



THE UNIVERSITY
of EDINBURGH



<https://www.youtube.com/watch?v=LkhOlsKm>

Dbk

The 12 Days of Christmas:

PhD edition sing-along

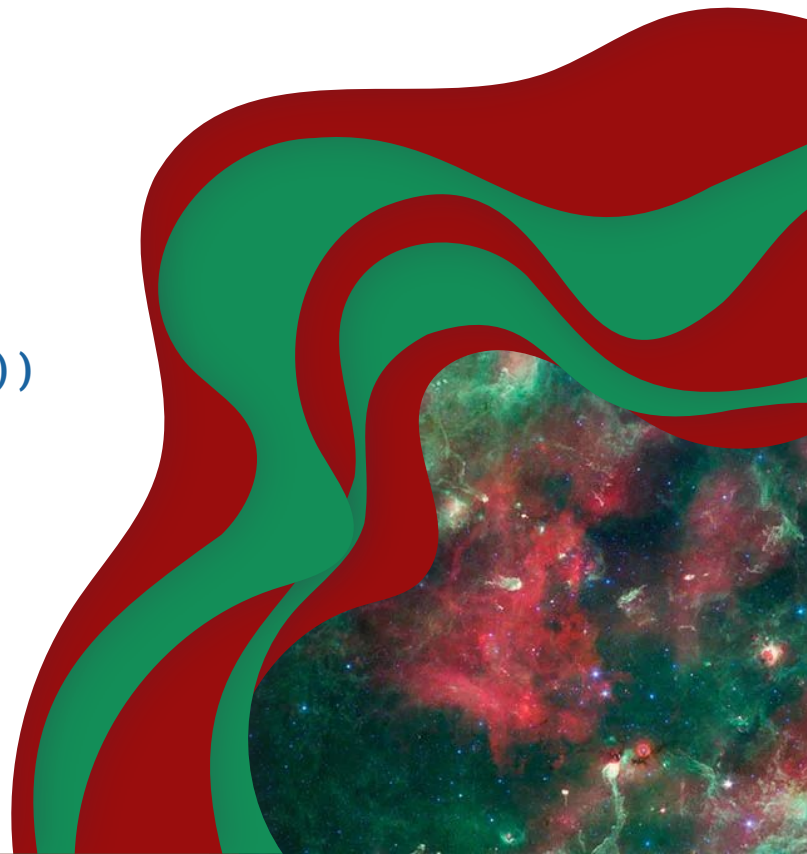
Lucy Kotsiopolou

Supervisor: Dr. Andrzej Szelc

SING with me!

(Or else... Krampus will eat you :))

NASA/JPL-Caltech/Harvard-Smithsonian CfA



1: PhD

On the ... day of Christmas
my true love gave to me:

1: PhD

My first day at the office in September 2023!



2: Experiments

On the ... day of Christmas
my true love gave to me:

1: PhD

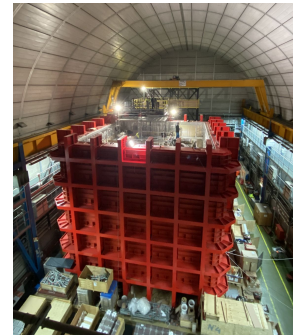
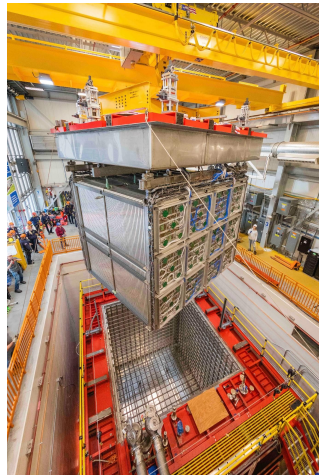
2: Experiments

I work on 2 experiments, SBND and DarkSide-20k!

FNAL (Fermilab National
Accelerator Laboratory)

📍 ~Chicago, U.S.

