Hadroproduction measurements for simulations of new neutrino beams

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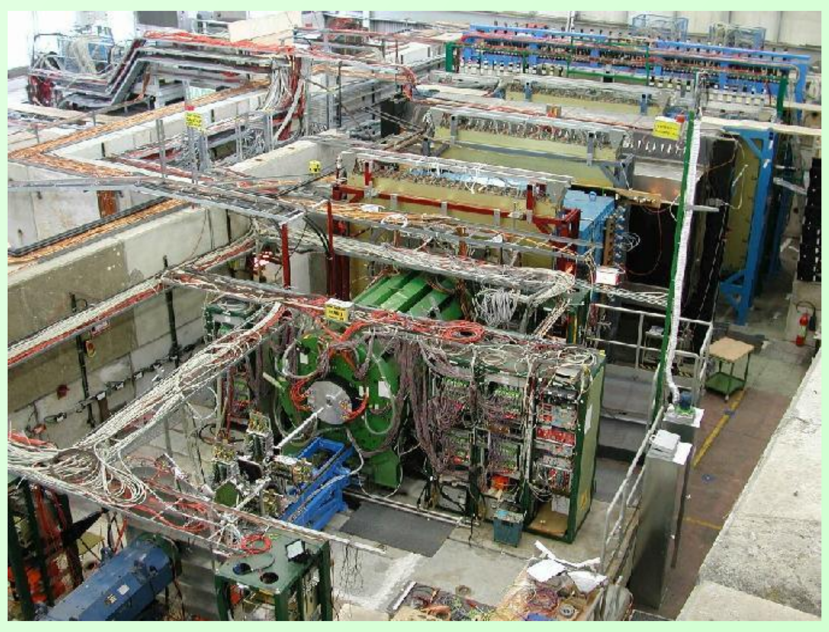
Available data for simulations of neutrino beamlines

Low energy beams (K2K, NUFACT, MINIBoone, ..) : mainly HARP

High Energy Beams (WANF, CNGS, NuMI, ..) : NA20, NA56/SPY, MIPP, NA61/SHINE

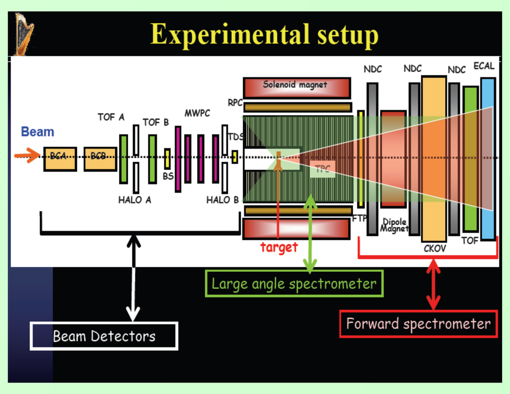
In addition a lot of old non-dedicated experiments with small statistics and high syst errors

HARP



HARP physics goals:

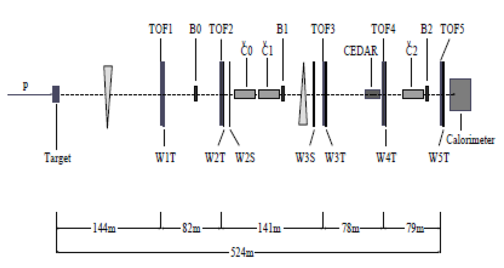
- Input for prediction of neutrino fluxes for the MiniBooNE , SciBOONE and K2K experiments
- Pion/Kaon yield for the design of the proton driver of neutrino factories and super-beams
- Input for precise calculation of the atmospheric neutrino flux and EAS
- Input for Monte Carlo generators (GEANT4, e.g. for LHC or space applications)



