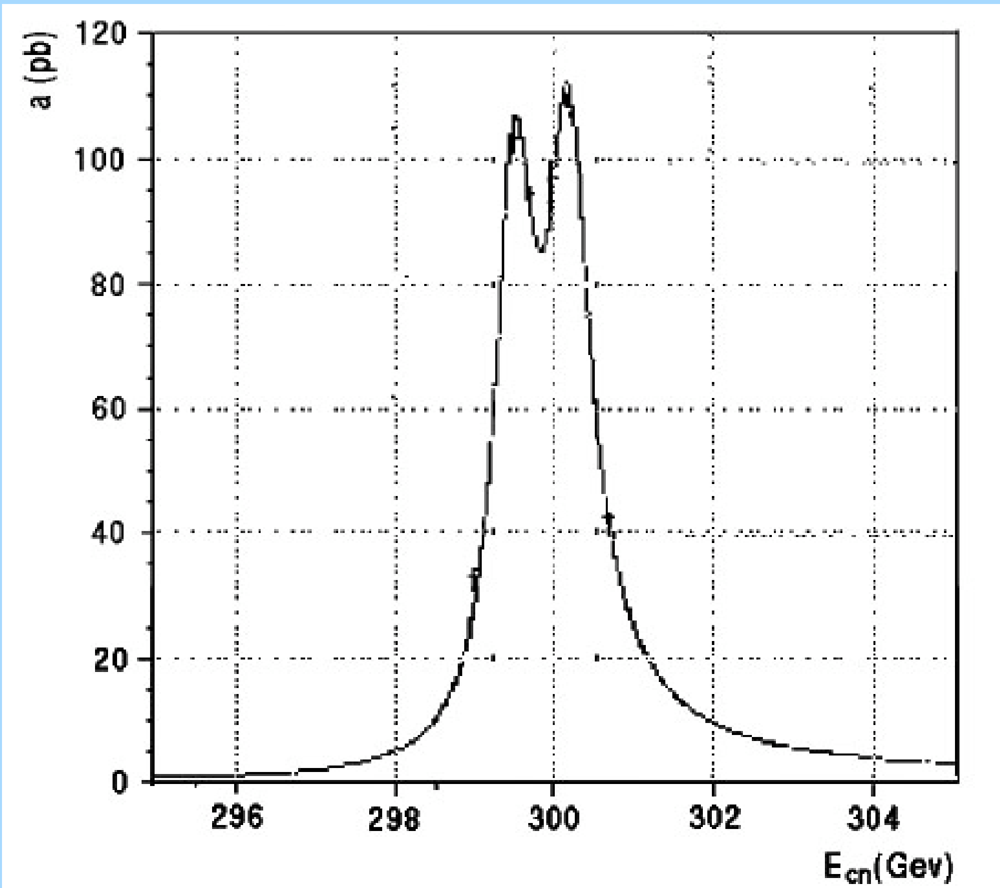
Muon collider Higgs boson factory: h^0 Higgs boson $m_{h0} \sim 120$ GeV



