



Possible neutrino factory and detector locations

Peter Gruber/PS

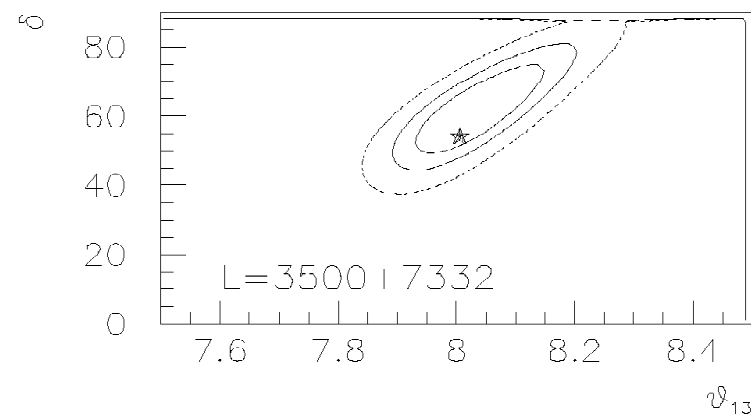
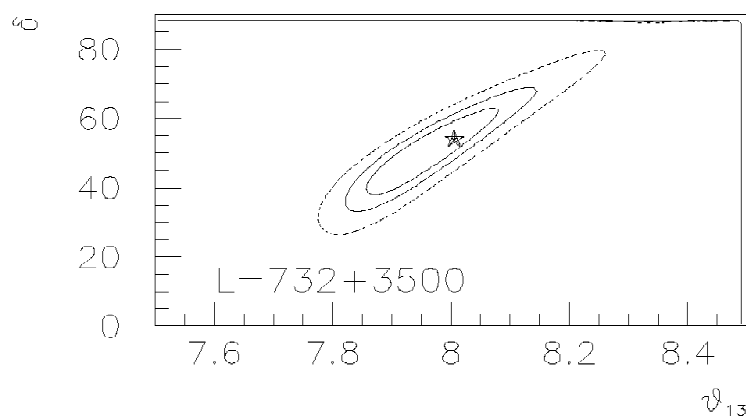


Physics requirements

◆ Three possible baselines

- ≈ 730 km
- ≈ 3500 km
- ≈ 7300 km

◆ Superposition of two distances





Decay ring design

◆ Maximize efficiency

- Efficiency: $\eta = \frac{\text{both_straight_sections}}{\text{circumference}}$

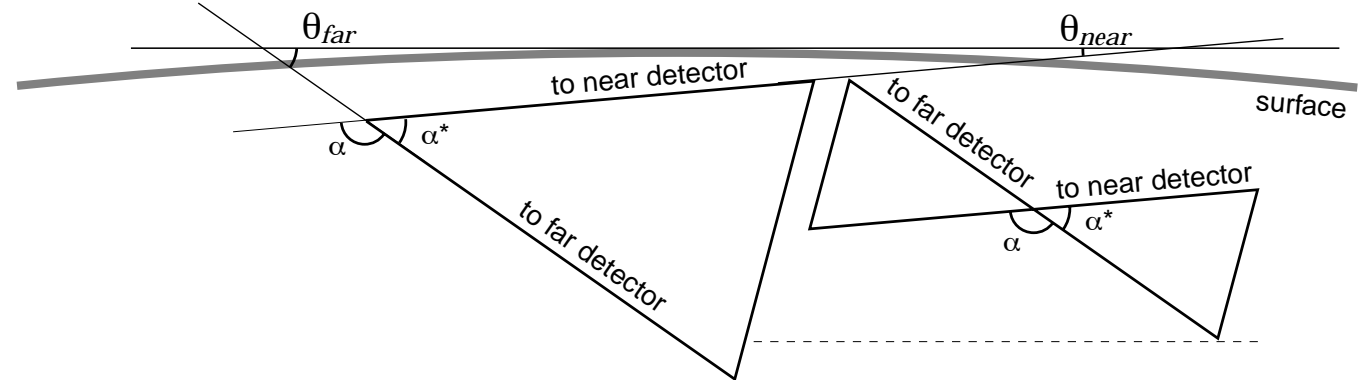
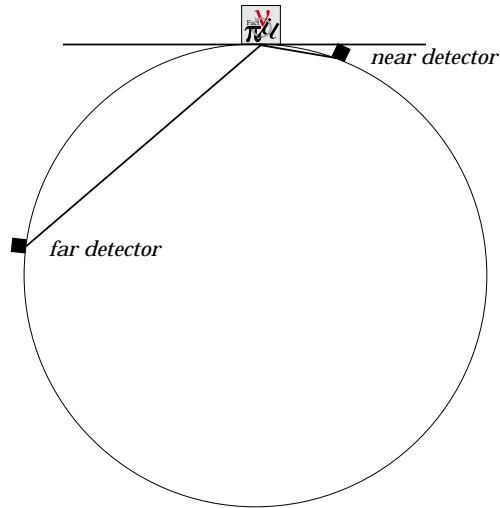
- η depends on geography, geometry, length of straight sections, bends

- Optimal case: $\eta = 90\%$ (725/3000km)

- Bad case: $\eta = 50\%$

◆ Factor 2 for overall performance!