Neutrino beam
experiment



LNGS (Gran Sasso
National Laboratory)

📍 ~L'Aquila, Italy

Direct dark matter
detection



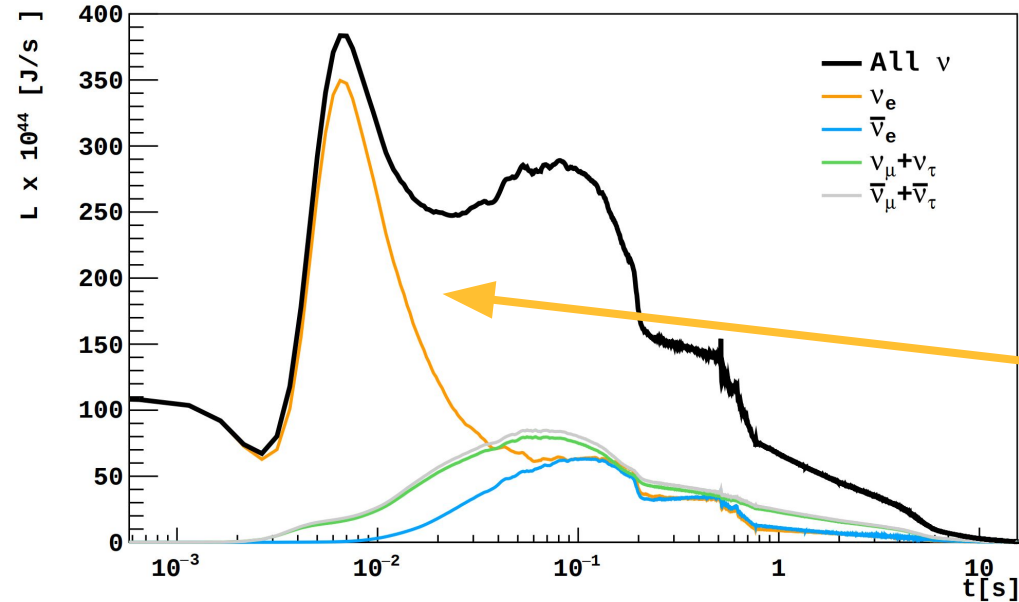
3: Flavours

On the ... day of Christmas
my true love gave to me:

- 1: PhD
- 2: Experiments
- 3: Flavours

All 3 neutrinos come out a supernova explosion!

Neutrino flux of supernova over time:



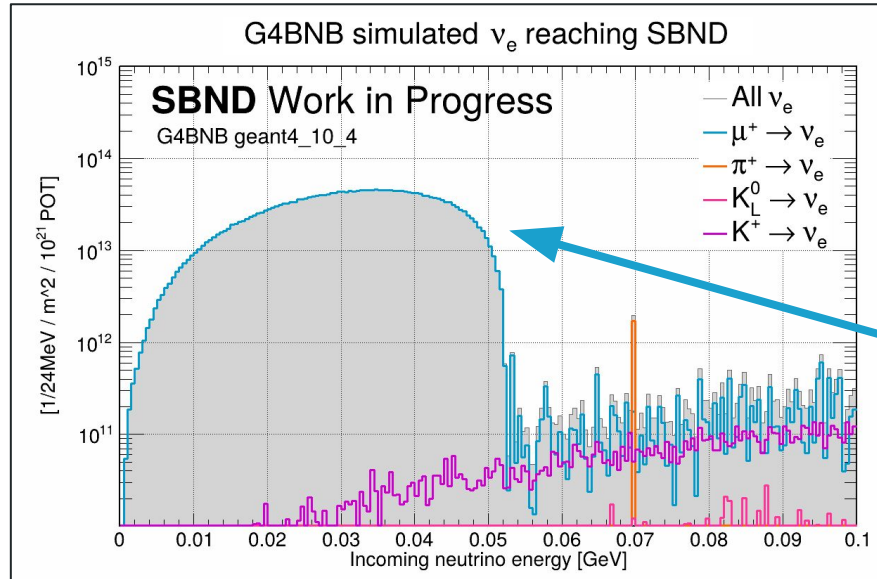
Sensitivity of future liquid argon dark matter search experiments to core-collapse supernova neutrinos, **The DarkSide-20k Collaboration**, (2020).

4: Fluxes

On the ... day of Christmas
my true love gave to me:

- 1: PhD
- 2: Experiments
- 3: Flavours
- 4: Fluxes

Man-made neutrino beam at Fermilab makes 4 ν_e fluxes!
“Low energy” ($<100\text{MeV}$) neutrino fluxes reaching SBND:



Big flux of ν_e from μ
decaying at rest!