Comparison of μ+μ- and e+e- production



A/H Higgs bosons



A and H Higgs bosons have opposite CP states

The interference between A and H can cause CP violation

A/H Higgs boson factory to observe CP violation

H/A Higgs mixing in CP-noninvariant supersymmetric theories

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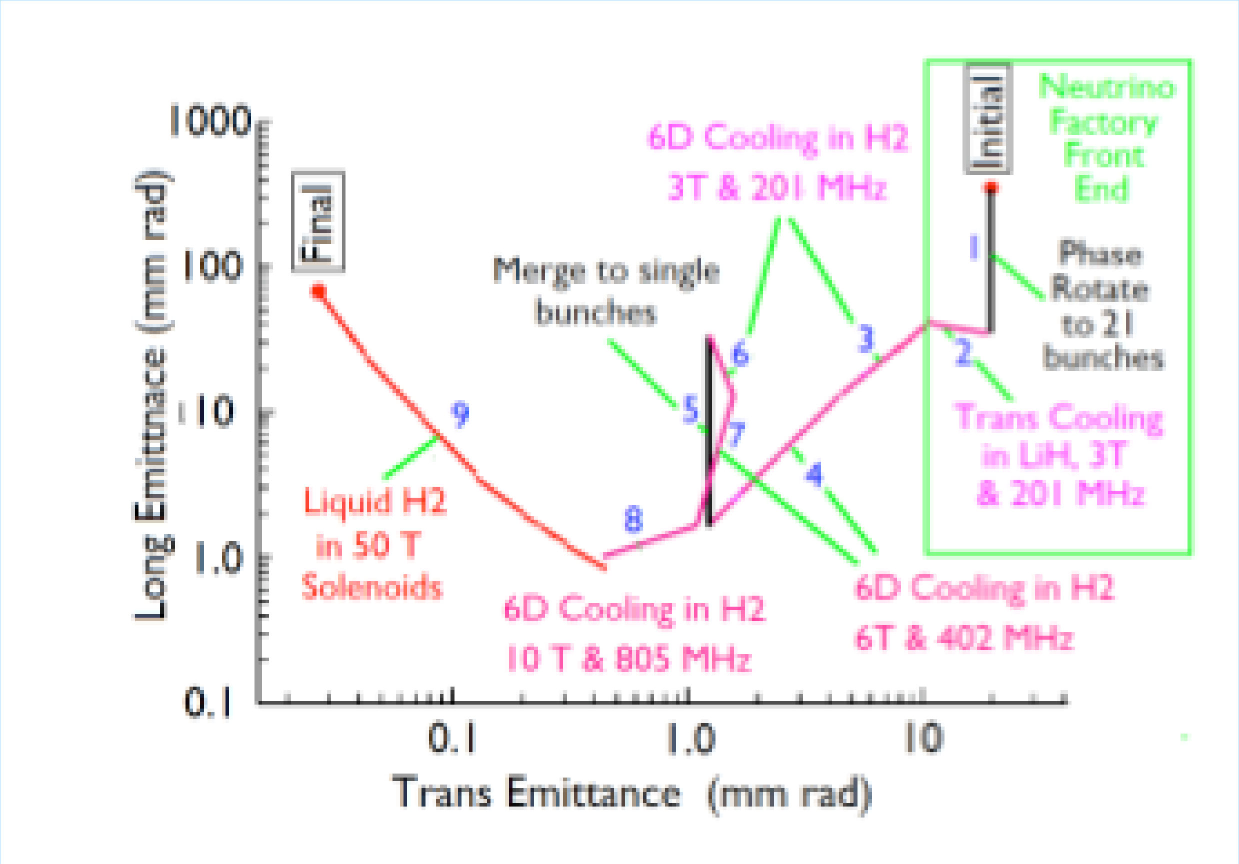
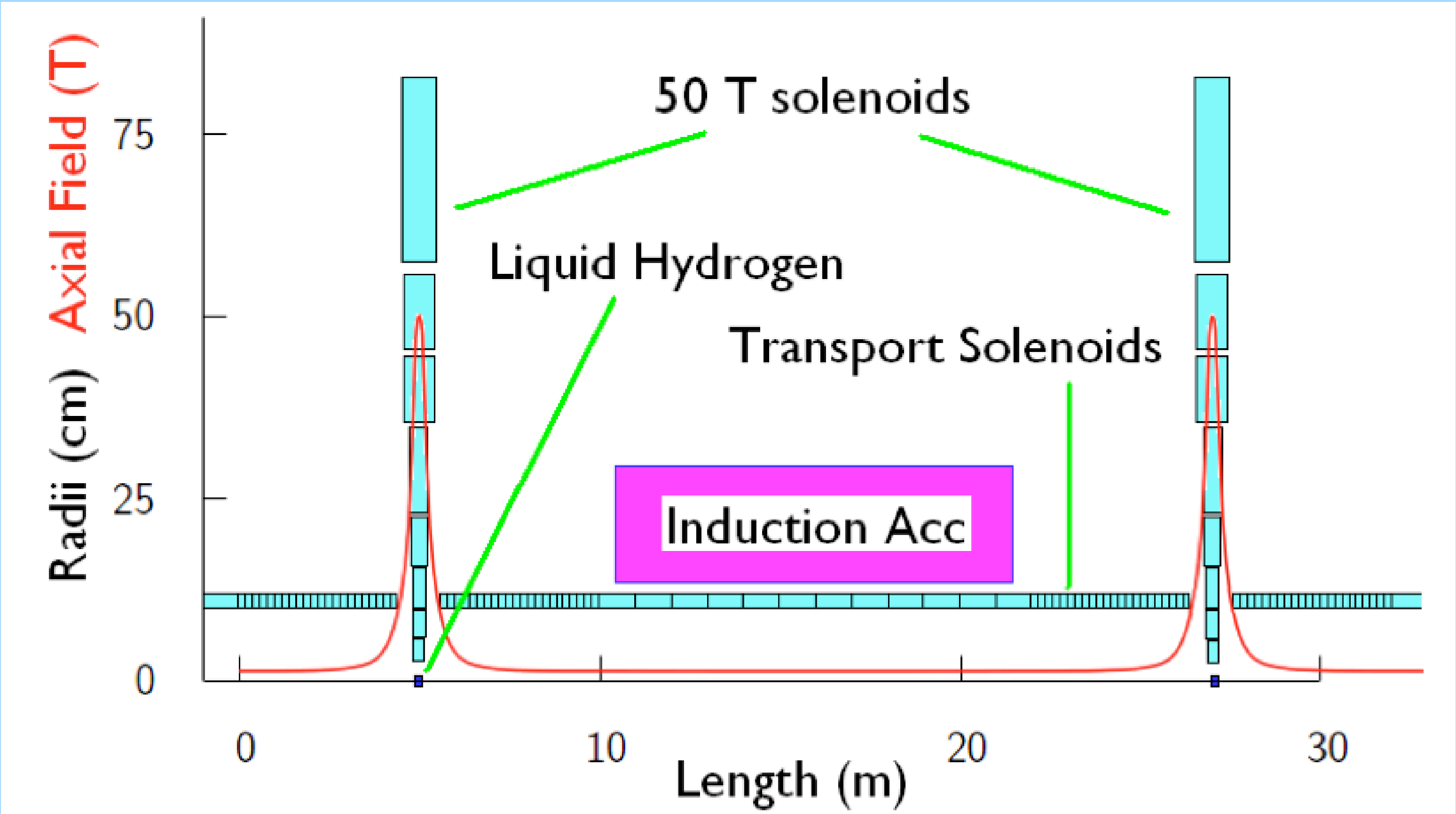
Abstract. For large masses, the two heavy neutral Higgs bosons are nearly degenerate in many 2-Higgs doublet models, and particularly in supersymmetric models. In such a scenario the mixing between the states can be very large if the theory is CP-noninvariant. We analyze the formalism describing this configuration, and we point to some interesting experimental consequences.