Harp detector layout and data taken

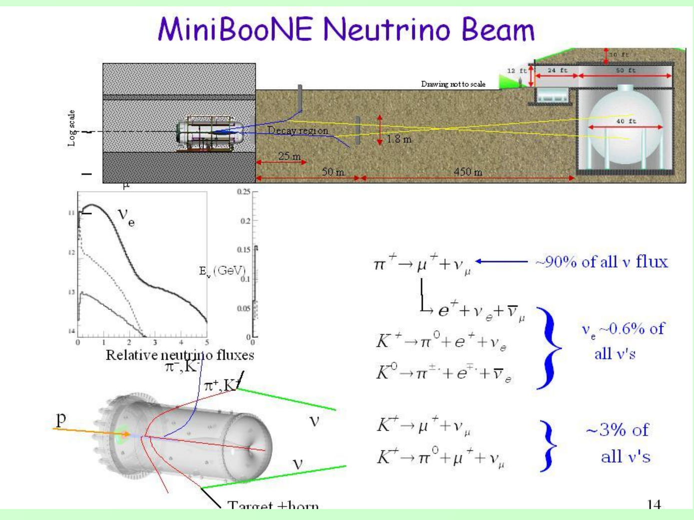
	Targetl	Target length (λ%)	Beam Momentum (GeV)	#events (Mevts)
Solid targets	Be, C, Al, Cu, Sn, Ta, Pb	2 (2001) 5 100	±3 ± 5 ± 8 ± 12 ± 15 For negative polarity, only 2% and 5%	233.16
K2K	Al	5, 50, 100, replica	+12.9	15.27
MiniBooNE	Be		+8.9	22.56
Cu "button"	Cu		+12.9, +15	1.71
Cu "skew"	Cu	2	+12	1.69
Cryogenic targets	N_7, 0_8, D_1, H_1	6 cm	±3 ± 5 ± 8 ± 12 ± 15	58.43
	H_2	18 cm	±3, ±8, ±14.5	13.83
Water	H_20	10, 100	+1.5, +8(10%)	9.6

NA56/SPY



- Measure p, kaon fluxes by 450 GeV/c p on Be (5% precision) ->knowledge of neutrino spectra
- Measure k/p ratio (3% precision) -> knowledge n_e/n_m ratio
- Equipped H6 beam from NA52 experiment in North Area
- Primary p flux measured by SEM
- Different Be targets (shapes, L)
- PID by TOF counters (low momenta) and Cerenkov (high momenta)
- Available results were parametrized (BMPT parametrization) or used to tune available MC (such as Fluka). Used for the study of available high-energy neutrino beamlines: WANF at SPS, CNGS, NuMi

Simulation of neutrino beams



Ingredients to compute a ν flux :

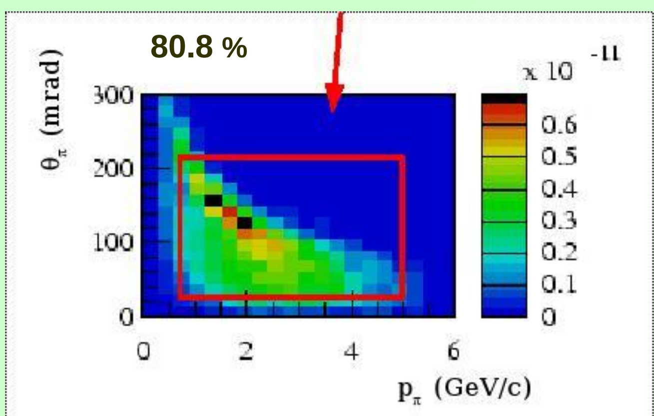
π(and k) production cross section (use same target and proton energy as the proton driver of the experiment)

Reinteractions (take data with thin and thick target))

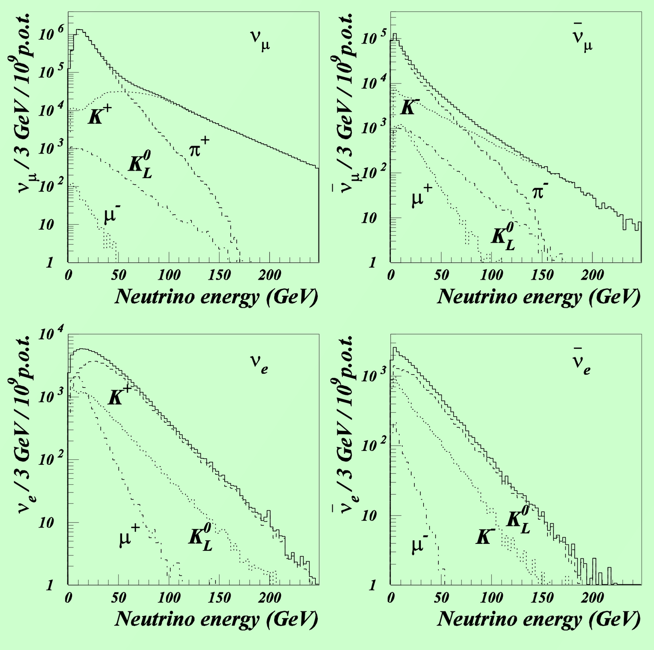
All the rest: simulation of the neutrino beamline: an "easy" problem.

