



Norman Graf  
(apologies to Trumbull)



# Snowmass@Seattle

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Energy Frontier Division

Chip Brock and Michael Peskin

July 3, 2013

# *You done good, Gordon!*

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Very successful and productive workshop

Thanks to **Michelle Brochman** and **Jordan Raisher!**



# You done good, Gordon!

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Very successful and productive workshop

Thanks to **Michelle Brochman** and **Jordan Raisher**!

*Jennifer Raines*

Dept Biz Manager – did all the high level coordination

*Stephen Higgins*

Front office lead – Make sure all the supplies were available, power cords, etc.

*Sandrine Girard*

Did all the folder stuffing, preparing and printing of badges, etc.

*Shane DeBolt*

The web site tech support

*And Patrick Cory*

who hasn't done much yet, but will pay the bills!

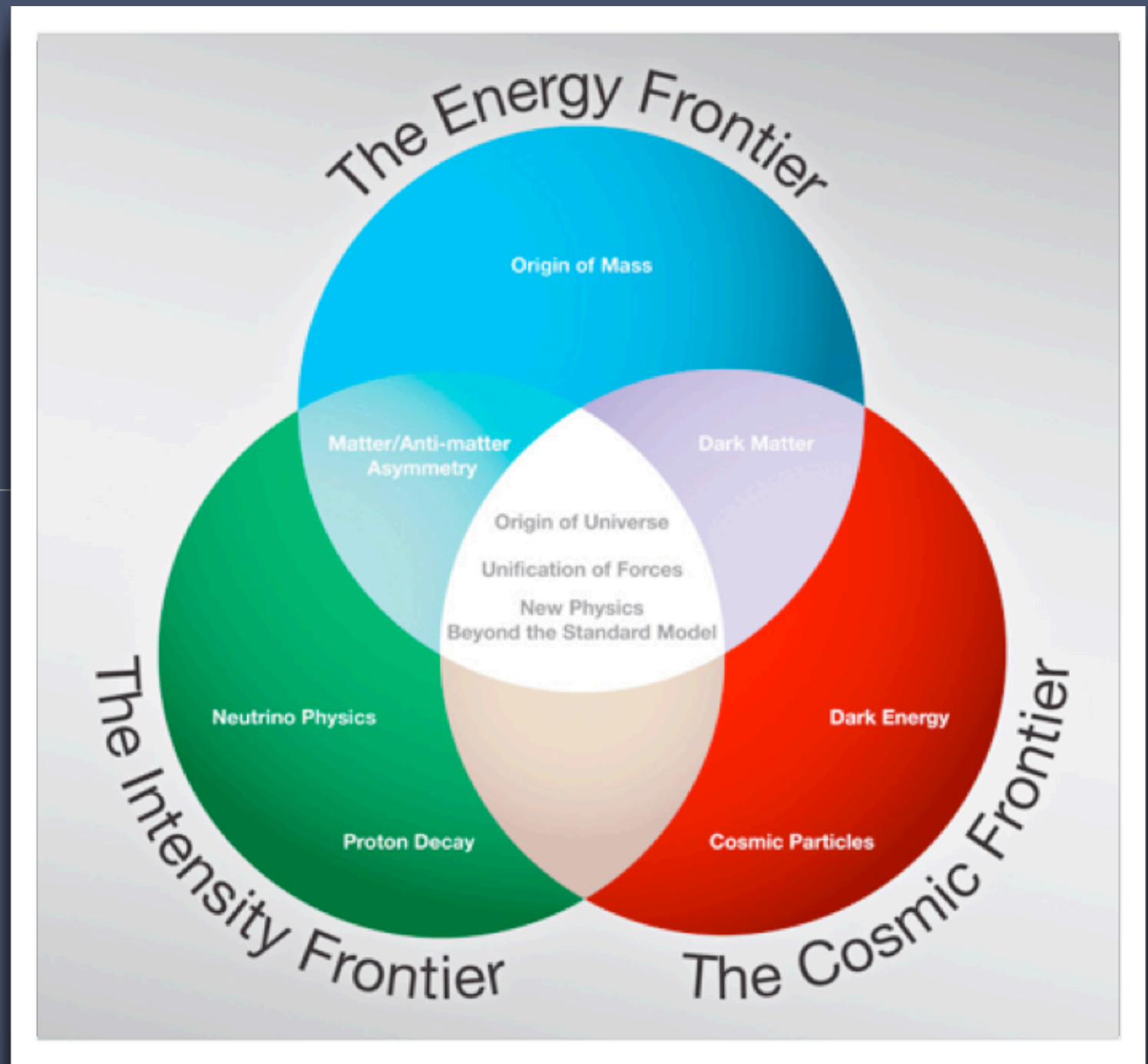
**and...the mic runners!**

Darren, Alex, Joon, MacKenzie, Jakub, Michelle, and Jordan.

**and...session conveners:** Jon, Shih-Chieh, Ann, Steve, Tiziano







# unusual way to do a “workshop,” eh?

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snowmass@Batavia (3)

snowmass@Princeton

snowmass@Irvine

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~~snowmass@Snowmass~~



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snowmass@Geneva!



**Aren't you glad we  
saved all this  
money?**

~~snowmass@Snowmass~~



our primary EF  
goal still is:

---

Put our best foot forward

*enthusiastically*

*carefully*



# EF Goals:

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## Concrete Goals: the science cases

### I. What scientific targets can be achieved before ~2018?

*at design specifications with  $\int \mathcal{L} dt \sim 100 \text{ fb}^{-1}$ ?*

### II. What are the scientific cases which motivate HL LHC running:

*“Phase 1”: circa 2022 with  $\int \mathcal{L} dt$  of approximately  $300 \text{ fb}^{-1}$*

*“Phase 2”: circa 2030 with  $\int \mathcal{L} dt$  of approximately  $3000 \text{ fb}^{-1}$*

How do the envisioned upgrade paths inform those goals?

Specifically, to what extent is precision Higgs Boson physics possible?

### III. Is there a scientific necessity for a “Higgs Factory”?

### IV. Is there a scientific case today for experiments at higher energies beyond 2030?

A high energy LHC?

High energy lepton collider?

Lepton-hadron collider?

VLHC?



# EF Goals:

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Community Goals: the context for this science