6D Cooling for muon colliders



Emittance required for muon collider



R. Palmer et al, PBL

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Inclusive b-quark production cross section with muons and jets in pp collisions at $\sqrt{s} = 7$ TeV

The CMS Collaboration

Abstract

The CMS collaboration measurement of the total and differential cross sections $d\sigma/dE_T^b$ and $d\sigma/d|\eta^b|$ for inclusive b-quark production in pp collisions at $\sqrt{s} = 7$ TeV is presented. The dataset corresponds to 3 pb^{-1} of integrated luminosity recorded in 2010. A sample of events containing jets and at least one muon is selected for the study. The transverse momentum of the muon with respect to the closest b-tagged jet axis discriminates b events from the background. The measured total b-quark cross section for transverse energy $E_T^b > 30$ GeV and pseudorapidity $|\eta^b| < 2.4$ is $\sigma(\mathrm{pp} \to \mathrm{b} + X) = 3.20 \pm 0.01(\mathrm{stat}) \pm 0.52(\mathrm{syst}) \pm 0.35(\mathrm{lumi})\ \mu\mathrm{b}$. The data are compared with QCD Monte Carlo predictions at LO and NLO accuracy.

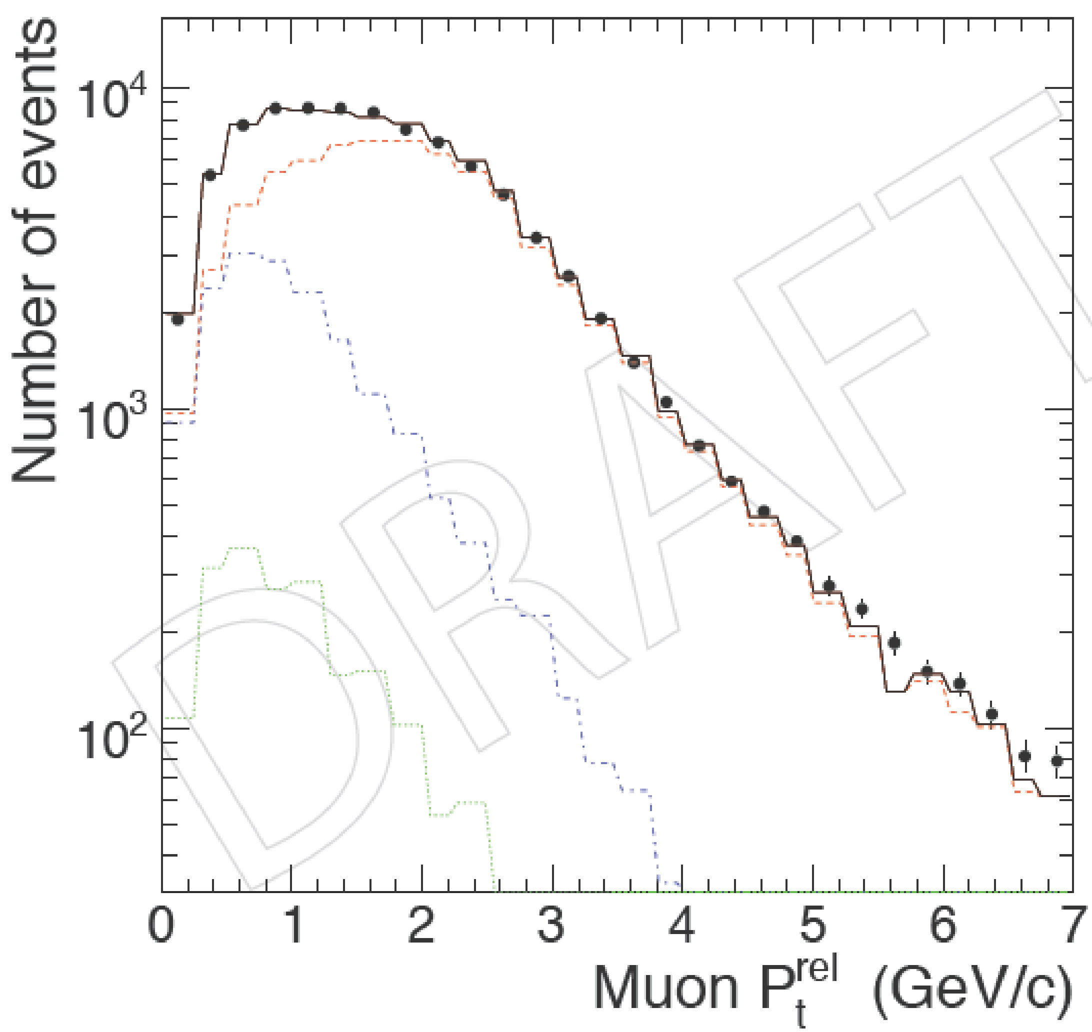

Figure 1: Fit of the muon p_T spectrum with respect to the closest b-tagged jet. The contributions of tagged muons from b events (dashed curve), c events (dot-dashed curve) and light quark events (dotted curve) as defined by the fit are shown. The solid curve is the sum of the three contributions.