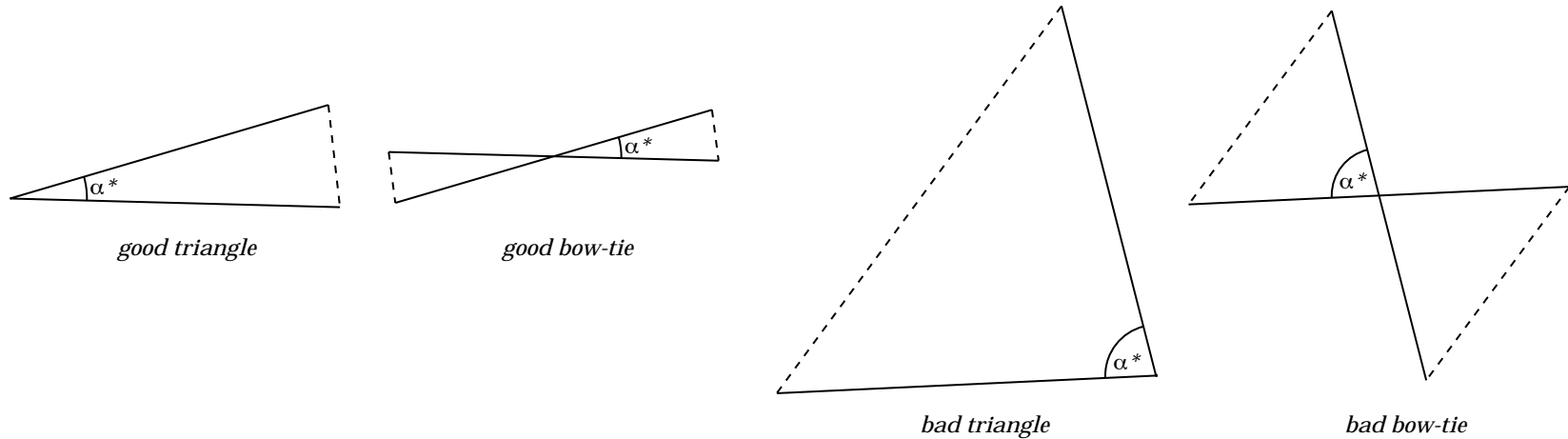
Decay ring



- ▶ Geography determines 3D-geometry
- ▶ $\alpha^* \propto \text{tilting}(\theta)$ **plus** different directions



Good and bad situations



Efficiency: $\eta = \frac{\text{length of both straight sections}}{\text{circumference}}$

No bending arcs

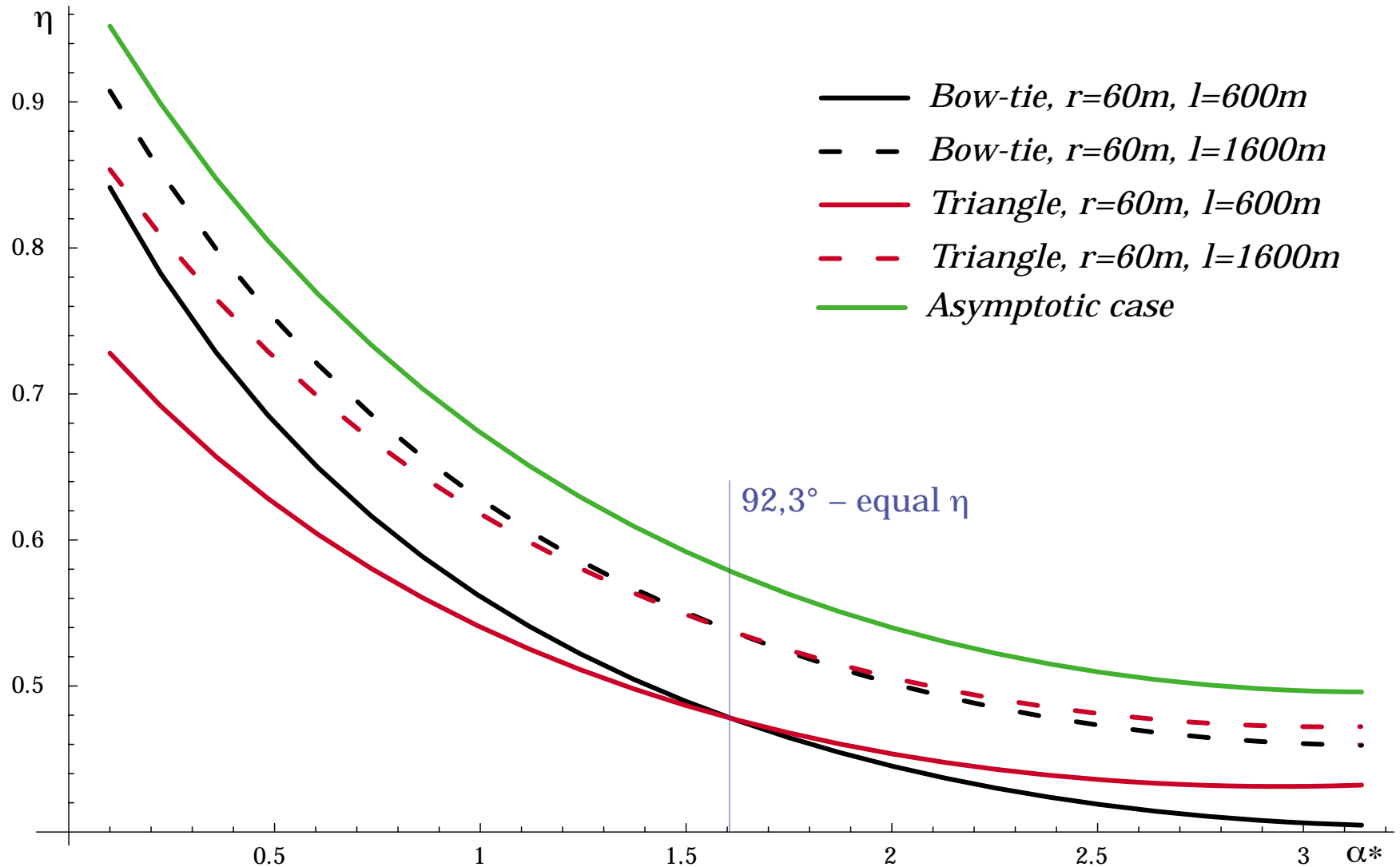
asymptotic efficiency:

$$\eta_{\text{as}} = \frac{2}{2 + \sqrt{2(1 - \cos \alpha^*)}}$$

$0.5 < \eta_{\text{as}} < 1$ for **both** detectors



Real decay rings





Finding scenarios

- ◆ Neutrino factories only at established Labs
 - BNL, CERN, Cornell, FNAL, KEK, RAL
- ◆ Try pairs of existing locations
- ◆ Find „opposite“ location for existing location
- ◆ Underground only: mines/tunnels