## I. Articulate to scientific audiences

*To other Particle Physicists:*

EF science in the context of the Intensity and Cosmic Frontiers' goals

*To other scientists*

## II. Justify to governmental audiences

*OHEP, EPP, OSTP, Congress...beyond our direct agencies*

*Not only science, but the internationalization of science*

## III. Explain to non-specialist audiences

*Universities*

*Public*

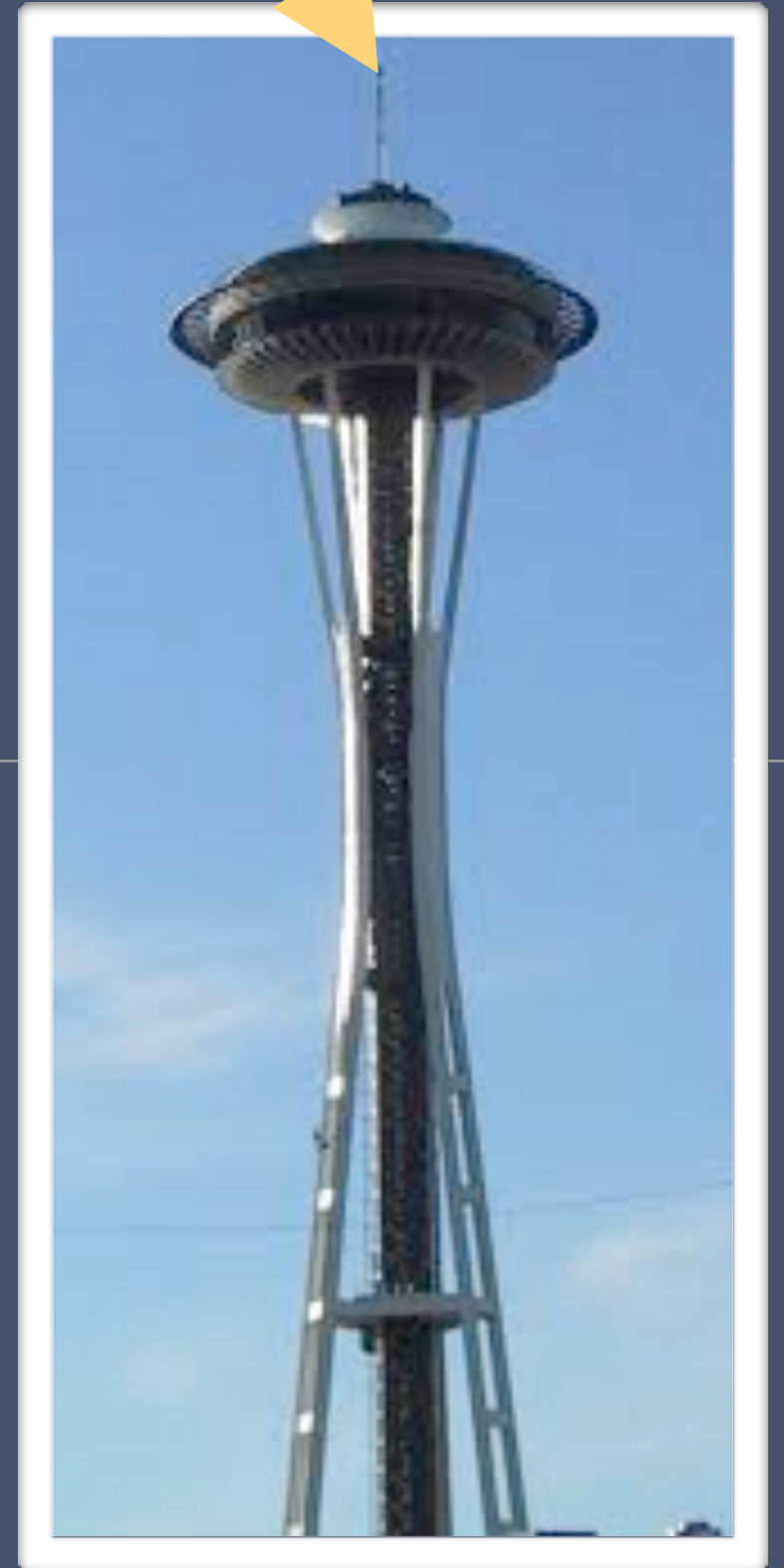
Lectures

Written documentation

Attractive on-line presence

# High Points of Seattle

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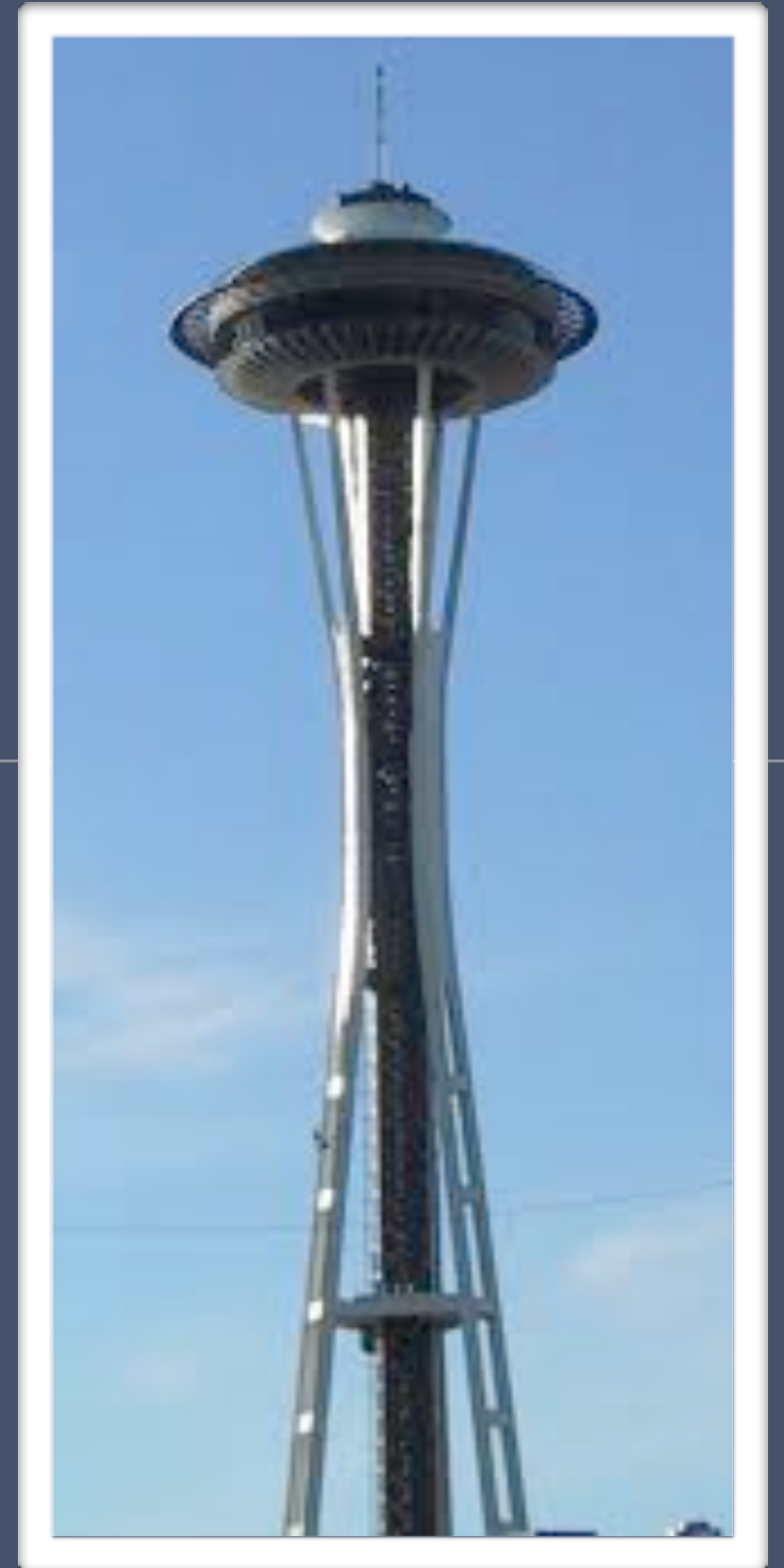




# High Points of Seattle

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1. many projects completing!
2. many white papers in process!
3. unique Snowmass ecumenical  
“spirit” continues!  
is there a lesson here?
4. Evident throughout...



# a typical 3 week Snowmass

## working time

(hiking time, eating time, day-trip time, wine time, shopping time...Aspen Time)



S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

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---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

January							February							March							April							May							June							July						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S

Irritating, sure.

But IMO there's more depth in  
Snowmass2013 than in previous times.



*we accomplish  
the goals by  
evaluating the  
physics*



we accomplish  
the goals by  
on-going – good progress  
evaluating the  
this week!  
physics



*we accomplish the  
goals by telling  
stories*



we accomplish the  
goals by telling  
on-going — still forming  
stories





# *one major concern*

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We have to answer Ulrich's  
questions about  
instrumentation



# time marches on

April 2013						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

May 2013						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

BNL all hands



QCD/Loopfest, FSU



Theory, KITP



Frontier Capabilities, MIT



ttH, Austin



# and on

Snowmass, UMinn

DPF, UC SC

white papers:  
final

## July 2013

S	M	T	W	T	F	S
30	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3

EPS

EPS

UW all hands

next stage of  
bulleted list of  
conclusions &  
what will be  
done in July

first draft WG 30  
page writeup

first draft EF  
summary

## August 2013

S	M	T	W	T	F	S
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

## September 2013

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

final SM2013  
report

Posting of  
WG reports  
on wiki

final WG  
reports

# How should we use July?

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**Prepare for Minneapolis – still Sleepless *After* Seattle**