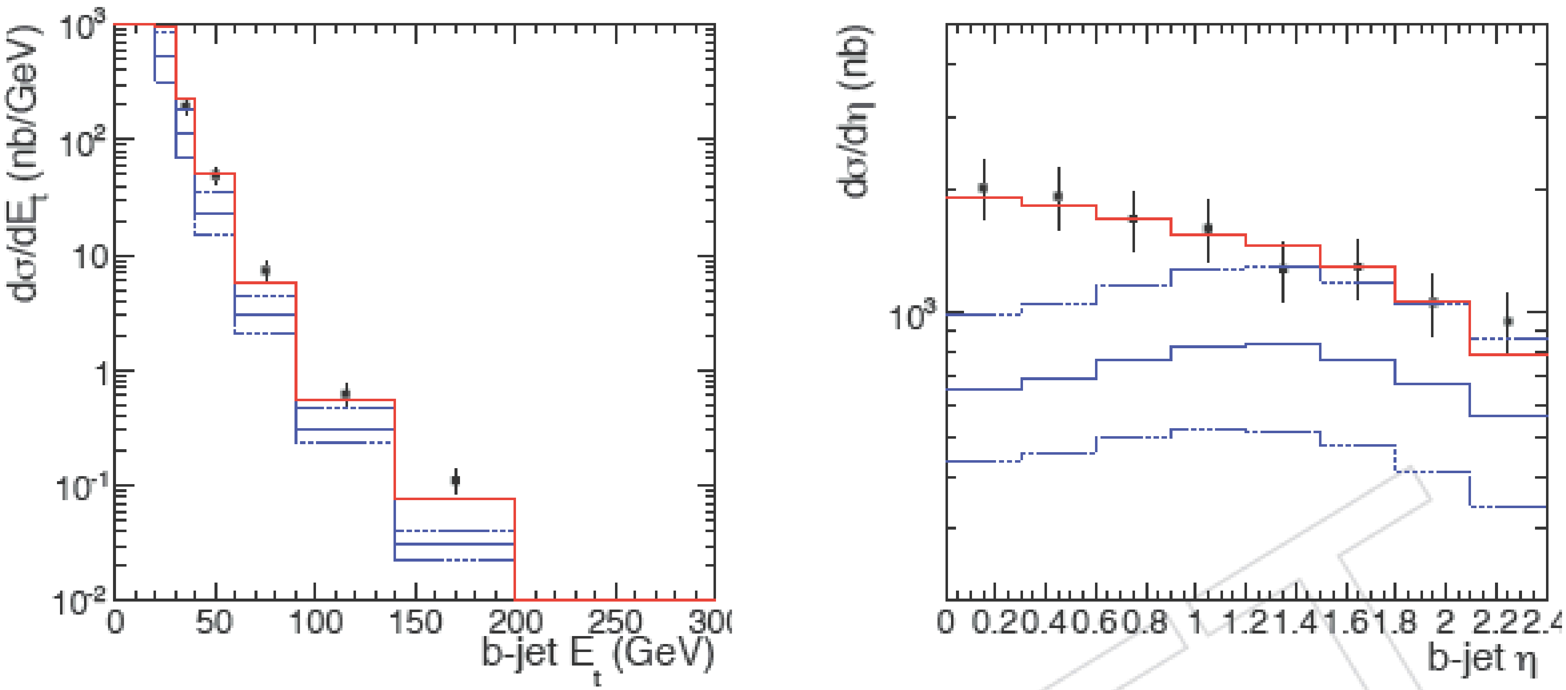

Figure 2: Differential cross section $\frac{d\sigma}{dE_T^b}$ for $|\eta^b| < 2.4$ (left) and $\frac{d\sigma}{d|\eta^b|}$ for $E_T^b > 30\,\mathrm{GeV}$ (right). The points with error bars are the CMS measurements. Measured cross section (points) is compared with Monte Carlo prediction of PYTHIA (red histogram) and MC@NLO (blue histogram). The dashed blue lines illustrate the MC@NLO uncertainty is due to variations in the QCD scale, the b-quark mass, and the parton distribution function.

Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy

The CMS Collaboration*

Abstract

A search for supersymmetry with R-parity conservation in proton-proton collisions at a centre-of-mass energy of 7 TeV is presented. The data correspond to an integrated luminosity of 35 pb^{-1} collected by the CMS experiment at the LHC. The search is performed in events with jets and significant missing transverse energy, characteristic of the decays of heavy, pair-produced squarks and gluinos. The primary background, from standard model multijet production, is reduced by several orders of magnitude to a negligible level by the application of a set of robust kinematic requirements. With this selection, the data are consistent with the standard model backgrounds, namely $t\bar{t}$, W + jet and Z + jet production, which are estimated from data control samples. Limits are set on the parameters of the constrained minimal supersymmetric extension of the standard model. These limits extend those set previously by experiments at the Tevatron and LEP colliders.