Two approaches: full simulation with hadronic MC (GEANT4, MARS, FLUKA) , fast simulation based on parametrization of hadroproduction data

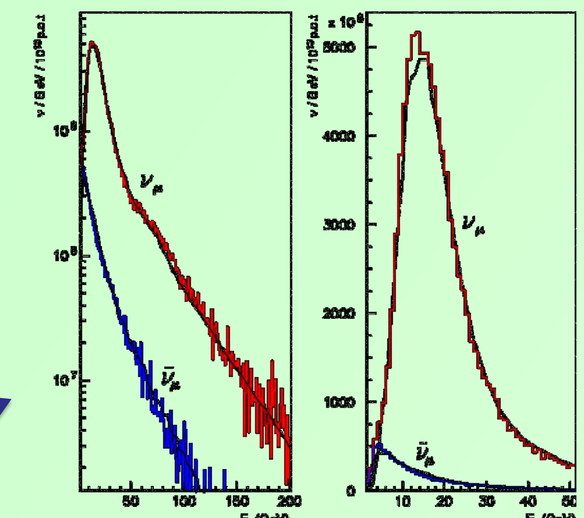
HARP p-Be-> p+-X data 8.9 GeV/c:
M. G. Catanesi et al., Eur. Phys. J. C52 (2007) 29
MiniBooNE with Harp input ,
A.A.Aguilar-Arevalo et al., Phys. ReV. Lett. 98 (2007)



Momentum and Angular distribution of pions decaying to a neutrino that passes through the MB detector.



Fluka full simulation (+ reweighting with NA56/SPY data): WANF ν beam for NOMAD



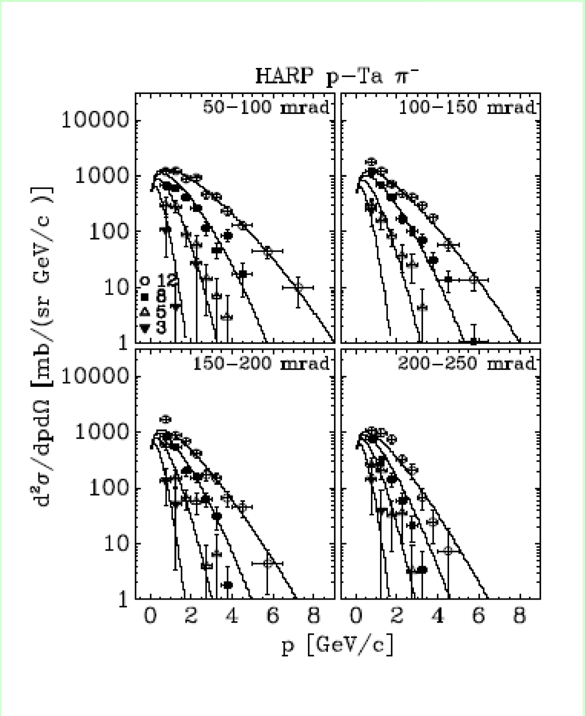
BMPT fast simulation: CHARM II ν beam

Both approachs point to good hadron production data

Available data parametrizations

Sanford-Wang empirical parametrization: 8 parameters, used for low energy beams (up to 30 GeV/c)

$$\frac{d^2\sigma}{dp\,d\Omega} = c_1 P_\pi^{c_2}\left(1-\frac{P_\pi}{P_p}\right) \times e^{\left(\frac{-c_3 P_\pi^{c_4}}{P_p^{c_5}} - c_6\theta_\pi (P_\pi - c_7 P_p \cos^{c_8}\vartheta_\pi)\right)}$$

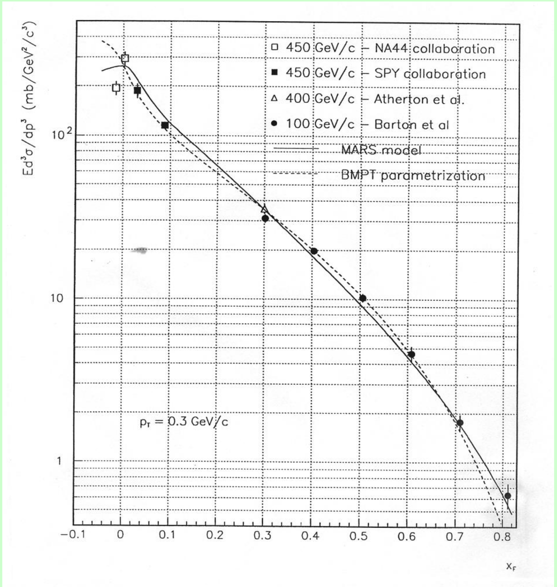


HARP data and many others have been parametrized with formulas of this type. It is only an empirical parametrization.