Lucy Kotsiopolou

Fermilab
neutrino beam

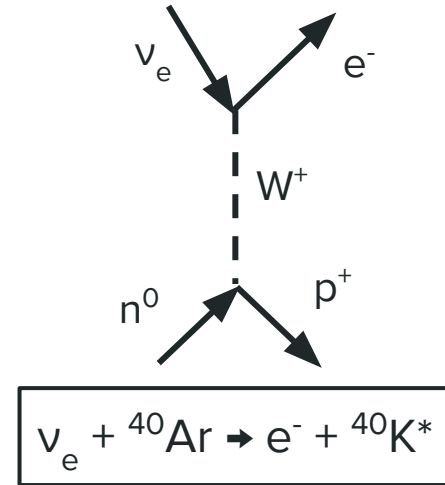


5: Particles

On the ... day of Christmas
my true love gave to me:

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- 2: Experiments
- 3: Flavours
- 4: Fluxes
- 5: Particles

ν_e on Argon cross section we want to measure!
Observe the process involving 5 particles:



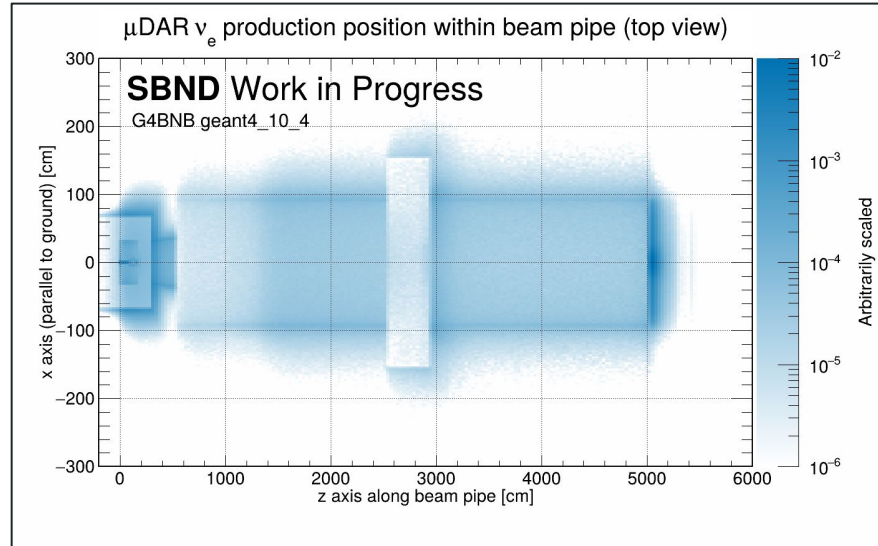
Charged current inelastic cross section at <100 MeV energies

6: Materials

On the ... day of Christmas
my true love gave to me:

- 1: PhD
- 2: Experiments
- 3: Flavours
- 4: Fluxes
- 5: Particles
- 6: Materials

Muons can bump on to 6 things and decay at rest to ν_e !
Top view on beam decay pipe:



Lucy Kotsiopoulos

Concrete
Beryllium
Dolomite
Steel
Aluminium
Air

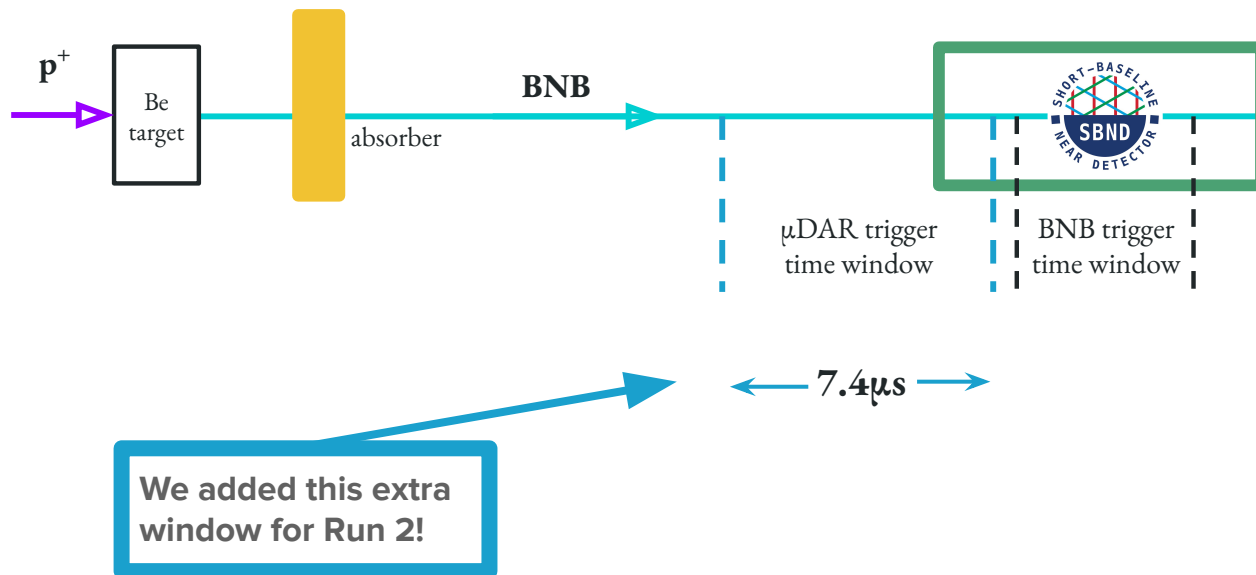
7: μ s

On the ... day of Christmas
my true love gave to me:

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- 3: Flavours
- 4: Fluxes
- 5: Particles
- 6: Materials
- 7: μ s

We “open” trigger system for 7.4μ s to catch these ν_e !

Trigger windows for SBND:



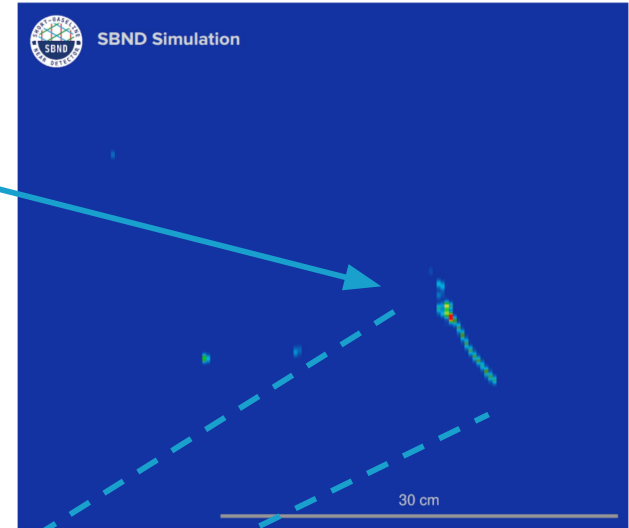
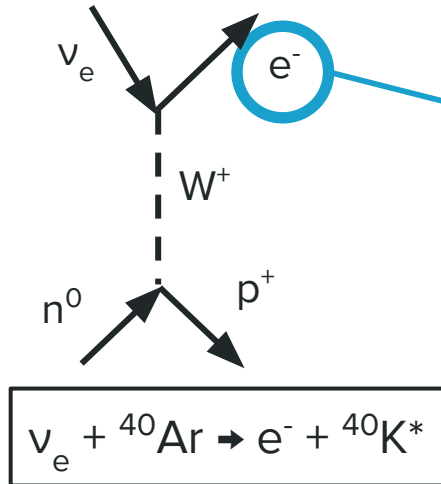
8: cm

On the ... day of Christmas
my true love gave to me:

- 1: PhD
- 2: Experiments
- 3: Flavours
- 4: Fluxes
- 5: Particles
- 6: Materials
- 7: μs
- 8:

Final state e^- of interaction is 8cm long in SBND

Neutrino flux vs. time of a Type II core-collapse supernova:



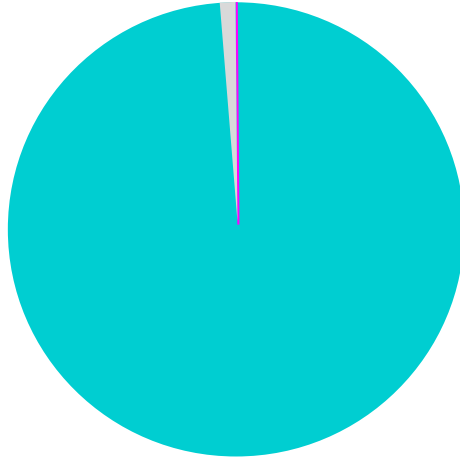
$\sim 8\text{cm long}$

9: 99%

On the ... day of Christmas
my true love gave to me:

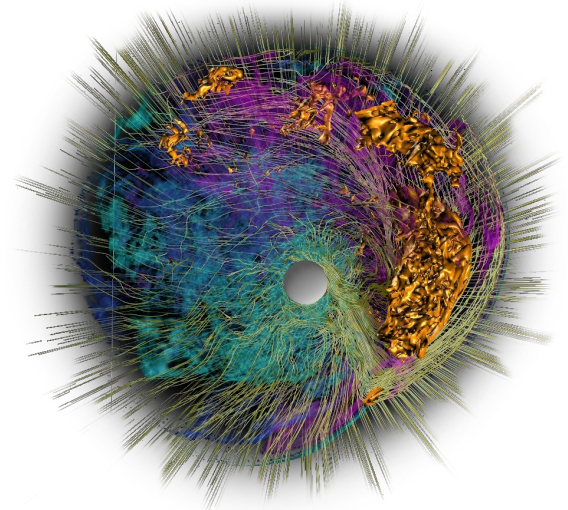
- 1: PhD
- 2: Experiments
- 3: Flavours
- 4: Fluxes
- 5: Particles
- 6: Materials
- 7: μs
- 8: cm
- 9: 99%

Neutrinos carry away 99% of the entire supernova energy!
(For a Type II core-collapse supernova)



0.01% EM radiation
1% Kinetic energy of
external star's layers

99% neutrinos



Neutrinos from a core collapse supernova,
Blondin and Mezzacappa (2016).

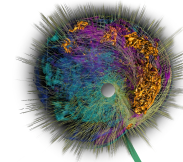
On the ... day of Christmas
my true love gave to me:

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- 2: Experiments
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- 4: Fluxes
- 5: Particles
- 6: Materials
- 7: μs
- 8: cm
- 9: 99%
- 10: kiloparsec

This diagram illustrates the structure of the Milky Way galaxy, showing its spiral arms, central bulge, and various star clusters and nebulae. The diagram is labeled with numerous names and coordinates, including the Centaurus Arm, Norma/Outer Arm, Perseus Arm, Sagittarius Arm, and the Sun's position. It also includes a scale bar for kiloparsecs (kpc) and kilolight-years (kly).

Key Features and Labels:

- Galactic Structure:** Centaurus Arm, Norma/Outer Arm, Perseus Arm, Sagittarius Arm, Norma Arm, Centaurus Arm, Sagittarius Arm, Norma/Outer Arm.
- Star Clusters and Nebulae:** M72, Pal 11, NGC 6326, NGC 6338, NGC 6353, NGC 6354, NGC 6355, NGC 6356, NGC 6357, NGC 6358, NGC 6359, NGC 6360, NGC 6361, NGC 6362, NGC 6363, NGC 6364, NGC 6365, NGC 6366, NGC 6367, NGC 6368, NGC 6369, NGC 6370, NGC 6371, NGC 6372, NGC 6373, NGC 6374, NGC 6375, NGC 6376, NGC 6377, NGC 6378, NGC 6379, NGC 6380, NGC 6381, NGC 6382, NGC 6383, NGC 6384, NGC 6385, NGC 6386, NGC 6387, NGC 6388, NGC 6389, NGC 6390, NGC 6391, NGC 6392, NGC 6393, NGC 6394, NGC 6395, NGC 6396, NGC 6397, NGC 6398, NGC 6399, NGC 6400, NGC 6401, NGC 6402, NGC 6403, NGC 6404, NGC 6405, NGC 6406, NGC 6407, NGC 6408, NGC 6409, NGC 6410, NGC 6411, NGC 6412, NGC 6413, NGC 6414, NGC 6415, NGC 6416, NGC 6417, NGC 6418, NGC 6419, NGC 6420, NGC 6421, NGC 6422, NGC 6423, NGC 6424, NGC 6425, NGC 6426, NGC 6427, NGC 6428, NGC 6429, NGC 6430, NGC 6431, NGC 6432, NGC 6433, NGC 6434, NGC 6435, NGC 6436, NGC 6437, NGC 6438, NGC 6439, NGC 6440, NGC 6441, NGC 6442, NGC 6443, NGC 6444, NGC 6445, NGC 6446, NGC 6447, NGC 6448, NGC 6449, NGC 6450, NGC 6451, NGC 6452, NGC 6453, NGC 6454, NGC 6455, NGC 6456, NGC 6457, NGC 6458, NGC 6459, NGC 6460, NGC 6461, NGC 6462, NGC 6463, NGC 6464, NGC 6465, NGC 6466, NGC 6467, NGC 6468, NGC 6469, NGC 6470, NGC 6471, NGC 6472, NGC 6473, NGC 6474, NGC 6475, NGC 6476, NGC 6477, NGC 6478, NGC 6479, NGC 6480, NGC 6481, NGC 6482, NGC 6483, NGC 6484, NGC 6485, NGC 6486, NGC 6487, NGC 6488, NGC 6489, NGC 6490, NGC 6491, NGC 6492, NGC 6493, NGC 6494, NGC 6495, NGC 6496, NGC 6497, NGC 6498, NGC 6499, NGC 6500, NGC 6501, NGC 6502, NGC 6503, NGC 6504, NGC 6505, NGC 6506, NGC 6507, NGC 6508, NGC 6509, NGC 6510, NGC 6511, NGC 6512, NGC 6513, NGC 6514, NGC 6515, NGC 6516, NGC 6517, NGC 6518, NGC 6519, NGC 6520, NGC 6521, NGC 6522, NGC 6523, NGC 6524, NGC 6525, NGC 6526, NGC 6527, NGC 6528, NGC 6529, NGC 6530, NGC 6531, NGC 6532, NGC 6533, NGC 6534, NGC 6535, NGC 6536, NGC 6537, NGC 6538, NGC 6539, NGC 6540, NGC 6541, NGC 6542, NGC 6543, NGC 6544, NGC 6545, NGC 6546, NGC 6547, NGC 6548, NGC 6549, NGC 6550, NGC 6551, NGC 6552, NGC 6553, NGC 6554, NGC 6555, NGC 6556, NGC 6557, NGC 6558, NGC 6559, NGC 6560, NGC 6561, NGC 6562, NGC 6563, NGC 6564, NGC 6565, NGC 6566, NGC 6567, NGC 6568, NGC 6569, NGC 6570, NGC 6571, NGC 6572, NGC 6573, NGC 6574, NGC 6575, NGC 6576, NGC 6577, NGC 6578, NGC 6579, NGC 