Rating scenarios

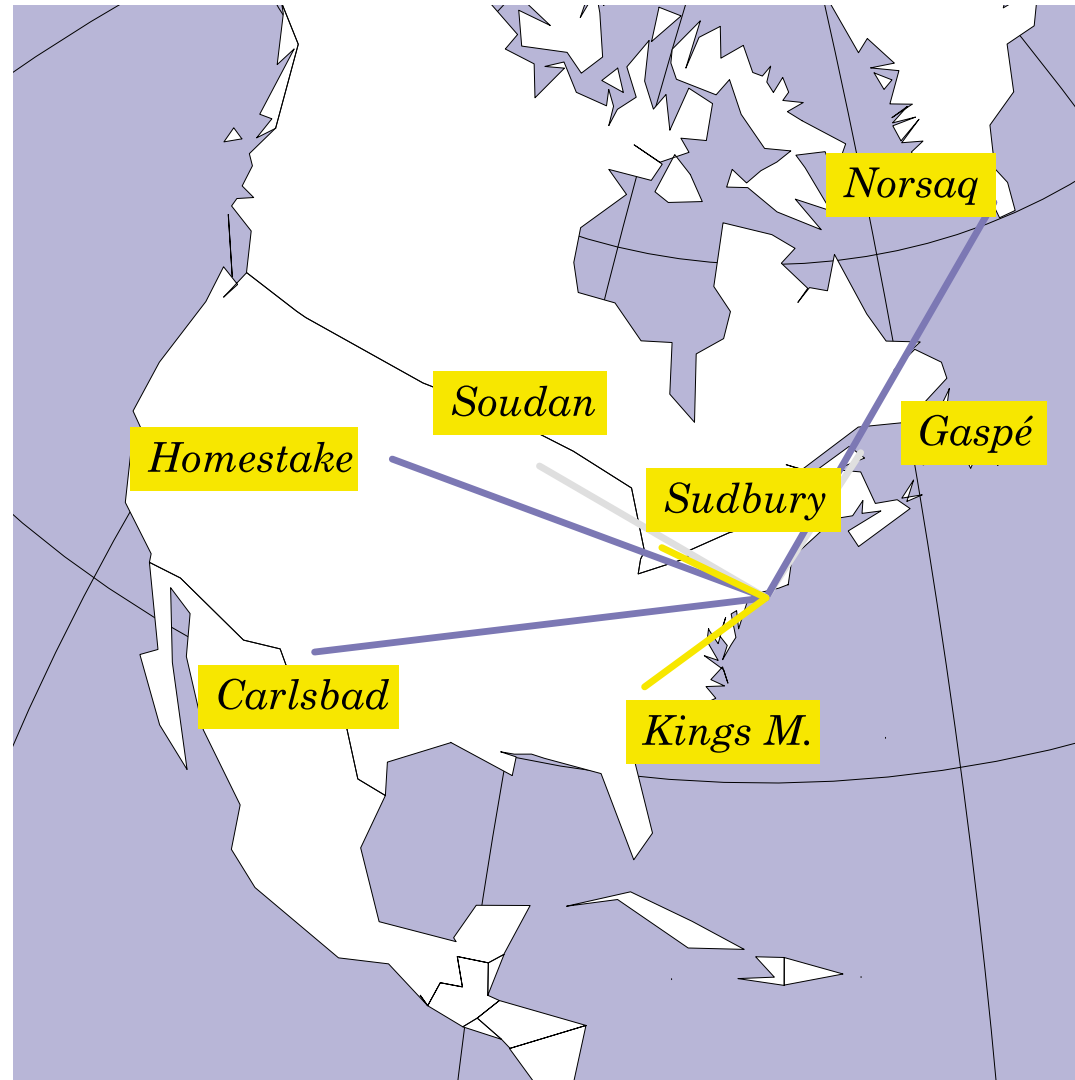
- ◆ Mathematica package calculates
 - Baseline length
best: 730km; 3500km; 7300km
 - Angle between two baselines
best: 180° (detectors + lab on one line)
 - Asymptotic efficiency
best: maximum
 - World map with lab in center, baselines
 - Only geometric factors are considered
- ◆ Package available
 - contact peter.gruber@cern.ch

■ Arlit:	7328.1
■ Baskan:	8017.1
■ Boulby:	5157.1
■ Carlsbad:	2768.3
■ Essen:	5724.4
■ Gaspé:	1109.9
■ GranSasso:	6506.3
■ Homestake:	2537.9
■ Kamioka:	9664.4
■ KingsMountain:	963.2
■ Lucenac:	5514.2
■ Norsaq:	2900.9
■ Soudan:	1669.9
■ Sudbury:	752.1