**Be sure the high-priority items are complete**

*okay continue to calculate, spin, fill-in tables, etc*

**Write internal draft of final EF reports by July 15**

*...but stay nimble and update it through August*

*We'll post drafts by the beginning of Minneapolis*

**Big Questions?**

*Sore spot. Some of us have tried.*

*<http://dpfnewsletter.org/?p=915> (half dozen attempts)*

*<http://goo.gl/8j3hZ> (all on one map...zoom into pdf)*



# <http://dpfnewsletter.org/>?

and collected...<http://goo.gl/8j3hZ> (all on one map...zoom into pdf)

The image displays a grid of 14 topic cards, each representing a different area of physics research. Each card has a title and a list of questions. The cards are:

- Higgs**
  - 6. What sets the Higgs mass?
  - 3) Is there a hierarchy problem?
  - 1. Is the 2012 Higgs Boson an excitation of the Higgs Field responsible for fermion mass?  
what are the couplings of Higgs Bosons to fermions?  
what is the coupling of Higgs to itself?  
Is the Higgs a composite particle?  
are there additional Higgs Bosons?  
what protects the mass of the Higgs Boson?  
Is the longitudinal polarization of the W and Z due to a primordial partner of the Higgs Boson?
- Dark Matter**
  - 7. What is dark matter?
  - 7. What is dark matter?
  - 6. Is there a quantum of Dark Matter?
  - 5) What is dark matter?
  - 4) What is the nature of dark matter?  
What can we learn if dark matter interacts purely gravitationally?  
Is dark matter represented by a single WIMP?  
If not, what is the pattern of organization of dark particles?  
If there is a complex dark world, can it help us understand (1)?
  - 5. What is the nature of the particles in the dark sector and how do they connect to the visible spectrum of the standard model?
- Quark nature: generations, mixing, masses**
  - 3. How many generations are there and why?
  - 7. What sets the quark masses?
  - 1) Why are there three generations?
  - 4. How many fundamental particles are there?  
are there more than 3 generations of leptons and quarks?  
Is the doublet structure of fermions the final story?  
what is the weak mixing among them?  
are quarks composite?
  - (1) Can we explain the patterns of quark and lepton masses and mixings?  
Why are the quark and lepton patterns different?  
Does the lepton pattern point to a new mass scale?  
Are neutrinos their own antiparticles?  
Will we need to know about dark matter before we can answer?  
Are there sterile neutrinos?
  - (7) What flavor symmetries are preserved up to what mass scale?  
What do we learn at each level of studying rare processes?  
What are the theoretical limitations accompanying each process?  
Do flavor-diagonal rare processes (dim-6, 2, ...) enjoy any advantage?  
Are there processes to which we have forgotten to pay attention?
- Neutrinos and leptons**
  - 5. Is the neutrino mass set by the SM Higgs? If not, what determines the neutrino masses and mass differences? Is there underlying physics that explains both the neutrino mixing matrix and the CKM matrix?
  - 2. What is the nature of Neutrinos?  
what are neutrino masses  
what are neutrino flavor and symmetry properties  
are neutrinos their own antiparticles?
  - 10) Why do quarks and leptons have the masses they have?  
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  - 8. What sets the lepton masses?
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copy  
Why are the quark and lepton patterns different?  
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Are there sterile neutrinos?
  - 7. Are neutrinos Majorana particles and thus fundamentally different from charged leptons and quarks?
- Matter-Antimatter**
  - 5. Why does the Universe contain more matter than antimatter?
  - 7. What is responsible for the apparent asymmetry between matter and antimatter?
  - 4) Why do we live in a matter dominated Universe?
  - (3) What is the source of the Universe's matter-antimatter asymmetry?  
Are there plausible electroweak-scale mechanisms?  
What are the constraints associated with a leptogenesis mechanism?  
Relation between leptogenesis and CP-violating neutrino oscillations.