6580, NGC 6581, NGC 6582, NGC 6583, NGC 6584, NGC 6585, NGC 6586, NGC 6587, NGC 6588, NGC 6589, NGC 6590, NGC 6591, NGC 6592, NGC 6593, NGC 6594, NGC 6595, NGC 6596, NGC 6597, NGC 6598, NGC 6599, NGC 6600, NGC 6601, NGC 6602, NGC 6603, NGC 6604, NGC 6605, NGC 6606, NGC 6607, NGC 6608, NGC 6609, NGC 6610, NGC 6611, NGC 6612, NGC 6613, NGC 6614, NGC 6615, NGC 6616, NGC 6617, NGC 6618, NGC 6619, NGC 6620, NGC 6621, NGC 6622, NGC 6623, NGC 6624, NGC 6625, NGC 6626, NGC 6627, NGC 6628, NGC 6629, NGC 6630, NGC 6631, NGC 6632, NGC 6633, NGC 6634, NGC 6635, NGC 6636, NGC 6637, NGC 6638, NGC 6639, NGC 6640, NGC 6641, NGC 6642, NGC 6643, NGC 6644, NGC 6645, NGC 6646, NGC 6647, NGC 6648, NGC 6649, NGC 6650, NGC 6651, NGC 6652, NGC 6653, NGC 6654, NGC 6655, NGC 6656, NGC 6657, NGC 6658, NGC 6659, NGC 6660, NGC 6661, NGC 6662, NGC 6663, NGC 6664, NGC 6665, NGC 6666, NGC 6667, NGC 6668, NGC 6669, NGC 6670, NGC 6671, NGC 6672, NGC 6673, NGC 6674, NGC 6675, NGC 6676, NGC 6677, NGC 6678, NGC 6679, NGC 6680, NGC 6681, NGC 6682, NGC 6683, NGC 6684, NGC 6685, NGC 6686, NGC 6687, NGC 6688, NGC 6689, NGC 6690, NGC 6691, NGC 6692, NGC 6693, NGC 6694, NGC 6695, NGC 6696, NGC 6697, NGC 6698, NGC 6699, NGC 6700, NGC 6701, NGC 6702, NGC 6703, NGC 6704, NGC 6705, NGC 6706, NGC 6707, NGC 6708, NGC 6709, NGC 6710, NGC 6711, NGC 6712, NGC 6713, NGC 6714, NGC 6715, NGC 6716, NGC 6717, NGC 6718, NGC 6719, NGC 6720, NGC 6721, NGC 6722, NGC 6723, NGC 6724, NGC 6725, NGC 6726, NGC 6727, NGC 6728, NGC 6729, NGC 6730, NGC 6731, NGC 6732, NGC 6733, NGC 6734, NGC 6735, NGC 6736, NGC 6737, NGC 6738, NGC 6739, NGC 6740, NGC 6741, NGC 6742, NGC 6743, NGC 6744, NGC 6745, NGC 6746, NGC 6747, NGC 6748, NGC 6749, NGC 6750, NGC 6751, NGC 6752, NGC 6753, NGC 6754, NGC 6755, NGC 6756, NGC 6757, NGC 6758, NGC 6759, NGC 6760, NGC 6761, NGC 6762, NGC 6763, NGC 6764, NGC 6765, NGC 6766, NGC 6767, NGC 6768, NGC 6769, NGC 6770, NGC 6771, NGC 6772, NGC 6773, NGC 6774, NGC 6775, NGC 6776, NGC 6777, NGC 6778, NGC 6779, NGC 6780, NGC 6781, NGC 6782, NGC 6783, NGC 6784, NGC 6785, NGC 6786, NGC 6787, NGC 6788, NGC 6789, NGC 6790, NGC 6791, NGC 6792, NGC 6793, NGC 6794, NGC 6795, NGC 6796, NGC 6797, NGC 6798, NGC 6799, NGC 6800, NGC 6801, NGC 6802, NGC 6803, NGC 6804, NGC 6805, NGC 6806, NGC 6807, NGC 6808, NGC 6809, NGC 6810, NGC 6811, NGC 6812, NGC 6813, NGC 6814, NGC 6815, NGC 6816, NGC 6817, NGC 6818, NGC 6819, NGC 6820, NGC 6821, NGC 6822, NGC 6823, NGC 6824, NGC 6825, NGC 6826, NGC 6827, NGC 6