BNL, detailed





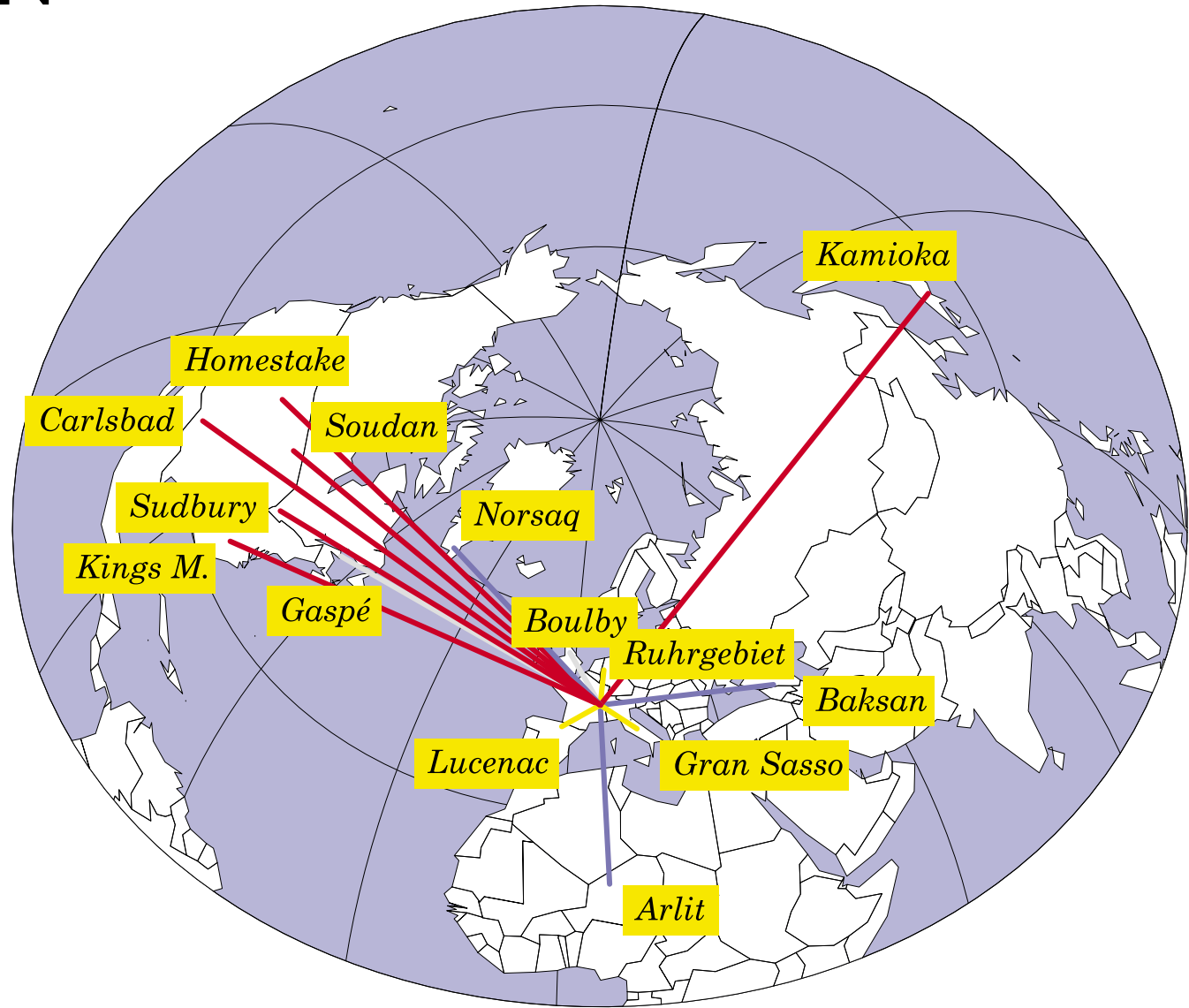
BNL, results

BNL						
KingsMountain	Norsaq	151.5	80.2%	169.0	963	2901
Arlit	Carlsbad	131.8	71.0%	179.6	7328	2768
Carlsbad	GranSasso	127.4	69.3%	170.7	2768	6506
Arlit	Homestake	126.2	68.9%	172.9	7328	2538
GranSasso	Homestake	114.3	64.8%	156.6	6506	2538
Baskan	Homestake	99.7	60.8%	150.3	8017	2538
Norsaq	Sudbury	93.2	59.3%	109.8	2901	752
Kamioka	Norsaq	57.5	53.3%	120.1	9664	2901



CERN

■ Arlit:	2968.5
■ Baskan:	2891.7
■ Boulby:	1002.2
■ Carlsbad:	7925.8
■ Essen:	582.4
■ Gaspé:	4962.7
■ GranSasso:	725.3
■ Homestake:	7328.1
■ Kamioka:	8760.1
■ KingsMountain:	6714.7
■ Lucenac:	731.8
■ Norsaq:	3570.3
■ Soudan:	6616.9
■ Sudbury:	6222.6