- Proton stability**
  - 6. Is the proton unstable, and does it matter if it is?
  - 9. Are protons stable?
  - 8. Is the proton stable?
- Technology**
  - 2. How far can we go toward building massless trackers, high resolution calorimeters without dead regions, and detectors with much higher rate tolerance?
  - 1. Can new very high gradient methods for accelerating high energy particle beams be realized? Can they be used for compact, lower-energy accelerator applications?
  - (10) How do we provide answers to these questions?  
What accelerators and underground installations are required?  
What advances in instrumentation and detectors are required?  
What are the present and future needs in computing?  
How do we communicate the importance of these questions?
- Symmetries and Forces**
  - 1. Why is there T-violation? What are the phases in CKM/PMNS and why do they have the values nearly maximal for CKM? they do? Are there other sources of T-violation?  
1. Why is there T-violation? What are the phases in CKM/PMNS?
  - 3. What causes some symmetries to break?
  - (2) Are there new symmetries and forces beyond SU(3) x SU(2) x U(1)?  
Is the standard model embedded in a grand unified theory?  
If so, can we learn about the stages in which it is broken?  
Are there hints at present of accessible extra gauge symmetries?  
Is supersymmetry just around the corner?  
At what scale is left-right symmetry broken?  
Does the proton decay? Do neutrons oscillate into antineutrons?
  - 3. How many fundamental forces are there in Nature?  
Is SU(3) x SU(2) x U(1) a subgroup of higher order groups in Nature?  
what is responsible for higher order symmetry breaking?  
are there additional spin 1 fields?  
Is Supersymmetry correct?  
do the forces of nature unify at high scale? What is that scale?
  - 9) What is the source of symmetry breaking in the electro-weak sector?
  - 10. Why is  $\alpha_s \sim 1$ ,  $\alpha_{EM} \sim 0.1$ , and  $G_F \sim 10^{-5}$ ?
  - 4. Why is the CKM matrix perturbative and the PMNS matrix elements large? Why aren't they exactly diagonal or all equal?
  - 8. Does grand unification occur, and what new physics enables it? Is there any deep reason to have such unification?
  - 4. What CP-violating mechanisms are causing the baryon asymmetry in the universe?
  - 9) Theorists love supersymmetry.
  - 2) Is there physics beyond the Standard Model?
- Dark Energy**
  - 9. Does dark energy signal the breakdown of general relativity, or is there a new field at work in the universe?
  - 8. Why is the universe accelerating?
  - (8) What is responsible for the apparent acceleration of the Universe?  
Is there a time-independent cosmological constant?  
If not, can one measure more than its first time derivative?  
Is there a theory for the cosmological constant or its equivalent?
  - 6) What is dark energy?
- Spacetime and Gravity**
  - 10. Do our familiar notions of space-time need revision with extra dimensions or new symmetries between fermions and bosons?
  - 2. How many space dimensions are there?
  - 5. Is there a shortest distance in Nature?  
are there more than 3 dimensions of space?  
Is it possible to definitively test string theory?
  - 4. Are there extra dimensions?
  - 9. Is space-time locality fundamental?
  - (3) What can we learn from string theory?  
What is the scale of the extra dimensions in string theories?  
What insights does it provide to solving strong-coupling problems?  
Are there any experimental tests of quantum gravity?  
Does it illuminate gauge symmetries beyond SU(3) x SU(2) x U(1)?  
Is one of its predictions low-energy supersymmetry?
  - 9. What is the quantum of Gravity?
  - 7) Can gravity be quantized?
- Society**
  - 11. Is it possible to motivate large societal investment in questions of such little practical import as those above?
  - 3. Our present measurements indicate the need for some high mass scale (the strong CP problem, neutrino masses, suppression of FCNCs, metastability of the Higgs potential at large scales, etc.). Can we provide the information that illuminates the character and location of this new scale?