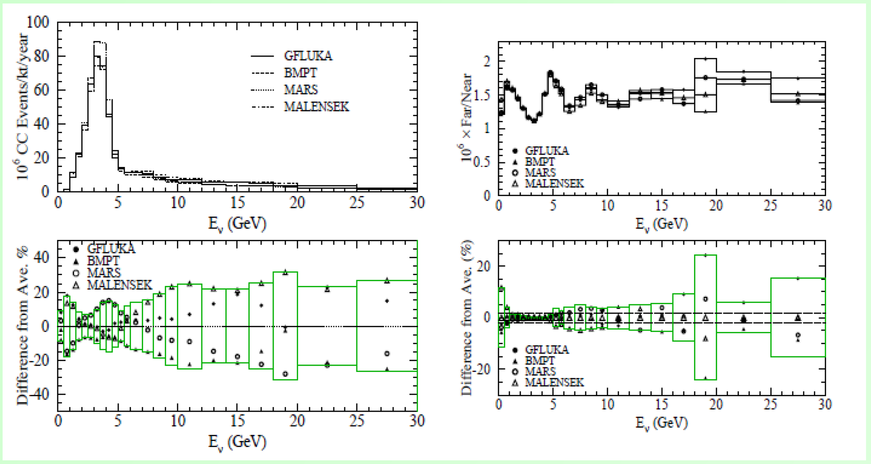
The BMPT parametrization : empirical formula based on general physical argument, for high energy beams (see ref. 9)

$$\left(E\frac{d^3\sigma}{dp^3}\right)_{Be} = A(1-x_R)^\alpha\left(1+\frac{a}{x_R^\gamma}p_t + \frac{a^2}{2x_R^\delta}p_t^2\right) e^{-\left(\frac{a}{x_R^\gamma}p_t\right)}(1+Bx_R)x_R^{-\beta}$$

- Approximate factorization in x and p_t
- $(1-x)^\alpha$ behavior in the forward direction for $x \to 1$ (quark counting rule)
- $x^{-\beta}$ behavior in for $x \to 0$ (non direct hadron formation mechanism)
- Exponential fall in p_t for soft interaction

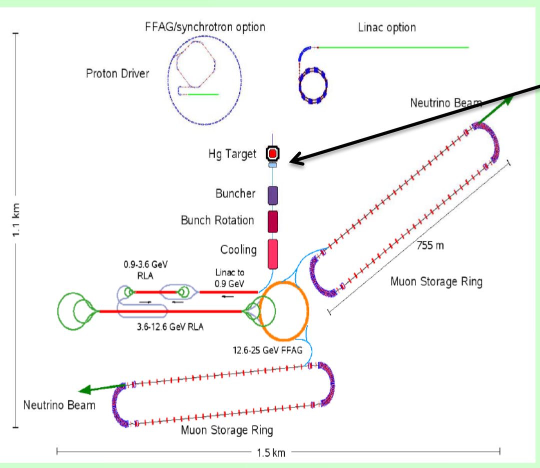


Comparison with Barton et al. (100 GeV/c)