CERN, detail





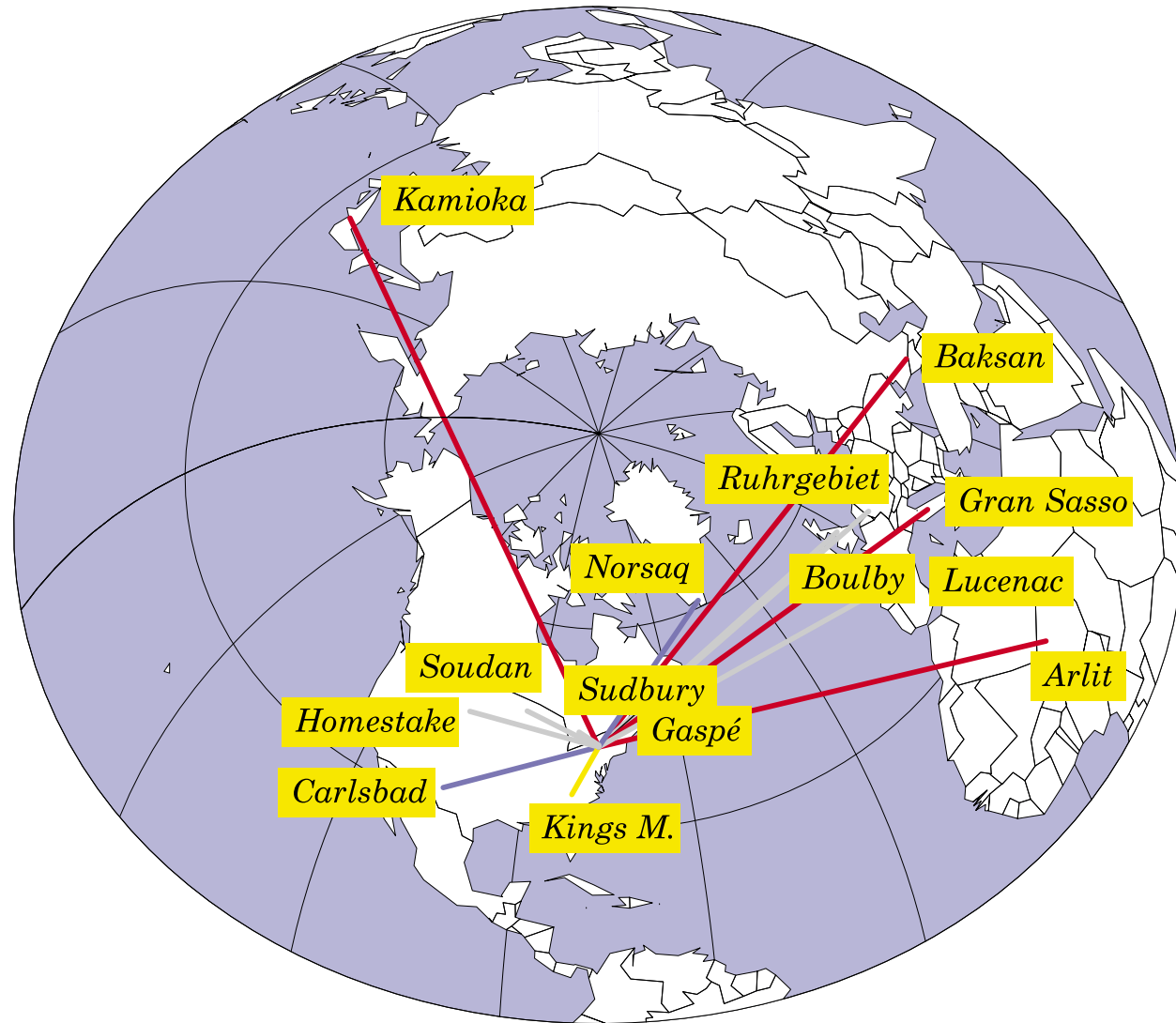
CERN, results

CERN						
Arlit	Essen	161.6	86.2%	177.7	2969	582
GranSasso	Norsaq	156.8	83.2%	176.4	725	3570
Baskan	Lucenac	152.4	80.7%	168.8	2892	732
Baskan	KingsMountain	125.8	68.7%	170.9	2892	6715
Baskan	Sudbury	123.4	67.8%	165.9	2892	6223
Arlit	Homestake	116.8	65.6%	165.5	2969	7328
Arlit	Soudan	116.5	65.5%	161.4	2969	6617
Baskan	Carlsbad	113.2	64.5%	164.9	2892	7926
Arlit	Sudbury	111.7	64.1%	154.6	2969	6223



Cornell

■ Arlit:	7546
■ Baskan:	8065
■ Boulby:	5257
■ Carlsbad:	2487
■ Essen:	5825
■ Gaspé:	1169
■ GranSasso:	6637
■ Homestake:	2198
■ Kamioka:	9468
■ KingsMountain:	899
■ Lucenac:	5681
■ Norsaq:	2910
■ Soudan:	1316
■ Sudbury:	399