<http://dpfnews>

<http://goo.gl/8j3hZ> (all on c

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## Early Universe & Astrophysics

6. What mechanism engenders inflation?

2. Do all particle constituents of the Universe have a common origin?

1. Was the Universe one entity at the Big Bang?

(8) What can we learn from astrophysical sources?

What do we learn from gamma rays of 100 GeV and above?

What is the source of ultra-high-energy cosmic rays?

Can we detect (and learn things from) neutrinos above a PeV?

What will we learn from the next supernova explosion in our Galaxy?

What can we learn about non-gravitational dark matter interactions?

# How should we look at Minneapolis

---

many of those pink mornings

I, Monday, July 29

## 2, Tuesday, July 30

3, Wednesday, July 31

#### 4, Thursday, August 1

## 5, Friday, August 2

0900	welcomes	<div>highlights of EF working group reports</div>	working groups (incl. joint instrumentation w/ CF)	<div>working groups joint; EF- Instrumentation w/ EF)</div>	working groups (incl. joint instrumentation w/ IF)		
	EF: I5+5						
	Comp F						
1000	IF						
	Inst F						
	break						
1100	CF	<div>capabilities report</div>	<div>LHC white papers</div>				
	Communication						
	Capabilities						
1200							
	lunch	lunch	lunch			lunch	lunch
	Young Snowmass						
1400	DOE	<div>Colloquium: Higgs Boson, Higgs Sector, and naturalness</div>	talk	<div>Colloquium: Cosmic survey: Dark energy, inflation, neutrinos, etc</div>	talk		
	NSF						
	Fermilab Director						
1500	break						
		question	question	<div>Colloquium: Finding New Physics Through Loops &amp; Radiative Corrections; Top Quark Prop</div>	question		
1600		disc	disc	disc	disc		
		break	break	break	break		
1700	Colloquia: Dark Matter		Panel:		Panel:		
		Panel: Must there be new physics? Where will we find it?	What can we learn about short distance physics without discovering new particles?	Panel: Selling long-term science.	Communication, Education, and Outreach: Making common cause with scientists in other fields		
1800							
				EF PI's with DOE	CF PI's with DOE		
1900		Reception	Mid-Course Conveners				
2000					Physics Slam		



	6, Saturday, August 3	7, Sunday, August 4	8, Monday, August 5	9, Tuesday, August 6
0900	working groups (incl. instrumentation internal)		Introduction	Plenary: EF
			Plenary: IF	
1000				
			Plenary: Comp	Plenary: EF
1100		Colloquium: Intensities beyond the planned era: physics goals and technologies	Theory Panel	break
				View from Europe
1200			Plenary: CF	View from Japan
				Physics Horizons
1300	lunch	lunch	lunch	Conclusions
				lunch
1400				
	Colloquium: Lepton and Quark Flavor and CP	Colloquium: Transformative technologies for instrumentation and data	Plenary: Ed Out	
1500	Colloquium: Weakly coupled particles		Plenary: Inst	
			break	
1600	break	break	Plenary: HEP & NP	
1700	Grand Panel: What should be the balance in the US program between domestic and overseas facilities ?	Parallel (plenary within each Frontier): What Have We Learned?	Plennary: HEP & Astro	
1800				
1900			Inst meet with DOE	
			Theory meet with DOE	
2000		Banquet		

So, we come to the end of:

**NEXT TO THE**

**THE LAST FRONTIER**

A Rousing Tale of Adventure, Lust and Madness.



**SNOWMASS**

Michael and I are gratified  
by our community's

---

hard work and commitment to our science.