Application to the NUMI beam

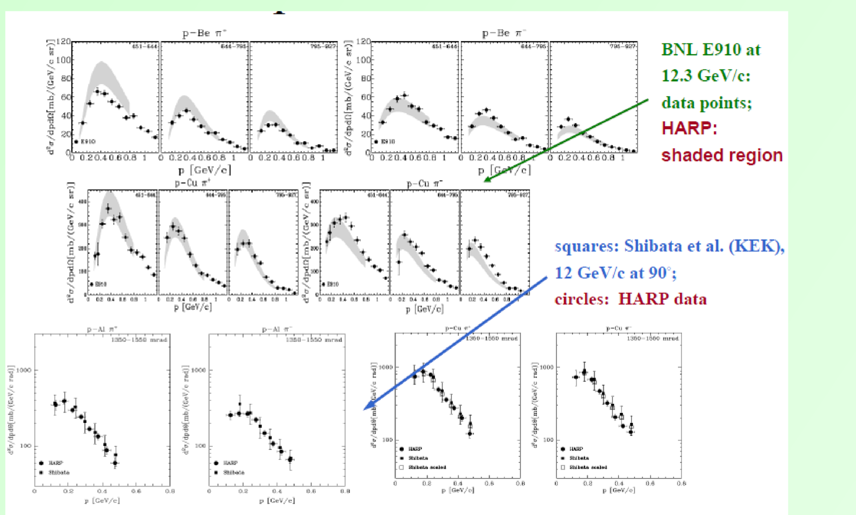
Results for NF optimization



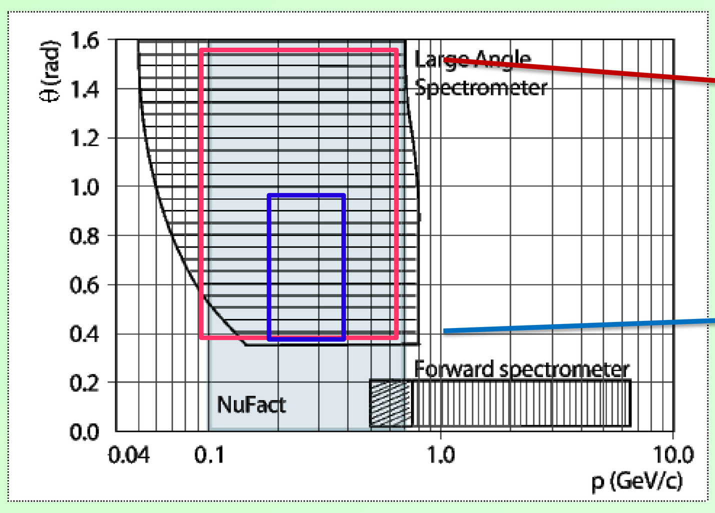
Layout of a Neutrino Factory (US study 2)

maximize $\pi^+(\pi^-)$ production yield in target as a function of:
- proton energy
- target material
- Geometry
- collection efficiency (p_L,p_T)

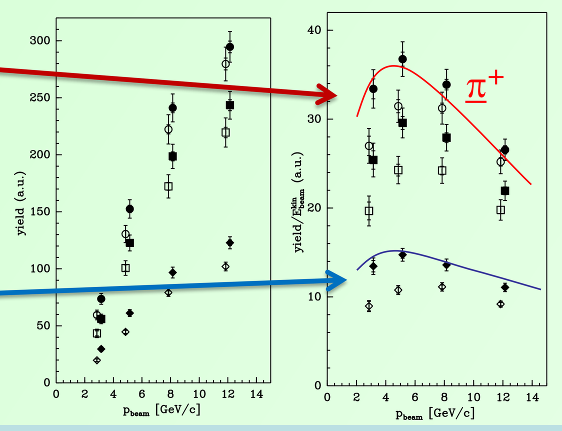
different simulations show large discrepances for π production distributions, both in shape and normalization. Experimental knowledge is rather poor



available data, to be compared with Harp LA analysis



Aim: measure p_T distribution with high precision for high Z targets



Cross-sections to be fed into neutrino factory studies to find optimum design: Ta and Pb x-sections at large-angle (see Eur. J. Phys C51 (2007) 787)

Useful references

1. *M.G. Catanesi et al. (HARP Coll.)* Nucl. Phys. **B732** (2006) 1
2. *M.G. Catanesi et al. (HARP Coll.)* Eur. Phys. J. **C51** (2007) 787
3. *M.G. Catanesi et al (HARP Coll.)* Eur. Phys. J. **C52** (2007) 29
4. *M.G. Catanesi et al. (HARP Coll.)* Phys. ReV. **C77** (2008) 055207
5. *M. Apollonio et al. (HARP Coll.)* Phys . ReV. **C80** (2009) 035208
6. *M,. Apollonio et al. (HARP Coll.)* Phys. ReV. **C80** (2009) 065
7. *G. Ambrosini et al. (NA56 Coll.),* Eur. Phys. J C10 (1999) 605
8. *M. Bonesini, A. Marchionni, F. Pietropaolo, T. Tabarelli de Fatis*, Eur. Phys. J. C20 (2001) 13
9. *M. Bonesini, A. Guglielmi ,* Phys. Rept. 433 (2006) 65