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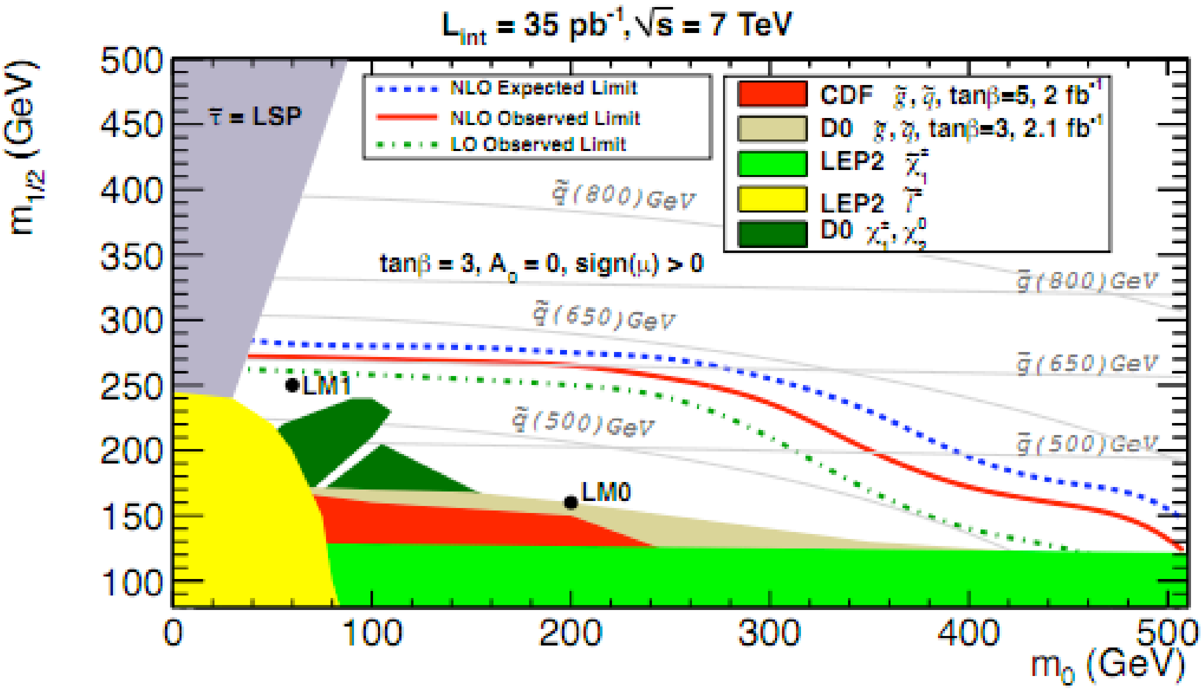