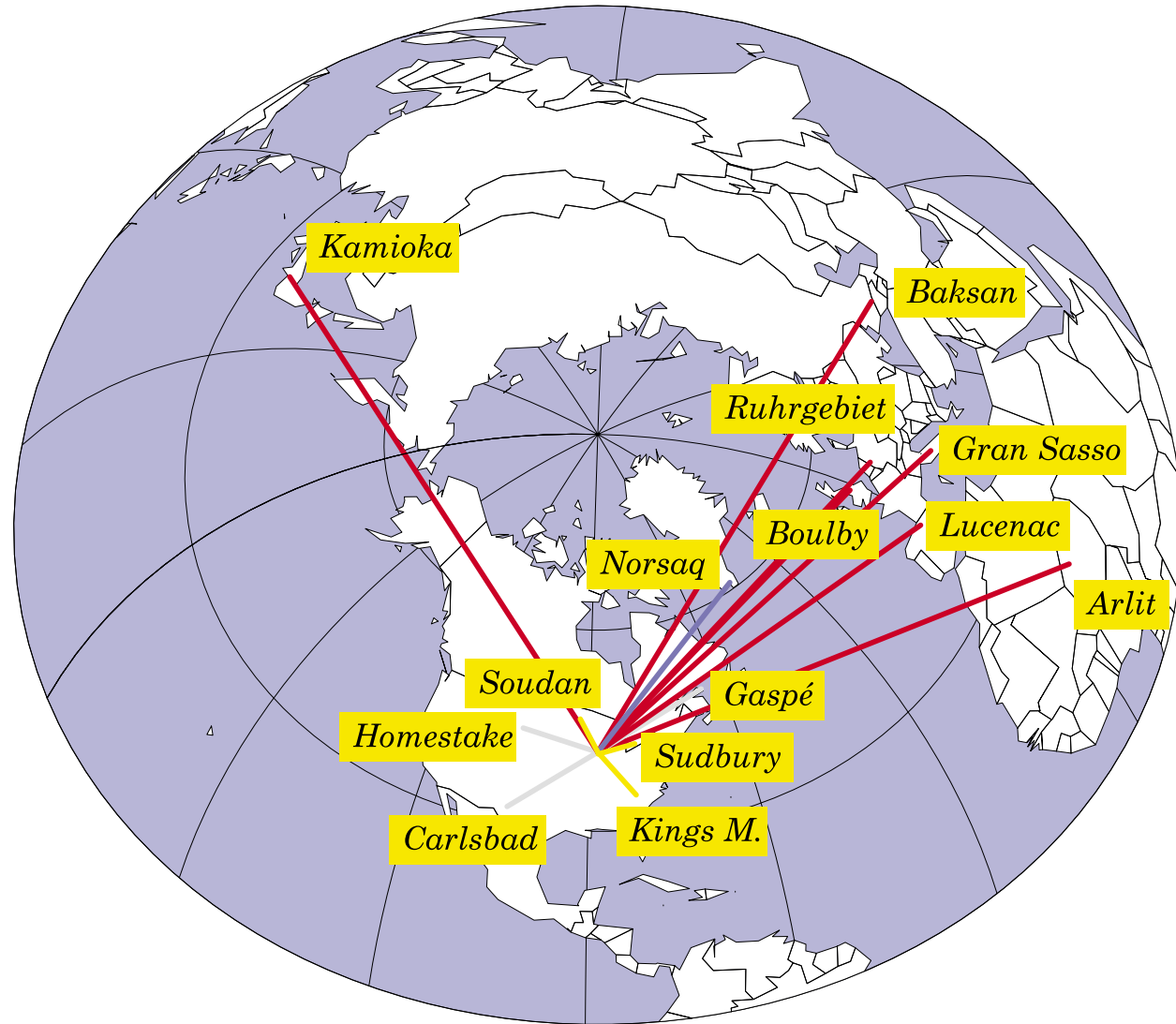
Cornell, results

Cornell						
KingsMountain	Norsaq	161.9	86.4%	179.2	899	2910
Arlit	Carlsbad	132.3	71.2%	180.0	7547	2488
Carlsbad	GranSasso	130.9	70.7%	173.7	2488	6637
GranSasso	Homestake	117.5	65.9%	159.0	6637	2198
Baskan	Carlsbad	116.7	65.6%	167.3	8065	2488
Baskan	Homestake	102.5	61.5%	151.9	8065	2198
Carlsbad	Kamioka	69.6	54.9%	129.0	2488	9468



Fermilab

■ Arlit:	8293
■ Baksan:	8544
■ Boulby:	5937
■ Carlsbad:	1547
■ Essen:	6487
■ Gaspé:	1993
■ GranSasso:	7313
■ Homestake:	1289
■ Kamioka:	9164
■ KingsMountain:	947
■ Lucenac:	6446
■ Norsaq:	3523
■ Soudan:	618
■ Sudbury:	606





Fermilab, results

FNAL						
KingsMountain	Norsaq	98.1	60.4%	118.4	947	3524
Kamioka	Norsaq	67.5	54.6%	129.7	9164	3524



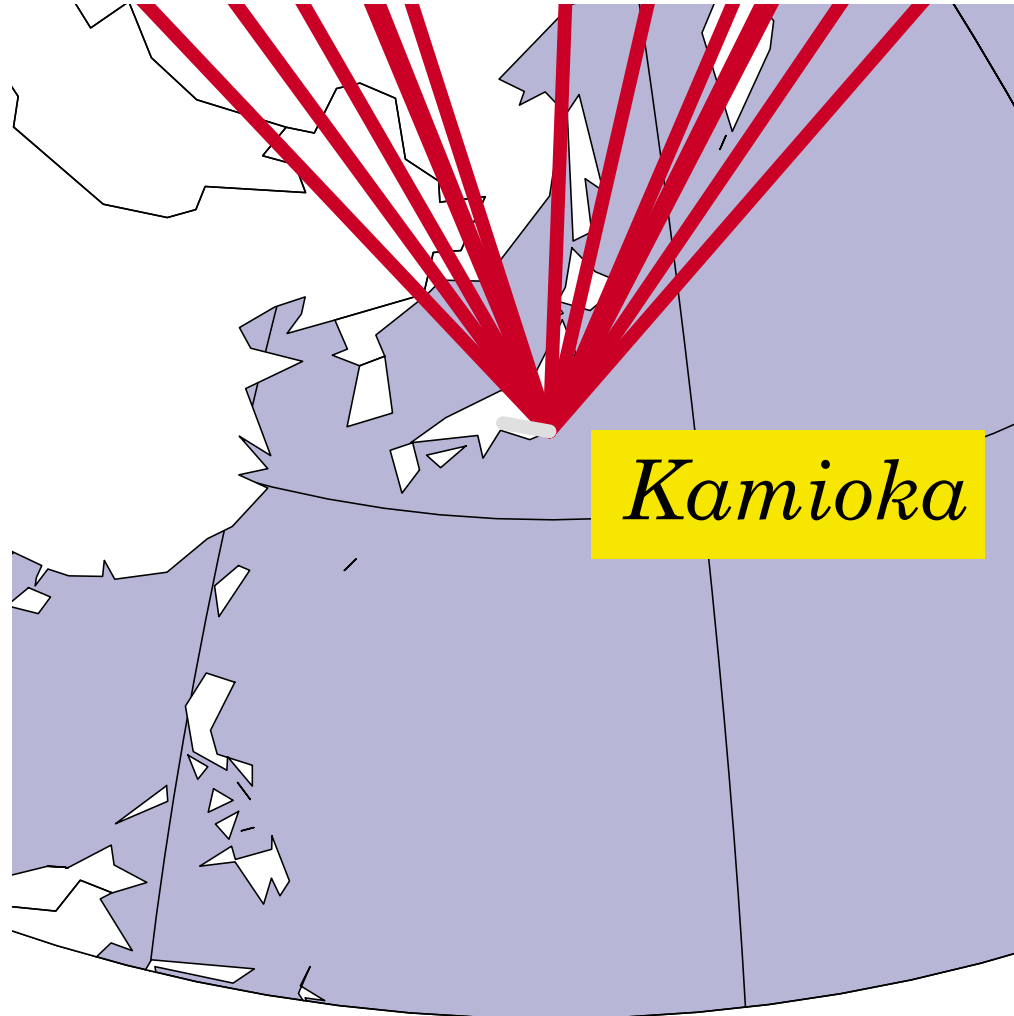
KEK

■ Arlit:	10384
■ Baksan:	7412
■ Boulby:	8601
■ Carlsbad:	8785
■ Essen:	8527
■ Gaspé:	9238
■ GranSasso:	8867
■ Homestake:	8309
■ Kamioka:	291
■ KingsMountain:	9718
■ Lucenac:	9357
■ Norsaq:	8492
■ Soudan:	8645
■ Sudbury:	9210