Could DarkSide-20k see supernova neutrinos???



Red lines are a 10kpc distance

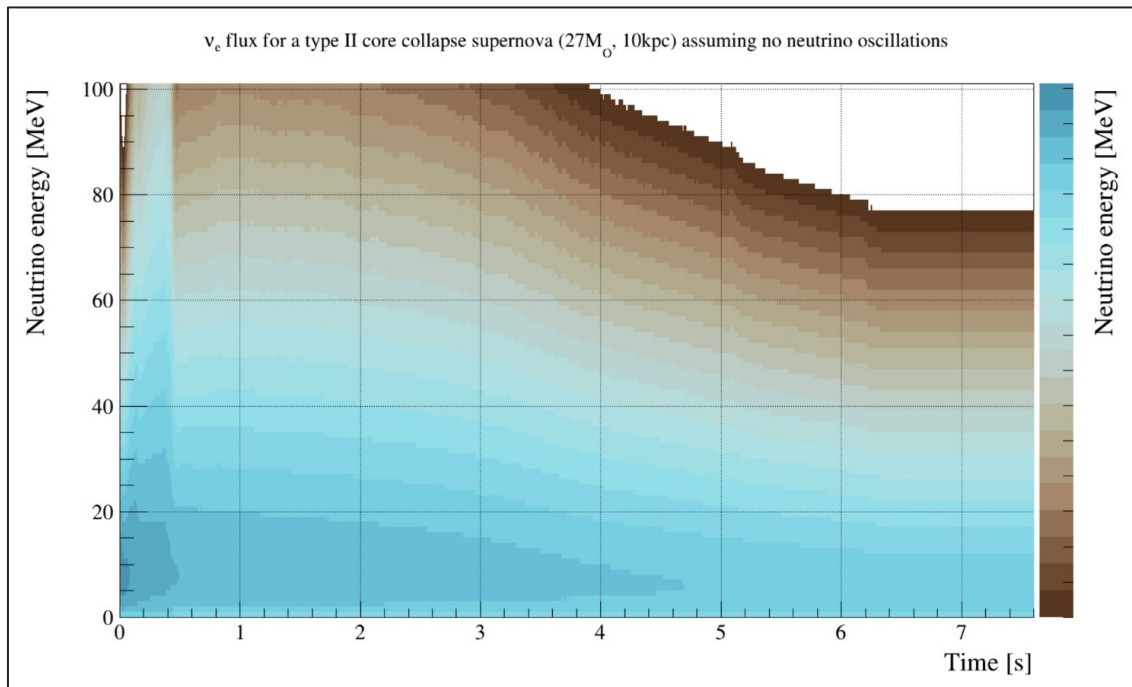
11: Solar masses

On the ... day of Christmas
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- 1: PhD
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- 6: Materials
- 7: μs
- 8: cm
- 9: 99%
- 10: kpc
- 11: Solar masses

~~New~~ Will study supernovae of $11M_{\odot}$ progenitor star mass!

Observe neutrino flux over time and energy of $27M_{\odot}$ (didn't have the other plot :())



Lucy Kotsiopoulos

12: LTA months

On the ... day of Christmas
my true love gave to me:

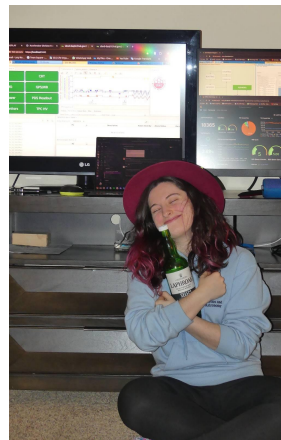
- 1: PhD
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- 3: Flavours
- 4: Fluxes
- 5: Particles
- 6: Materials
- 7: μs
- 8: cm
- 9: 99%
- 10: kpc
- 11: Solar masses
- 12: LTA months

Had an amazing time on LTA in Fermilab (Chicago)!

Thank you PPE for sending me :D



Hosted a wine club at Fermilab



Shifting :)



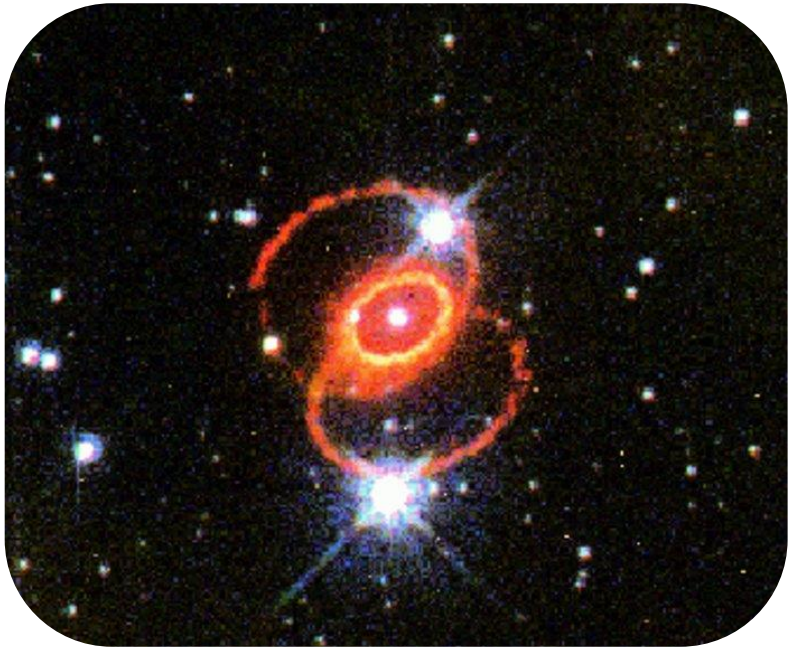
Made many new wonderful friends :)



Held a parrot!



Thanksgiving in
Fermilab control room!



Thank you!

*A photo of Supernova 1987A's remnants as seen in 1995 by the
Hubble space telescope, **GSFC/NOAO/NASA/ESA/STIS Instrument**
Definition Team (1995)*

Backup slides