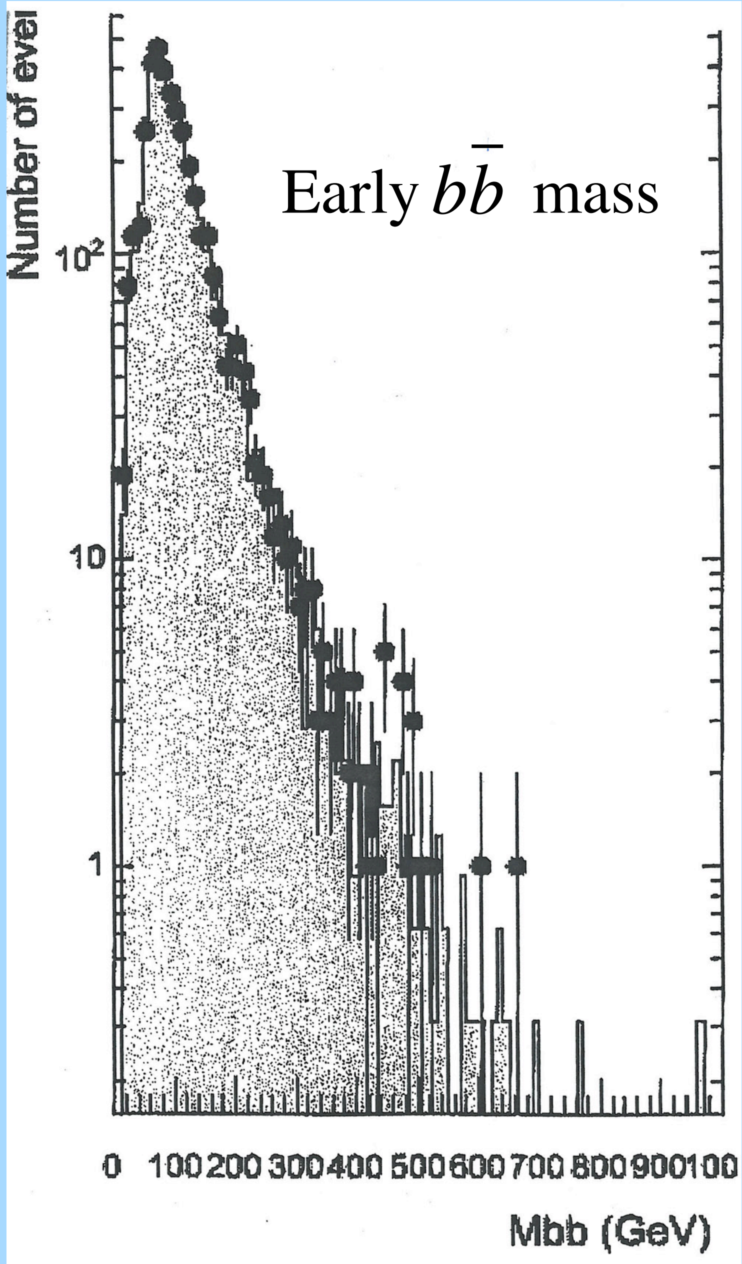
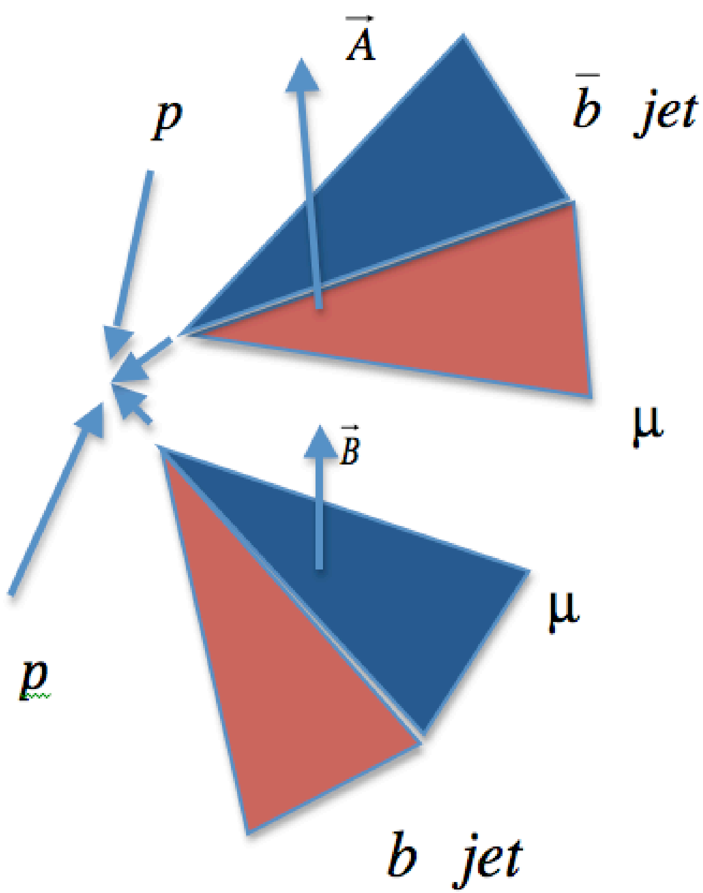