KEK, detail

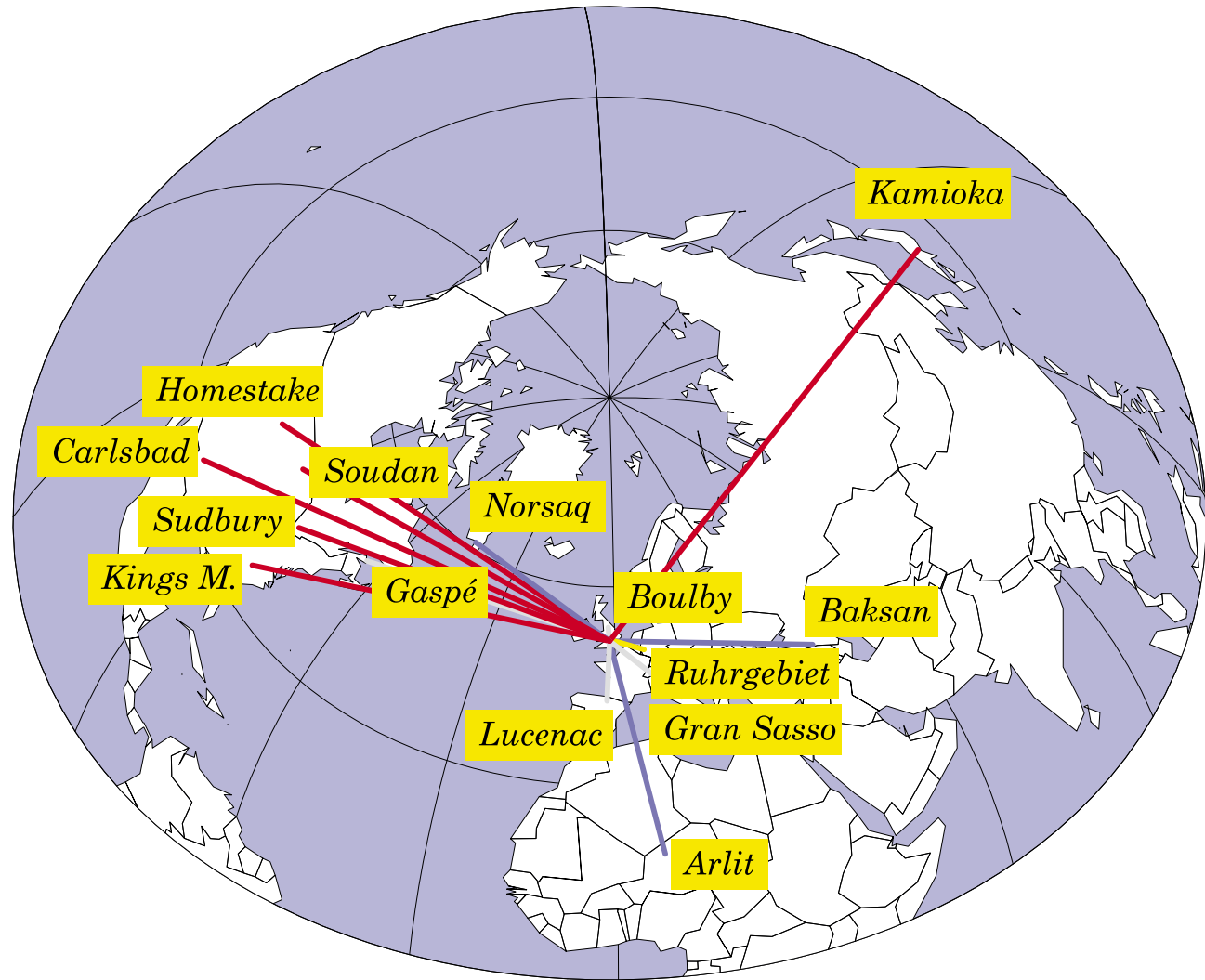




KEK, results

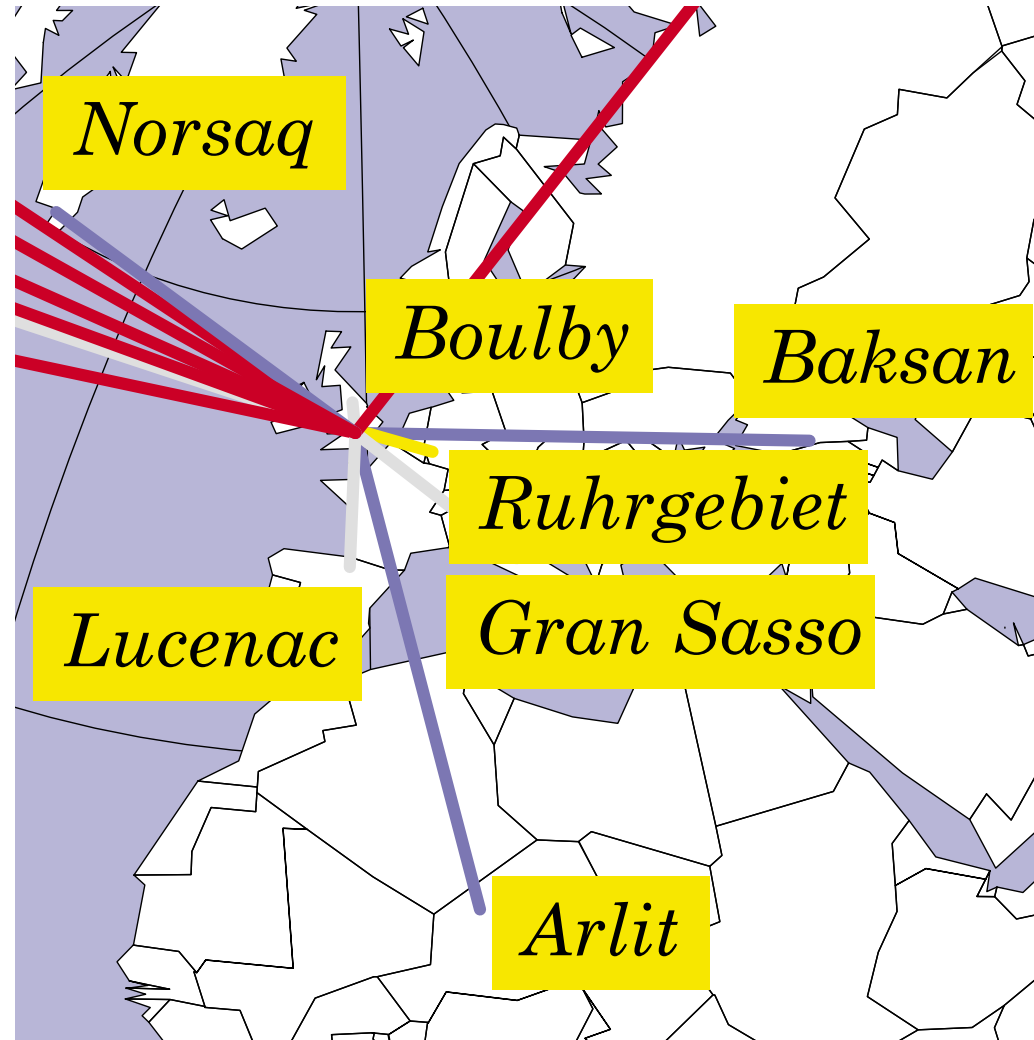
- ◆ For KEK, no suitable scenarios were found.
- ◆ Further investigation, specially involving sites in Australia and eastern Russia has to be done.