**Our conveners are doing a huge amount.**

*Thanks to:*

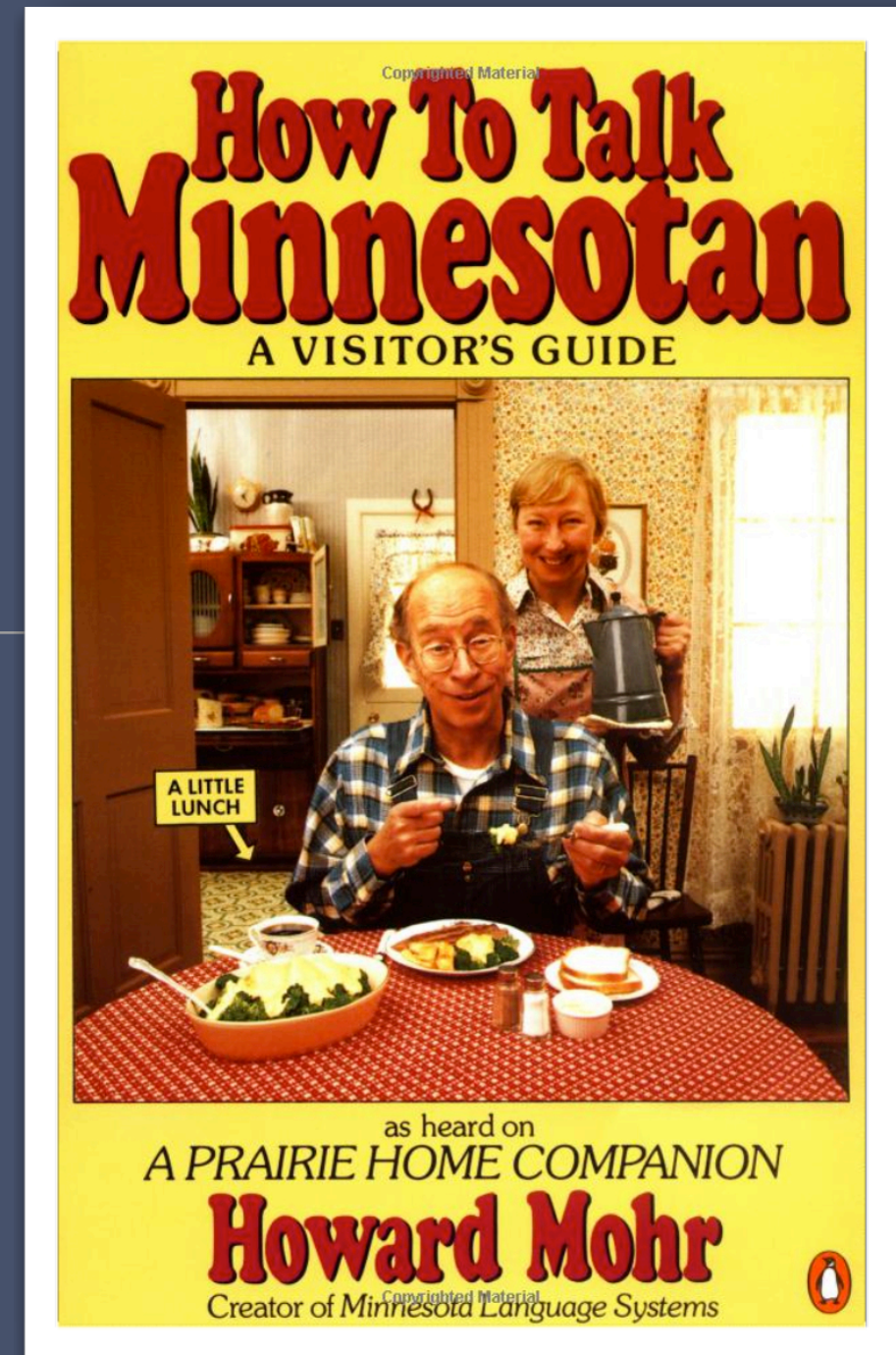
Jianming, Andrei, Heather, Rick, Sally, Doreen, Ashutosh, Robin, Reinhard, Kirill, Cecilia, Kaustubh, Daniel, Liantao Wang, Yuri, Ken, John, Frank, Soeren, Michele, Marina, Joey, Meenakshi, and Eric, Mark, Markus, and Mark and Sanjay and Sergei and Fermilab LPC



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*See you in Minneapolis!*



"It's sure bin a long, hard workshop, eh?"

"Ya, fer sure."