Figure 5: Measured (red line) and expected (dashed blue line) 95% CL exclusion contour at NLO in the CMSSM $(m_0, m_{1/2})$ plane for $\tan\beta = 3$, $A_0 = 0$ and sign$(\mu) > 0$. The measured LO exclusion contour is shown as well (dot-dashed green line). The area below the curves is excluded by this measurement. Exclusion limits obtained from previous experiments are presented as filled areas in the plot. Grey lines correspond to constant squark and gluino masses. The plot also shows the two benchmark points LM0 and LM1 for comparison.


Early $b\bar{b}$ mass
Number of eve
10^2
10
1
0 100 200 300 400 500 600 700 800 900 100
Mbb (GeV)

Search for CP/P V and A/H

If we can identify a term $\left\langle \overrightarrow{P_b} \times \overrightarrow{\sigma_b} \bullet \overrightarrow{\sigma_{\bar{b}}} \right\rangle$ this correlates function violates CP/P.



$$\left\langle \overrightarrow{P_b} \times \overrightarrow{A_{\bar{b}}} \bullet \overrightarrow{B_b} \right\rangle$$

could be related to

$$\left\langle \overrightarrow{P_b} \times \overrightarrow{\sigma_{\bar{b}}} \bullet \overrightarrow{\sigma_b} \right\rangle$$

A UCLA graduate student (Lu) is studying this now.

Summary

In the recent history of elementary particle physics the cooling of a beam to 6D (momentum and angle) has been very important for the discovery of the w/z bosons at CERN and the top quark at FNAL. With the advent of the muon collider concept, 6D cooling will become crucial again. To develop important discoveries such as the properties of the h^0 Higgs bosons (the origin of mass) and CP violation(the possible origin of large amounts of matter in the universe compared to antimatter) could be studied. The Higgs factory would produce the largest number in the world. The muon collider Higgs factories could be a major breakthrough. We have shown one form of 6D muon cooling that uses a 50 Tesla magnet (the largest field so far) being studied by the company Particle Beam Lasers Inc. and Brookhaven National Labs.