■ Arlit:	3636
■ Baksan:	3366
■ Boulby:	229
■ Carlsbad:	7293
■ Essen:	565
■ Gaspé:	4264
■ GranSasso:	1514
■ Homestake:	6655
■ Kamioka:	8621
■ KingsMountain:	6095
■ Lucenac:	1002
■ Norsaq:	2788
■ Soudan:	5925
■ Sudbury:	5548





RAL, detail





RAL, results

RAL						
Essen	Norsaq	139.3	74.2%	154.5	566	2789
Baskan	KingsMountain	132.5	71.3%	176.5	3366	6096
Baskan	Soudan	124.9	68.4%	168.1	3366	5925
Arlit	Homestake	120.6	66.9%	168.7	3636	6655
Arlit	Soudan	120.4	66.8%	164.8	3636	5925
Baskan	Carlsbad	120.3	66.8%	170.6	3366	7293



Bad Scenarios: $50% < \eta < 51%$

LAB	Detector1	Detector2	Efficiency	Distance1	Distance2
RAL	Baskan	Essen	50.16%	3366.2	565.6
RAL	Norsaq	Soudan	50.24%	2788.9	5925.2
RAL	Norsaq	Sudbury	50.33%	2788.9	5548.6
FNAL	Boulby	Norsaq	50.17%	5937.7	3523.8
FNAL	Essen	Norsaq	50.24%	6487.0	3523.8
FNAL	GranSasso	Norsaq	50.45%	7317.7	3523.8
FNAL	Lucenac	Norsaq	50.47%	6446.2	3523.8
FNAL	Baskan	Norsaq	50.68%	8544.5	3523.8
FNAL	Lucenac	Sudbury	50.89%	6446.2	606.9
Cornell	Boulby	Norsaq	50.30%	5257.4	2910.2
Cornell	Essen	Norsaq	50.37%	5825.3	2910.2
Cornell	Baskan	Norsaq	50.68%	8065.4	2910.2
Cornell	GranSasso	Norsaq	50.69%	6637.1	2910.2
Cornell	Carlsbad	Sudbury	50.81%	2487.9	399.5
CERN	Norsaq	Soudan	50.24%	3570.3	6616.9
CERN	Norsaq	Sudbury	50.31%	3570.3	6222.6
CERN	Homestake	Norsaq	50.34%	7328.1	3570.3
CERN	Carlsbad	Norsaq	50.51%	7925.8	3570.3
CERN	KingsMountair	Norsaq	50.58%	6714.8	3570.3
BNL	Homestake	Sudbury	50.11%	2537.9	752.2
BNL	Essen	Norsaq	50.48%	5724.4	2900.9
BNL	Carlsbad	Sudbury	50.85%	2768.3	752.2
BNL	GranSasso	Norsaq	50.86%	6506.4	2900.9



Comparison short BL

Short Baseline							
Cornell	KingsMountain	Norsaq	161.9	86.4%	179.2	899	2910
CERN	Arlit	Essen	161.6	86.2%	177.7	2969	582
CERN	GranSasso	Norsaq	156.8	83.2%	176.4	725	3570
CERN	Baskan	Lucenac	152.4	80.7%	168.8	2892	732
BNL	KingsMountain	Norsaq	151.5	80.2%	169.0	963	2901
RAL	Essen	Norsaq	139.3	74.2%	154.5	566	2789
RAL	Baskan	Kings Mt	132.5	71.3%	176.5	3366	6096



Comparison long BL

Long baseline							
Cornell	Arlit	Carlsbad	132.3	71.2%	180.0	7547	2488
BNL	Arlit	Carlsbad	131.8	71.0%	179.6	7328	2768
Cornell	Carlsbad	GranSasso	130.9	70.7%	173.7	2488	6637
BNL	Carlsbad	GranSasso	127.4	69.3%	170.7	2768	6506
BNL	Arlit	Homestake	126.2	68.9%	172.9	7328	2538
CERN	Baskan	Kings Mt	125.8	68.7%	170.9	2892	6715
RAL	Baskan	Soudan	124.9	68.4%	168.1	3366	5925
CERN	Baskan	Sudbury	123.4	67.8%	165.9	2892	6223
RAL	Arlit	Homestake	120.6	66.9%	168.7	3636	6655
RAL	Arlit	Soudan	120.4	66.8%	164.8	3636	5925
RAL	Baskan	Carlsbad	120.3	66.8%	170.6	3366	7293
Cornell	GranSasso	Homestake	117.5	65.9%	159.0	6637	2198
CERN	Arlit	Homestake	116.8	65.6%	165.5	2969	7328



Conclusions

- ◆ There are sufficient locations to accommodate all physics needs
- ◆ For some labs, further investigation is needed
- ◆ The difference in efficiency between best and worst scenario is a factor of 1.7
- ◆ The 7000/3500 will always be less efficient by a factor of 20% compared to the 3500/700 scenario